ACRITARCHS OF LLANDEILO AND CARADOC AGE FROM CLASSIC LOCALITIES IN BRITAIN

by

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INTRODUCTION

The last two decades have seen the publication of a large number of papers dealing with Palaeozoic acritarchs including many devoted to the description of Ordovician assemblages. It has become clear that these microfossils have considerable potential for correlation and that they are frequently recovered from sequences otherwise devoid of fossil material. In Britain, acritarchs have been described in detail from the Cambrian (Potter 1974 M.S.); Tremadoc (Rasul 1971 M.S., 1974, 1977a, 1977b) and from the Silurian (Lister 1968 M.S., 1970; Hill 1974 M.S.). Until the recent work of Booth (1979 M.S.) dealing with Arenig-Llanvirn assemblages, no detailed systematic investigation of British Ordovician acritarchs had been attempted. The primary objective of the present study is to provide a comprehensive description of acritarchs from the Middle and Upper Ordovician of Britain, with particular emphasis on the type-areas of the Llandeilo and Caradoc. In conjunction with the work of Booth it is hoped that this account will go some way towards providing a biostratigraphical framework which will facilitate the use of these microfossils for the purposes of correlation in the Ordovician.

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SUMMARY

Sixty-seven samples from the Middle and Upper Ordovician are analyzed palynologically and acritarch assemblages from this stratigraphical level in the British sequence are examined in detail for the first time. Acritarchs from the type areas of the Llandeilo and Caradoc stages are described systematically and stratigraphically and three new genera, sixteen new species and six new combinations are proposed. Samples from the type-section of the Caradoc yield not only acritarchs of Caradoc age but abundant individuals reworked from pre-existing sediments. An inverted Tremadoc/Arenig-Llanvirn stratigraphy is revealed by plotting the vertical occurrences of these reworked microfossils; conclusions are drawn about the local palaeogeography and sediment sources during Caradoc time. Data from the classic Middle and Upper Ordovician rocks of Girvan suggest that in this region the lateral distribution of the contemporary microphytoplankton was facies-controlled. Certain acritarch species are shown to be geographically widespread and stratigraphically restricted and the potential of these microfossils for use in international correlation is emphasized; it is clear that more data are required before this potential can be fully realized. Acritarch taxa from the Llandeilo-Caradoc of the Anglo-Welsh region are compared with those recorded in sediments of similar age from other parts of the world.

Chapter One

STRATIGRAPHY AND SAMPLING

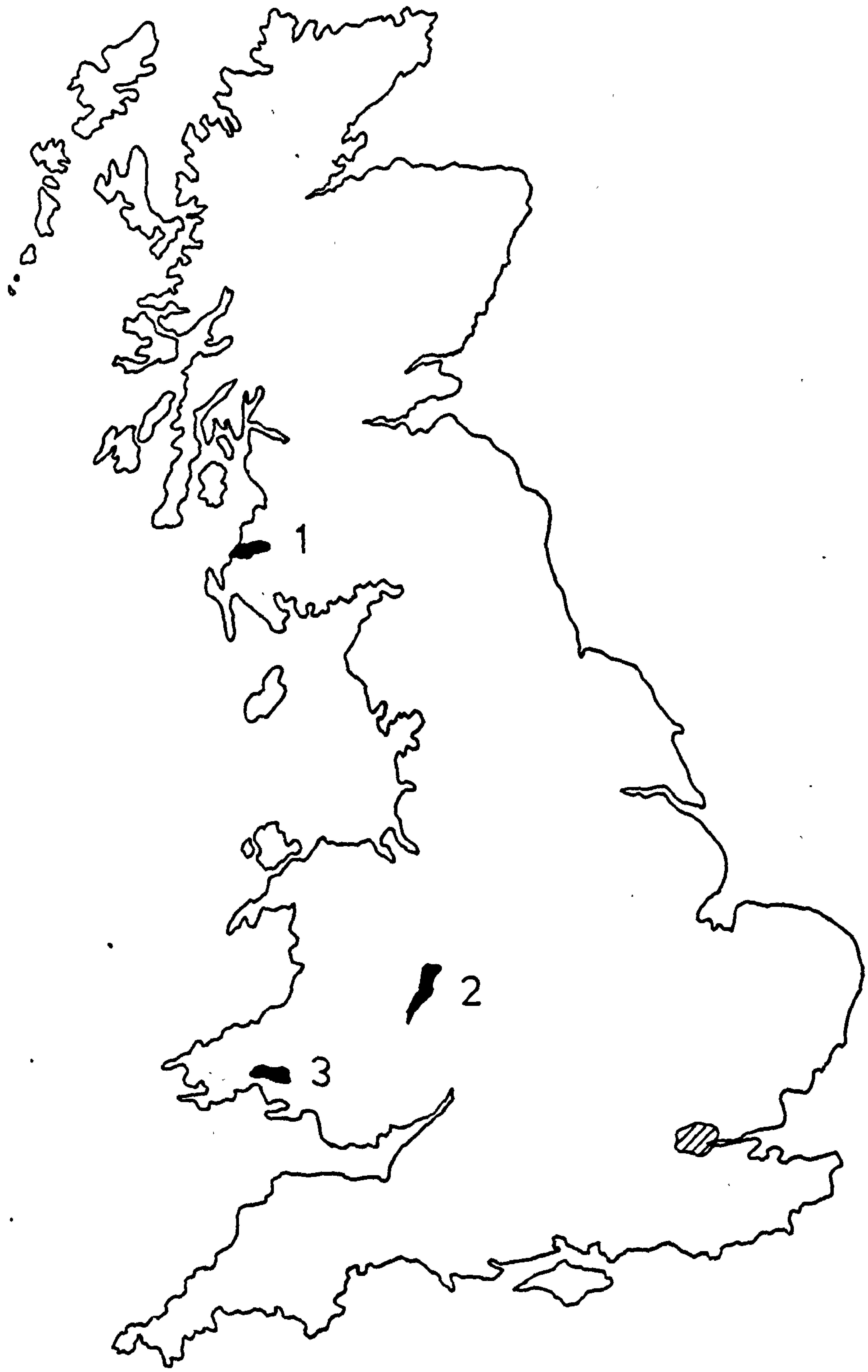
In this introductory chapter a brief outline is given of the geographical and stratigraphical position of each horizon sampled and, where relevant, additional geological information is provided. As far as possible these data are given in the form of maps, diagrams or tables. For the most part the stratigraphical divisions and terminology used are those of Williams, Strachan et al. (1972), but for some sequences, reference is made to more detailed studies such as the classic work by Williams (1962) on the Upper Ordovician of the Girvan district.

Three widely separated areas of Middle and Upper Ordovician sediments are investigated here and they are listed below together with the stratigraphical intervals collected from each area.

	Geographical Area	Stratigraphical Series Collected
1.	Girvan, Ayrshire, Scotland.	Llandeilo and Caradoc.
2.	Shropshire, England.	Caradoc.
3.	Llandeilo, South Wales.	Llandeilo.

The regional setting of these areas is shown in text-fig.1.

Text-fig. 1 General location map.



1 Girvan
2 Shropshire
3 Llandeilo

The symbol ● adjacent to a sample number in the following diagrams indicates that acritarchs were recovered from the sample in workable numbers. The symbol ■ shows that acritarchs were either absent or were extremely rare.

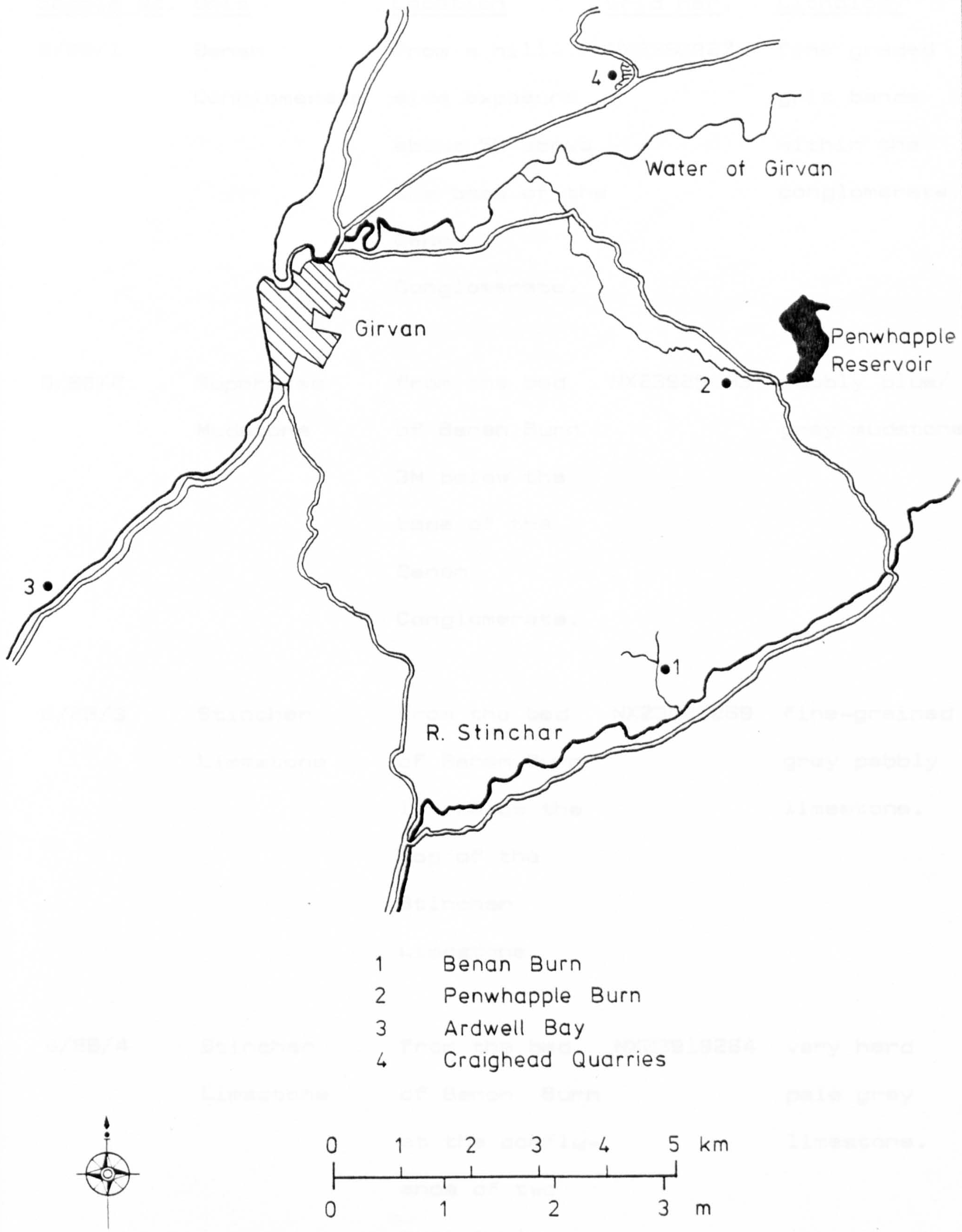
At a number of exposures sampled, beds of very different lithology were superimposed, or horizons of one lithology enclosed structures of a different composition - for example, a band of limestone nodules within a calcareous shale formation. Where this occurred, samples were taken from both rock types to ensure maximum recovery of microfossils from the location.

Girvan.

The sequence of Ordovician rocks exposed in the Girvan district has been recognised as one of particular interest and importance since the early work of Lapworth [1882] and Peach and Horne [1899]. In the present study sediments of Llandeilo and Caradoc age were collected for palynological analysis as well as two samples from the basal Ashgill. Rocks of Caradoc age crop out over a wide area to the south and east of Girvan, but exposure is generally poor with individual outcrops tending to be small and widely scattered. Here attention has been concentrated on four localities, which, taken together, provide access to sediments deposited throughout Llandeilo and Caradoc time, in sequences as continuous as can be found in the area. The positions of these four localities are shown in text-fig.2.

One of the most notable features of the Ordovician rocks of the Girvan district is the rapid and spectacular lateral variations in lithology which occur. This factor was taken into account when choosing the collecting localities so that the maximum number of potentially productive lithologies was sampled, as well as a stratigraphical spread of samples obtained; thus the fine-grained calcareous sediments of the Craighead Inlier were sampled although they are lateral equivalents of the Ardwell Beds which were also collected. A map showing the location of every sample site is given below for each of the four localities, together with a table showing the sample details. The stratigraphical positions of all samples from the Girvan area are shown in text-fig.7. A composite section of this type is necessary to illustrate the complexities of local correlation.

SAMPLE LOCALITIES IN THE GIRVAN DISTRICT



Text-fig. 2

TABLE 1 : Benan Burn.

Sample No.	Unit	Location	Grid Ref.	Lithology
G/BB/1	Benan Conglomerate	from a hill-side exposure about 5M above the base of the Benan Conglomerate.	NX23809278	fine graded grit bands within the conglomerate.
G/BB/2	Superstes Mudstone	from the bed of Benan Burn 3M below the base of the Benan Conglomerate.	NX23929283	rubbly blue/grey mudstone.
G/BB/3	Stinchar Limestone	from the bed of Benan Burn 15M below the top of the Stinchar Limestone.	NX23829269	fine-grained grey pebbly limestone.
G/BB/4	Stinchar Limestone	from the bed of Benan Burn at the confluence of two tributaries.	NX23919264	very hard pale grey limestone.

Sample No.	Unit	Location	Grid Ref.	Lithology
G/BB/5	Confinis Flags	from the bed of Benan Burn.	NX23929258	fine-grained bluish sand-stone.
G/BB/6	? Confinis Flags	from the bed of Benan Burn probably close to the base of the Confinis Flags.	NX23919241	fine greyish green grits.

Text - fig. 3

Sample Site	Sample Numbers
1	G/BB/1
2	G/BB/2
3	G/BB/3
4	G/BB/4
5	G/BB/5
6	G/BB/6


SAMPLE SITES AT BENAN
1
2
3
4
5
6
BENAN.
River Stinchar
500 YDS.
500 M.

Text-fig. 3

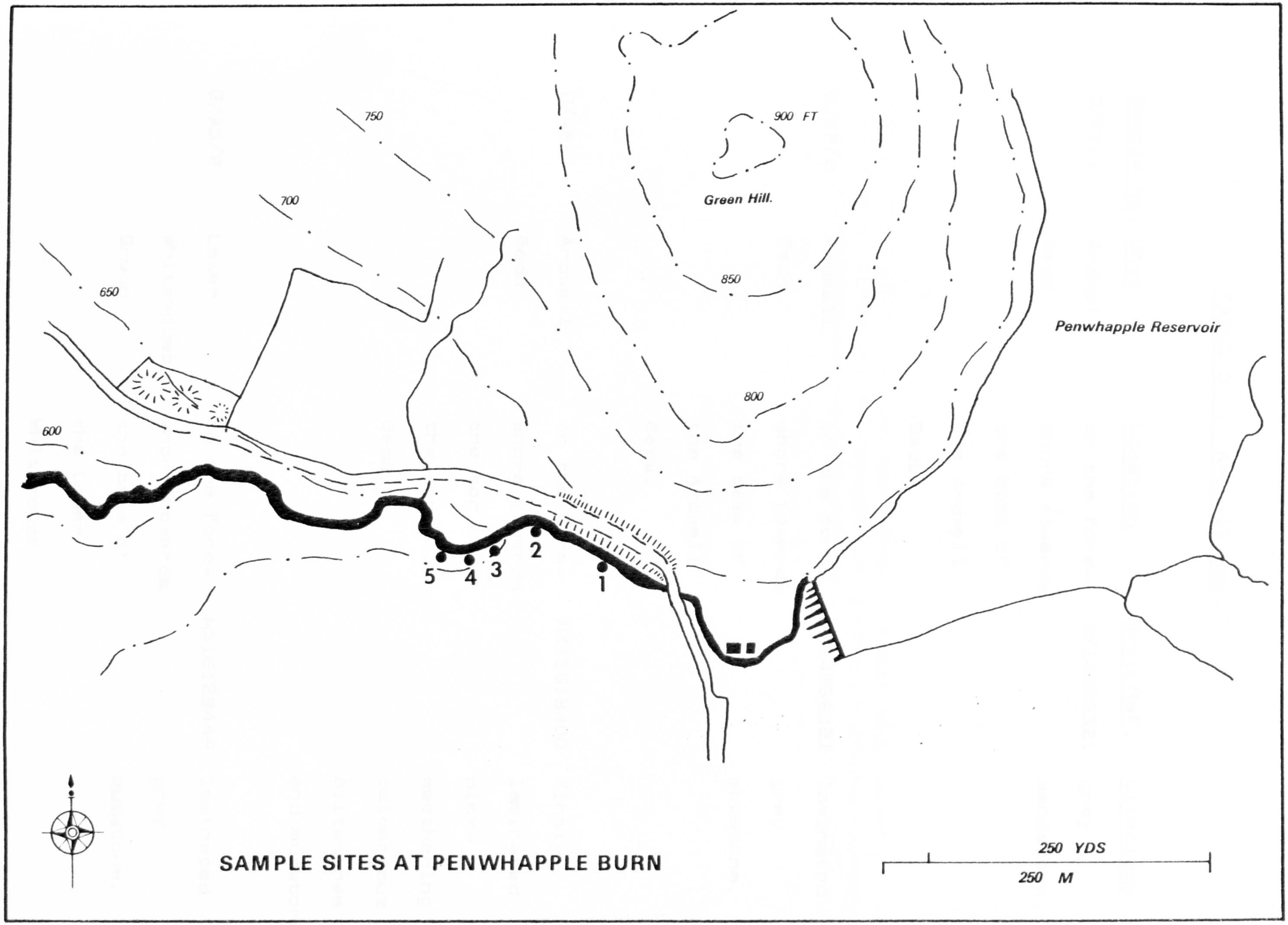
TABLE 2 : Penwhapple Burn.

Sample No.	Unit	Location	Grid Ref.	Lithology
G/PB/1	Balclatchie Group	south bank of Penwhapple Burn.	NX25439689	ironstained laminated mudstone.
G/PB/2	Balclatchie Group	south bank of Penwhapple Burn.	NX25439689	ironstained nodules.
G/PB/3	Balclatchie Group	south bank of Penwhapple Burn.	NX25449688	dark green calcareous grit with fossil fragments.
G/PB/4	Balclatchie Group	south bank of Penwhapple Burn.	NX25449688	green rubbly mudstone.
G/PB/5	Balclatchie Group	south bank of Penwhapple Burn.	NX25479688	soft dark green sandstone.
G/PB/7	Balclatchie Group	south bank of Penwhapple Burn.	NX25509689	green sphaeroidal sandstone.

Sample No.	Unit	Location	Grid Ref.	Lithology
G/PB/8	Balclatchie Group	south bank of Penwhapple Burn.	NX25539690	shattered rubbly brown weathering mudstone.
G/PB/9	Balclatchie Group	south bank of Penwhapple Burn.	NX25539690	massive dark grey blocky mudstone.

Text - fig. 4

Sample Site	Sample Numbers
1	G/PB/10 [Doon Hill conglomerate - not processed]
2	G/PB/8 G/PB/9
3	G/PB/7
4	G/PB/5
5	G/PB/4 G/PB/3 G/PB/2 G/PB/1



750
700
650
600
900 FT
Green Hill.
850
800
Penwhapple Reservoir
1
2
3
4
5
250 YDS
250 M
SAMPLE SITES AT PENWHAPPLE BURN

Text-fig. 4

TABLE 3 : Ardwell Bay.

Sample No.	Unit	Location	Grid Ref.	Lithology
G/KP/1	Ardwell Beds	on the fore-shore towards the base of the Ardwell Beds.	NX14869321	grey sandstone.
G/KP/2	Ardwell Beds	on the fore-shore towards the base of the Ardwell Beds.	NX14869321	laminated grey mudstone.
G/AB/1	Ardwell Beds	on the fore-shore towards the top of the Ardwell Beds.	NX15819400	finely laminated pink-weathering calcareous siltstones and mudstones.
G/AB/2	Lower Whitehouse Group	on the fore-shore towards the base of the Lower Whitehouse Group.	NX16129448	laminated grey mudstone.

Sample No.	Unit	Location	Grid Ref.	Lithology
G/WS/1	Upper Whitehouse Group	on the foreshore towards the base of the Upper Whitehouse Group.	NX16359467	purple mudstone.
G/WS/2	Upper Whitehouse Group	on the foreshore towards the base of the Upper Whitehouse Group.	NX16379469	green mudstone.
G/WS/3	Barren Flags	on the foreshore, exact horizon uncertain but within the Barren Flags.	NX16609491	finely laminated 'paper-shale' mudstones.
G/WS/4	Barren Flags	on the foreshore, exact horizon uncertain but within the Barren Flags.	NX16609491	coarse-grained sandstone.

Text - fig. 5

Sample Site	Sample Numbers
1	G/WS/1
1A	G/WS/2
2	G/AB/2
3	G/WS/3
	G/WS/4
8	G/AB/1


SAMPLE SITES AT ARDWELL BAY AYRESHIRE
Black Neuk.
WOODLAND
Port Cardloch
3
1a
1
2
ARDWELL BAY
ARDWELL
8
7
Ardmillan House.
BYNE HILL
Cairn Hill.
500YDS
500 M

TABLE 4 : Craighead Quarries

Sample No.	Unit	Location	Grid Ref.	Lithology
G/CQ/1	Craighead Limestone	from quarry C of Williams (1962).	NS014234	hard bedded limestone.
G/CQ/2	Craighead Limestone	from quarry C of Williams (1962).	NS014234	pebbly calcareous mudstone.
G/CQ/3	Kiln Mudstone	from the entrance cutting to quarry A of Williams (1962).	NS014234	dark grey/ green mudstone.

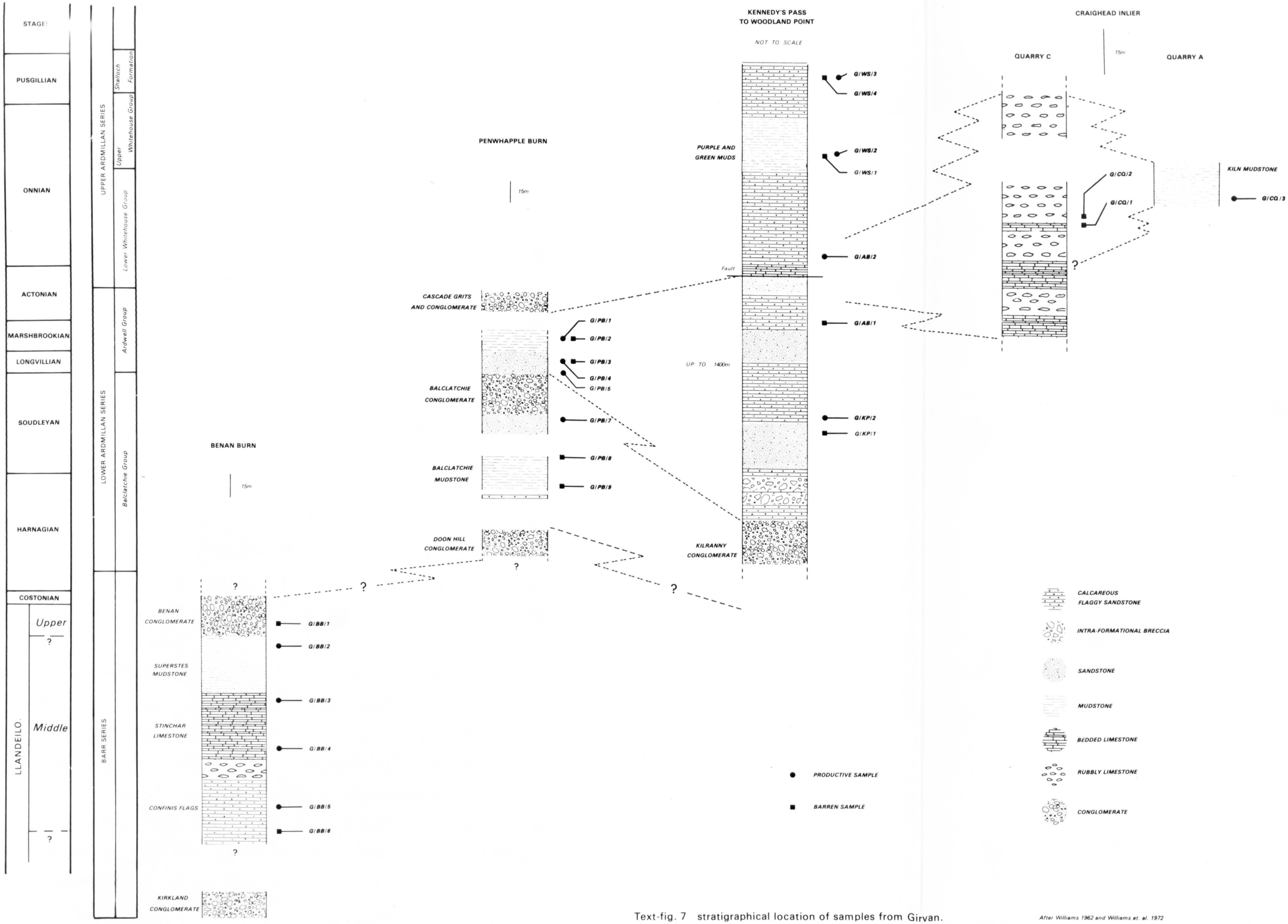
Text - fig. 6

Sample Site	Sample Numbers
1	G/CQ/1
	G/CQ/2
2	G/CQ/3

Diagram after Williams 1962.


SAMPLE SITES AT CRAIGHEAD QUARRIES
1
To Dailly.
Main Quarry
2
100 FT
30 M

Text-fig. 6



Text-fig. 7 stratigraphical location of samples from Girvan.

Shropshire.

1) Southern Caradoc Area.

Shropshire has been an area of outstanding interest to geologists working in the Ordovician since Murchison (1839) published his classic volume 'The Silurian System'. It was in this work that the term 'Caradoc Sandstone' was first used, a name applied by Murchison to strata cropping out in the county of Shropshire, extending from the Wrekin in the north-east down to Coston in the south-west. The clearest section was said by Murchison (p.216) to occur in the valley of the River Onny, near Horderley in south Shropshire. Usage of the term Caradoc has been much restricted by subsequent workers and it was given formal status as a Series of the Upper Ordovician by Lapworth (1916) who subdivided it. The exposures to be seen along the valley of the River Onny have long been accepted as the type section of the Caradoc on historical grounds; even now, some one hundred and forty years after Murchison, it remains the best exposed and most complete succession of Caradoc rocks in the district. Extensive stratigraphical and palaeontological researches have been carried out on these sediments and their associated rich shelly faunas, and the succession has been subdivided and described in great detail. This area was the location of Bancroft's original work on the Stages and Zones of the Caradoc Series. Dean (1958), provided a review of the history of research in the area while modern accounts of the geology are to be found in Dean (1964) and Greig et al. (1968). The Stage names and terminology used here are those of Williams, Strachan et al. (1972).

Due to deterioration of the type section it is now no longer possible to distinguish between the Glenburrell Beds and the Smeathen Wood Beds anywhere adjacent to the River Onny. For this reason the two units are treated as a single entity in this study and are referred to throughout as the Harnage Shales.

In collecting samples for palynological analysis from the Caradoc of Shropshire, particular importance was attached to the type section for obvious reasons. Since one of the aims of this study is to establish the stratigraphical distribution of acritarchs within the British Caradoc, investigation of a sequence or sequences, both widely known and well understood was considered essential. The type section of the Series consists of sediments laid down in a shallow water shelf environment and almost without exception the lithologies present appear eminently suited to the deposition and preservation of palynomorphs. Thus the section is ideal in terms of microfossil potential as well as correlative value.

A reasonably even spread of samples was obtained from the section, covering the whole stratigraphical sequence; a minor exception was the Harnage Shales which are now poorly exposed. The middle part of this unit is not seen at all. In an attempt to rectify this situation, additional samples were collected from other exposures within a few miles of the River Onny. A number of such outcrops are described by Greig et al. and in each case the Harnagian age is based on the macrofaunas obtained. Unfortunately it proved impossible to precisely correlate these exposures with those of the Onny Valley. This meant that any samples taken and used would be of uncertain stratigraphical position relative to the exactly located samples already held. The inclusion in this way of imprecisely correlated samples was considered undesirable since it could clearly lead to a misinterpretation of the microfloral succession. For this reason only material from the type section of the southern Caradoc area is reported on in this section.

The sites from which samples were collected are shown in text-fig.8 while the stratigraphical distribution of the samples is given in text-fig.9.

TABLE 5 : Southern Caradoc Area.

Sample No.	Unit	Location	Grid Ref.	Lithology
OV/C/1	Coston Beds	10M above the base of the Coston Beds, western end of lower quarry	SO41178614	medium grained indurated sandstone.
OV/C/2	Coston Beds	20M above the base of the Coston Beds, from the prominent lst. band in the centre of the lower quarry.	SO41178614	dark, fine-grained crystalline limestone.
OV/C/3	Coston Beds	30M above the base of the Coston Beds, eastern end of the lower quarry.	SO41178614	coarse gritstone.
OV/HS/1	Harnage Shales	30cm above the base of the Harnage Shales; extreme eastern exposure in lower quarry.	SO41188614	soft, greenish, brown-weathering mudstone.

Sample No.	Unit	Location	Grid Ref.	Lithology
OV/HS/2	Harnage Shales	just below the top of the Harnage Shale, from the bed of the River Onny 38M east of the footbridge.	SO41288614	soft, greenish blocky mudstone.
OV/LHS/1	Lower Horderley Sandstone	about 5M above the base of the sand-stone, from above the old railway 20M north of the old stone footbridge.	SO41338604	fine-grained green micaceous sandstone.
OV/LHS/2b	Lower Horderley Sandstone	about 15M above the base of the sand-stone, from above the old railway track.	SO41348603	soft, brown-weathering mudstone band.

Sample No.	Unit	Location	Grid Ref.	Lithology
OV/MHS/2	Middle Horderley Sandstone	the lower part of the Middle Horderley Sandstone, from the western end of the old quarry.	SO41518597	massive, fine-grained red and green sandstones.
OV/MHS/1	Middle Horderley Sandstone	the central part of the Middle Horderley Sandstone, from the eastern end of the old quarry.	SO41548591	massive, fine-grained red and green sandstones.
OV/UHS/1	Upper Horderley Sandstone	towards the top of the Horderley Sandstone, from the south side of the old railway.	SO41758570	fine-grained greenish micaceous sandstone.

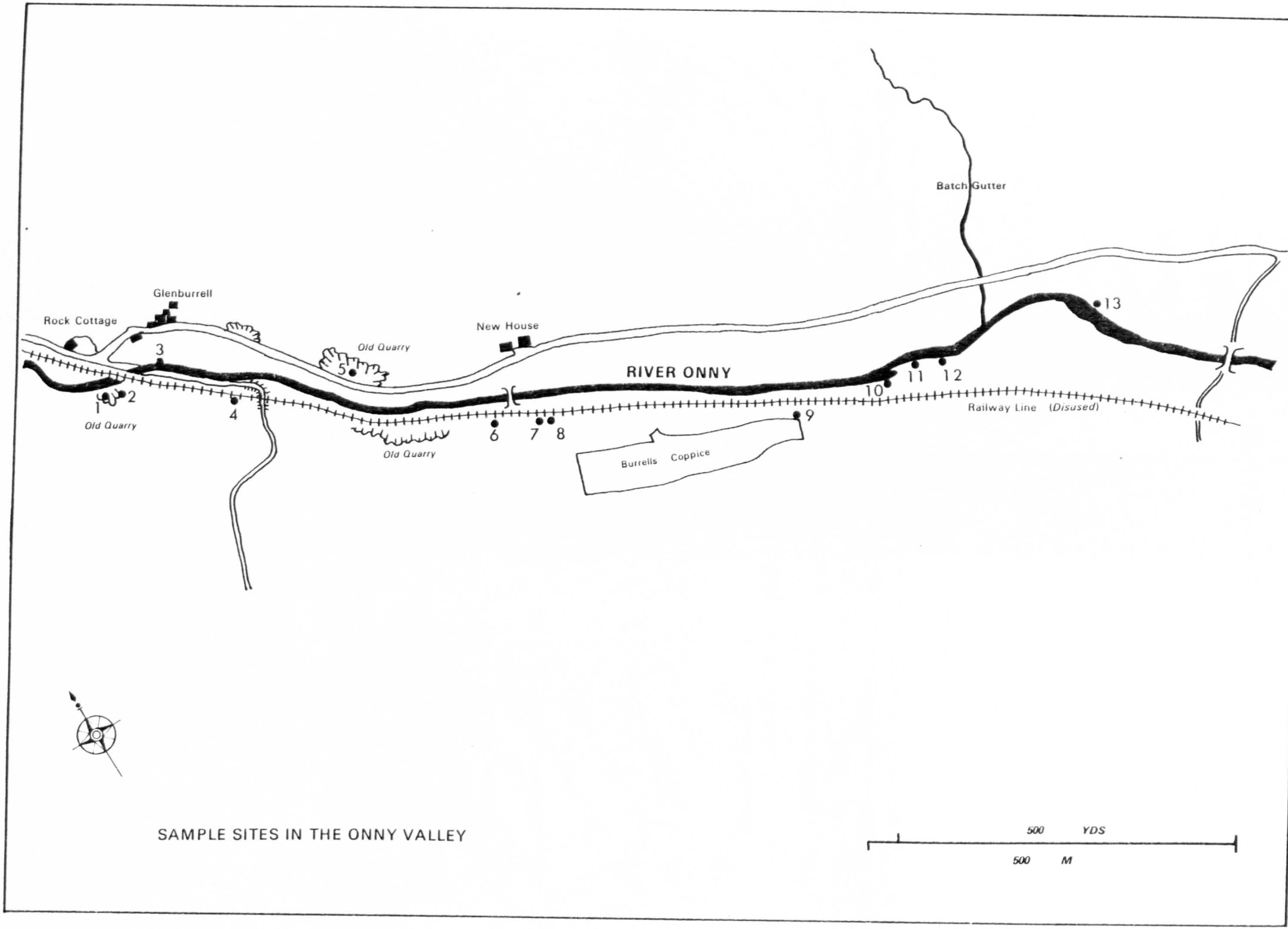
Sample No.	Unit	Location	Grid Ref.	Lithology
OV/A/1	Alternata Limestone	within the lower part of the Alternata Limestone, from the south side of the old railway.	SO41788568	dark grey, silty limestone.
OV/A/2	Alternata Limestone	within the lower part of the Alternata Limestone, from the south side of the old railway.	SO41788568	dark grey, silty limestone.
OV/LCL/2	Lower Cheney Longville Flags	within the Lower Cheney Longville Flags from the N.E. corner of Burrells Coppice.	SO42098544	finely-laminated silty flags.
OV/LCL/1	Lower Cheney Longville Flags	within the lower Cheney Longville Flags from the N.E.corner of Burrells Coppice.	SO42098544	finely-laminated silty flags.

Sample No.	Unit	Location	Grid Ref.	Lithology
OV/UCL/1	Upper Cheney Longville Flags	towards the top of the Upper Cheney Longville Flags, from a small exposure in the south bank of the River.	SO42248542	yellow-weathering fine-grained flags.
OV/AS/2	Acton Scott Beds	the lower part of the Acton Scott Beds, from a small exposure in the south bank of the river.	SO42318542	soft grey mudstones and shales.
OV/AS/1	Acton Scott Beds	the upper part of the Acton Scott Beds, from a small exposure in the south bank of the river.	SO42378539	soft grey mudstones and shales.

Sample No.	Unit	Location	Grid Ref.	Lithology
OV/O/3	Onny Shales	the lowest exposed beds of the Onny Shales.	SO42588536	blocky, grey mudstone.
OV/O/4	Onny Shales	70cm above the lowest exposed shales.	SO42588536	blocky, grey mudstone.
OV/O/2	Onny Shales	6M below the Silurian unconformity.	SO42638530	blocky, grey mudstone.
OV/O/1	Onny Shales	30cm below the Silurian unconformity.	SO42638530	blocky, grey mudstone.

Text - Fig. 8

Sample Site	Sample Numbers
1	OV/C/1
	OV/C/2
	OV/C/3
2	OV/HS/1
3	OV/HS/2
4	OV/LHS/1
	OV/LHS/2
5	OV/MHS/1
	OV/MHS/2
6	OV/UHS/1
7	OV/A/1
8	OV/A/2
9	OV/LCL/2
	OV/LCL/1
10	OV/UCL/1
11	OV/AS/2
12	OV/AS/1
13	OV/O/3
	OV/O/4
	OV/O/2
	OV/O/1


SAMPLE SITES IN THE ONNY VALLEY
Batch Gutter
Glenburrell
Rock Cottage
New House
Old Quarry
Old Quarry
Old Quarry
RIVER ONNY
Burrells Coppice
Railway Line (Disused)
1
2
3
4
5
6
7
8
9
10
11
12
13
500 YDS
500 M

Text-fig. 8

Text - Fig. 9

A diagrammatic vertical section through the type - section of the Caradoc showing the stratigraphical distribution of samples.


ONNY SHALES
ACTON SCOTT BEDS
CHENEY LONGVILLE FLAGS
ALTERNATA LIMESTONE
CHATWALL SANDSTONE
HARNAGE SHALES
HOAR EDGE GRITS
OV/O/1
OV/O/2
OV/O/4
OV/O/3
OV/AS/1
OV/AS/2
OV/UCL/1
OV/LCL/1
OV/LCL/2
OV/A/2
OV/A/1
OV/UHS/1
OV/MHS/1
OV/MHS/2
OV/LHS/2
OV/LHS/1
OV/HS/2
100 M
OV/HS/1
OV/C/3
OV/C/2
OV/C/1

Text-fig. 9

2) Northern Caradoc Area.

A second important outcrop of Caradoc strata occurs some 15Km to the north-east of the Onny Valley around the site of the now demolished Chatwall Hall. The rocks of this area have been extensively studied, the term 'Chatwall Sandstone' being introduced by Callaway (1877). Further new terminology was introduced by Lapworth (1916) who divided the Ordovician rocks of Shropshire into 'Groups' based on place names from within the county (see Dean 1958, p.213). Lapworth published no details of his work but his terminology has become important since it was applied to this general area by the Geological Survey in the Shrewesbury Memoir (Pocock et al. 1938). The most recent study of the Chatwall district is that of Dean (1960) who remapped the vicinity on the twenty five inch scale and carried out a bed by bed collection of the shelly macrofauna. This detailed work showed that around Chatwall the succession present is by no means complete. It had long been realized that the sequence only included Stages from the Costonian to the Marshbrookian with sediments of Actonian age present but rarely exposed. Dean showed that within these strata, at least two unconformities occurred, indicating that sedimentation was much less continuous in this northern area than in the Onny Valley. The location of sample sites at Chatwall is shown in text-fig.10, and the stratigraphical distribution of samples in text-fig.11.

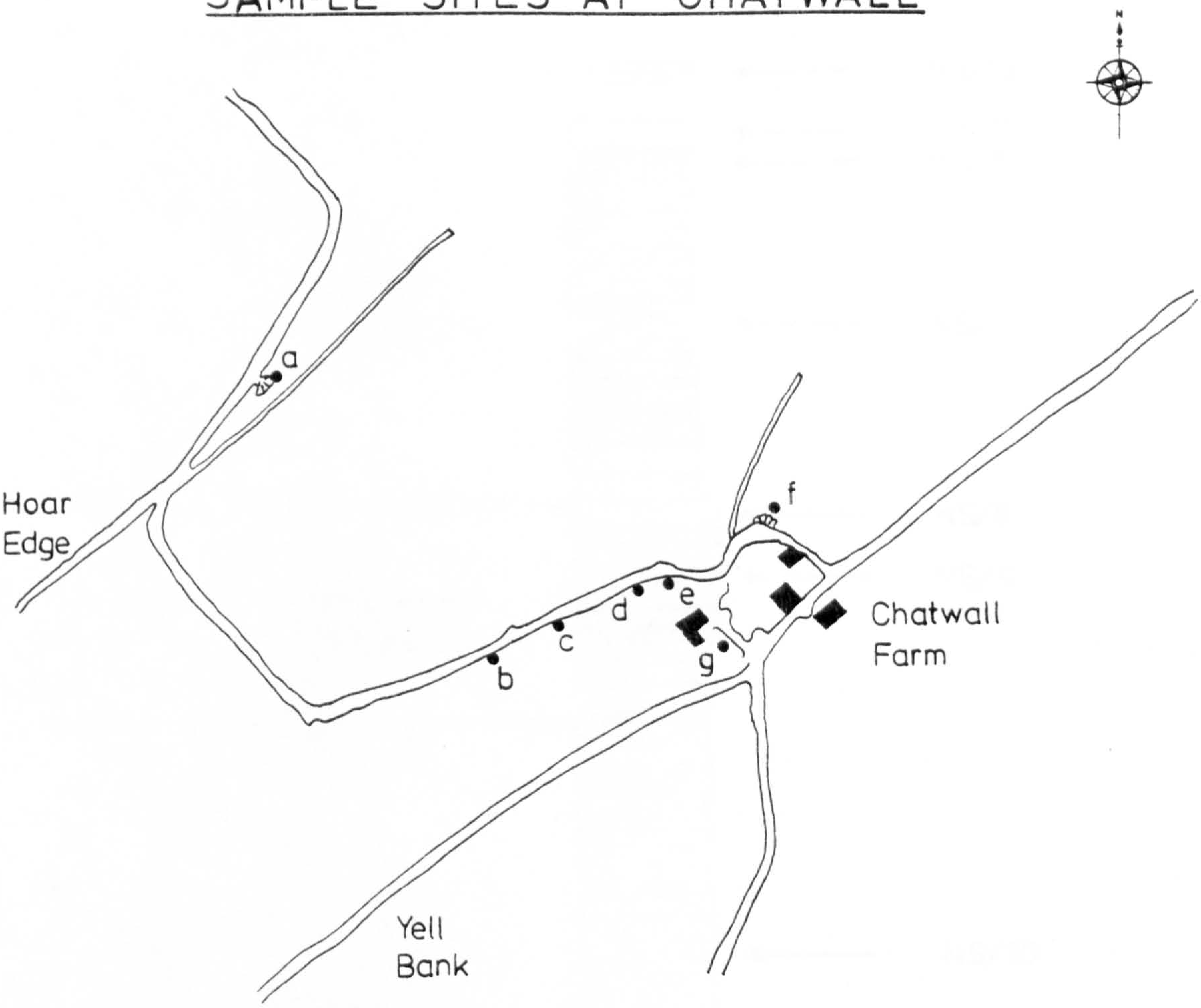
TABLE 6 : Northern Caradoc Area.

Sample No.	Unit	Location	Grid Ref.	Lithology
NS/13	Hoar Edge Grits	from the large quarry just above the road.	SO95809774	coarse-grained yellowish sandstone.
NS/3	Harnage Shales	about 6M below the top of the Harnage Shales, from the bank above the road.	SO51089742	mottled red/green hard silty mudstone sometimes laminated.
NS/4	Harnage Shales	just below the top of the Harnage Shales, from the bank above the road.	SO51149747	soft green rubbly mudstone.
NS/1	Chatwall Flags	just above the base of the Chatwall Flags, from the bank above the road.	SO51259751	fine-grained, green, micaceous, silty sand-stone.

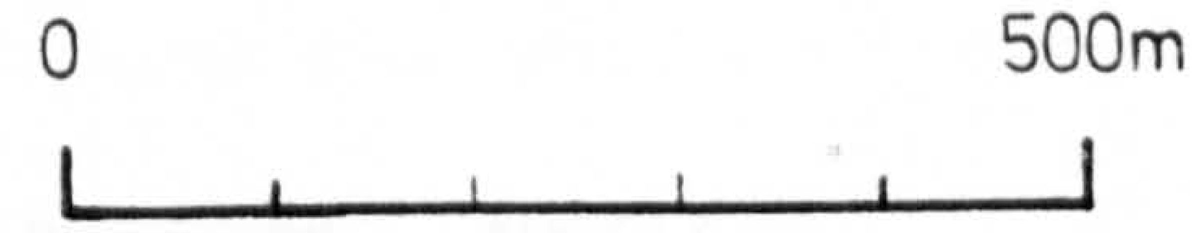
Sample No.	Unit	Location	Grid Ref.	Lithology
NS/5	Chatwall Flags	about 3M stratigraphically above NS/1, from the bank above the road.	SO51269751	buff-coloured laminated flagstones.
NS/2	Chatwall Flags	about 3M stratigraphically above NS/5, from the obvious small quarry on the bend of the road.	SO51399758	fine-grained green, micaceous flagstone.
NS/10	Chatwall Flags	within the cutting from the S.W.face, low in bed 1 of Dean.	SO51379745	buff-coloured sandstones and shales.
NS/9	Chatwall Sandstone	within the cutting, from the S.W.face, bed 8 of Dean.	SO51379745	buff-coloured sandy shales.

Sample No.	Unit	Location	Grid Ref.	Lithology
NS/8	Chatwall Sandstone	within the cutting, from the S.W.face, bed 13 of Dean, from 60cm. above the conglomerate.	SO51379745	massive, grey/green current bedded sandstone.
NS/7	Alternata Limestone	within the cutting, from the S.W.face, bed 21 of Dean.	SO51379745	flaggy yellow sandstones.
NS/6	Alternata Limestone	within the cutting, from the S.W.face, bed 23 of Dean.	SO51379745	flaggy yellow sandstones.
NS/11	Alternata Limestone	from the small quarry face to the east of the end of the cutting.	SO51399743	buff-coloured calcareous sandstone.
NS/12	Alternata Limestone	from the floor of the track leading to the cutting 4M S.E. of the field gate.	SO51379744	grey sandy limestone with abundant shelly fossils.

SAMPLE SITES AT CHATWALL

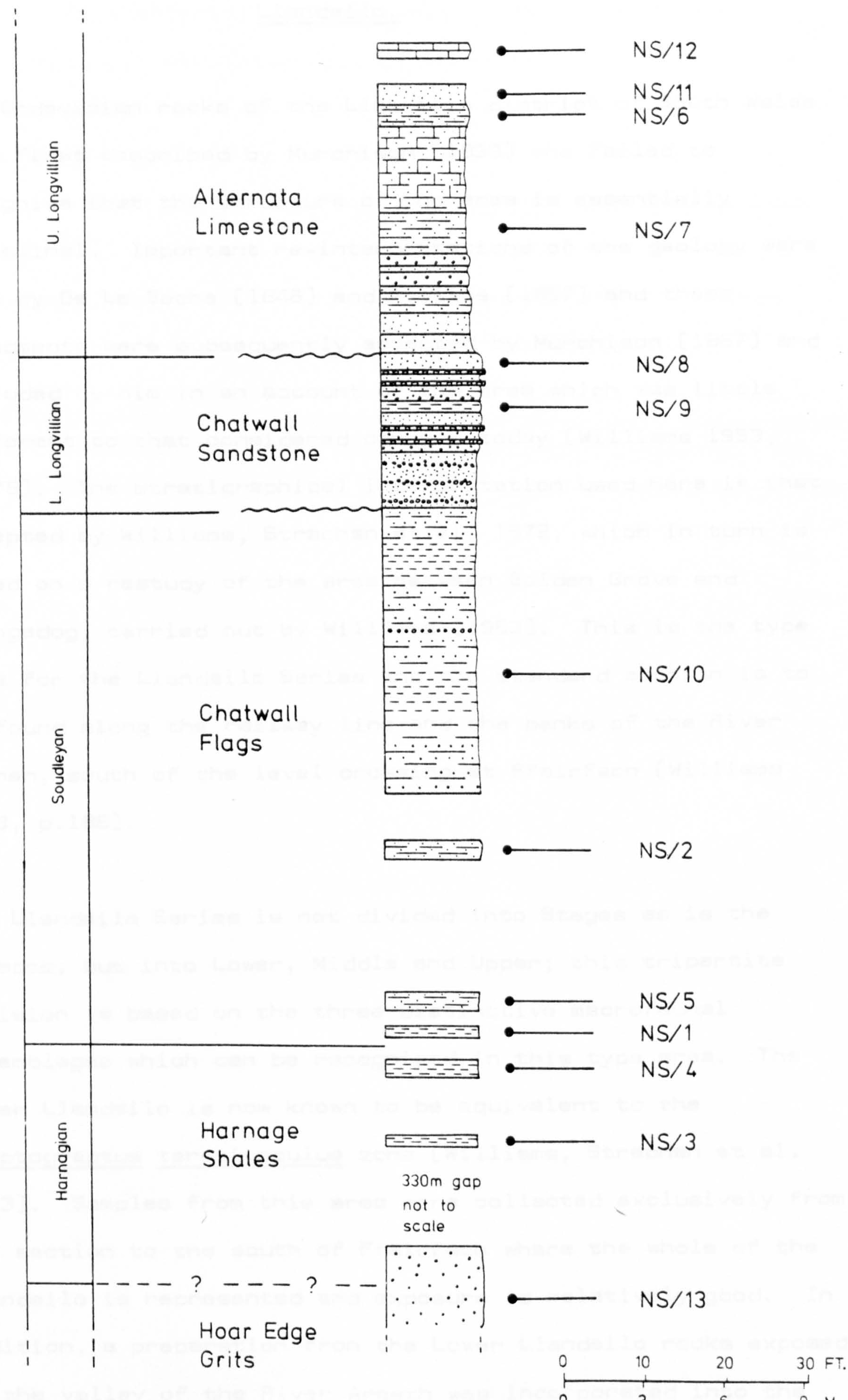


Sample site	Sample number
a	NS/13
b	NS/3
c	NS/4
d	NS/1
e	NS/5
f	NS/2
g	NS/6 - NS/12



Text-fig. 10

Showing the stratigraphical location of samples from Chatwall.



Text-fig. 11

Llandeilo.

The Ordovician rocks of the Llandeilo district of South Wales were first described by Murchison (1839) who failed to recognise that the structure of the area is essentially anticlinal. Important re-interpretations of the geology were made by De La Beche (1846) and Aveline (1857) and these amendments were subsequently accepted by Murchison (1867) and included by him in an account of the area which was little different to that considered correct today (Williams 1953, p.178). The stratigraphical interpretation used here is that accepted by Williams, Strachan et al. 1972, which in turn is based on a restudy of the area between Golden Grove and Llangadog, carried out by Williams (1953). This is the type area for the Llandeilo Series and the standard section is to be found along the railway line and the banks of the River Cennen, south of the level crossing at Ffairfach (Williams 1953, p.188).

The Llandeilo Series is not divided into Stages as is the Caradoc, but into Lower, Middle and Upper; this tripartite division is based on the three distinctive macrofaunal assemblages which can be recognised in this type area. The Lower Llandeilo is now known to be equivalent to the *Glyptograptus teretiusculus* zone (Williams, Strachan et al. p.33). Samples from this area were collected exclusively from the section to the south of Ffairfach where the whole of the Llandeilo is represented and exposure is relatively good. In addition, a preparation from the Lower Llandeilo rocks exposed in the valley of the River Araeth was incorporated into the study. This material was available in the palynological collections of the University of Sheffield and the relative stratigraphical position with reference to the Ffairfach samples is quite clear; it is known to have been collected from the upper part of the *Marrolithus inflatus maturus* Beds of Williams, a horizon not exposed at Ffairfach, and is therefore from above the highest sample [FF/SF/1] obtained from the Lower Llandeilo in the Ffairfach section.

All sample sites at Ffairfach are shown in text-fig.12 while the stratigraphical distribution of samples obtained is given in text-fig.13.

TABLE 7 : Llandeilo.

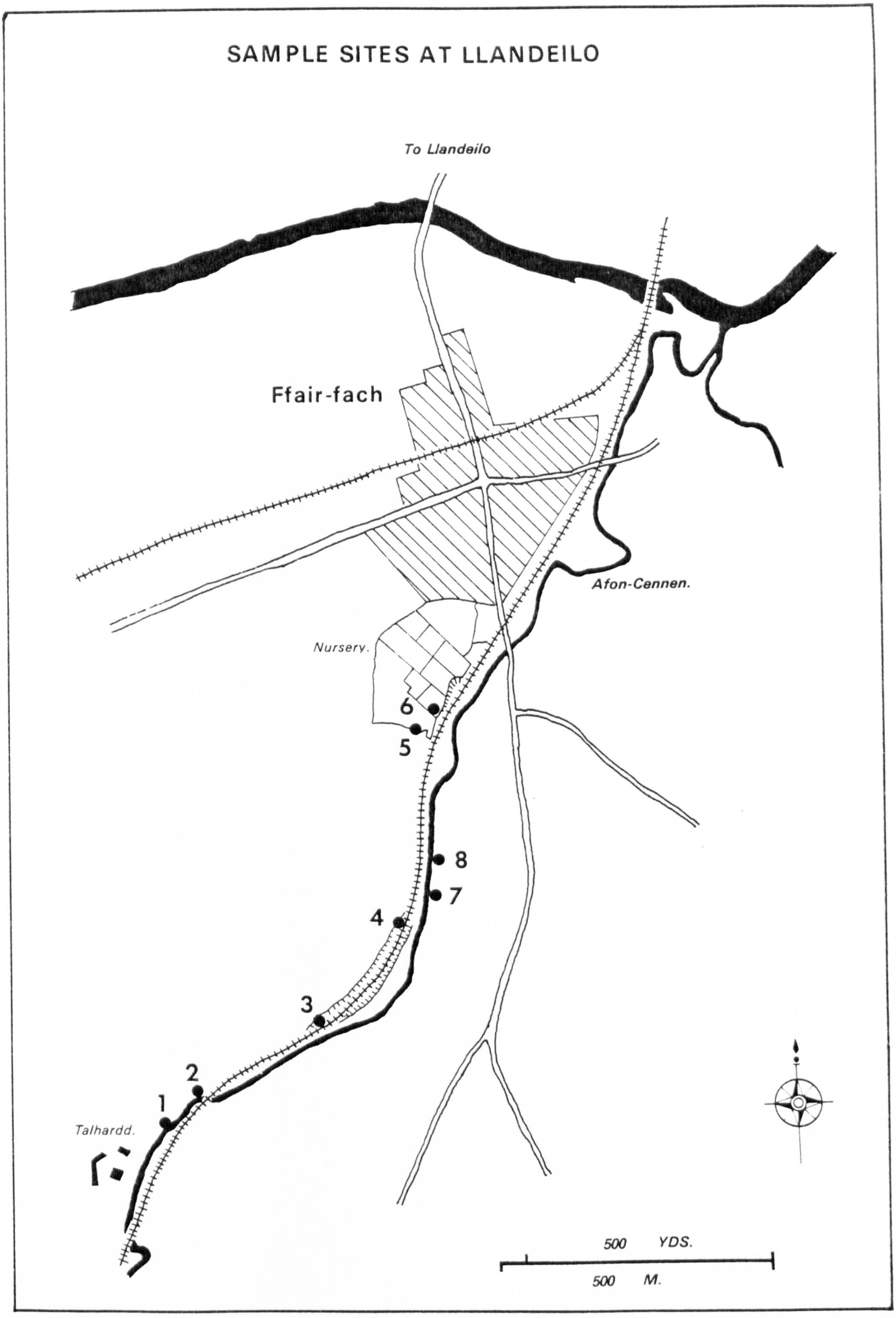
Sample No.	Unit	Location	Grid Ref.	Lithology
FF/LF/1	Lower Llandeilo	from a small exposure 5M W of the railway line. *L. lloydi* Flags.	SN62752107	calcareous shaly flagstone.
FF/SF/1	Lower Llandeilo	from a small exposure 1M above the base of a large Beech tree. Sandy Flags.	SN62732103	finely laminated brown shale.
Araeth	Lower Llandeilo	from close to the waterfall. *M. inflatus maturus* Beds.	SN66242369	not known
FF/M.a./2	Middle Llandeilo	from the bed of the River Cennen, about the middle of the *M. anomalis* Limestones.	SN62732079	steeply dipping, dark, bedded limestone.

Sample No.	Unit	Location	Grid Ref.	Lithology
FF/M.a./1	Middle Llandeilo	from the bed of the River Cennen, the top of the *M.anomalis* Limestones.	SN62732073	steeply dipping, dark, bedded limestone.
FF/MSE/1	Middle Llandeilo	from the cutting 5M W of the railway line, about the middle of the *M.simplex elevata* Flags.	SN62692066	steeply dipping, dark, bedded limestone.
FF/ML/2	Middle Llandeilo	from the N.W. face of the railway cutting, about the middle of Bed b IV of Williams.	SN62542047	steeply dipping, dark, bedded limestone.
FF/ML/1	Middle Llandeilo	from the bank of the River Cennen 3M up-stream from the railway bridge, the top of Bed b IV of Williams.	SN62322034	bedded calcareous flagstone.

Sample No.	Unit	Location	Grid Ref.	Lithology
FF/UL/1	Upper Llandeilo	from the bed of the River Cennen 200M downstream from Talhardd Farm, low in the Upper Llandeilo.	SN62252032	bedded dark limestone.

Text - fig. 12

Sample Site	Sample Numbers
1	FF/UL/1
2	FF/ML/1
3	FF/ML/2
4	FF/MSE/1
5	FF/SF/1
6	FF/LF/1
7	FF/M.a./1
8	FF/M.a./2


SAMPLE SITES AT LLANDEILO
To Llandeilo
Ffair-fach
Afon-Cennen.
Nursery.
Talhardd.
1
2
3
4
5
6
7
8
500 YDS.
500 M.

Text-fig. 12

Text - fig. 13

Diagrammatic vertical section through the type - area of the Llandeilo showing the stratigraphical distribution of samples.


LLANDEILO
Upper
Middle
Lower
FF/UL/1
FF/ML/1
FF/ML/2
FF/MSE/1
FF/M.a./1
FF/M.a./2
100 M
Araeth
FF/SF/1
FF/LF/1

Text-fig.13

Sample Numbering

As samples were collected in the field, they were allotted a unique code derived from the general area, the stratigraphical unit or specific locality sampled and a sample number. Thus OV/O/1 is the first sample taken from the Onny Shales in the Onny Valley while G/BB/4 is the fourth sample from the Benan Burn section at Girvan.

Abbreviations Used.

General Areas.

G	Girvan.
FF	Ffairfach.
NS	North Shropshire (Chatwall).
OV	Onny Valley.

Stratigraphical Units.

A	Alternata Limestone.
AS	Acton Scott Beds.
C	Coston Beds.
HS	Harnage Shales.
LCL	Lower Cheney Longville Flags.
LF	Lloydolithus lloydi Flags.
LHS	Lower Horderley Sandstone.
M.a.	Marrolithoides anomalis Limestones.
MHS	Middle Horderley Sandstone.
ML	Marrolithoides simplex elevata Flags. (poorly fossiliferous upper part).

MSE	M.simplex elevata Flags.
O	Onny Shales.
SF	Sandy Flags.
UCL	Upper Cheney Longville Flags.
UHS	Upper Horderley Sandstone.
UL	Upper Llandeilo.

Localities

AB	Ardwell Bay.
BB	Benan Burn.
CQ	Craighead Quarry.
KP	Kennedy's Pass.
PB	Penwhapple Burn.
WS	Whitehouse Shore.

Where samples were taken from adjacent horizons of differing lithology at a single exposure, the suffixes a, b, etc. were used; for example OV/LHS/1a and OV/LHS/1b.

Chapter two

METHODS OF ACRITARCH RECOVERY AND STUDY

Sample Preparation

Samples of unweathered sediment were taken at each exposure if possible, but failing this, the material chosen was always the least weathered that could be obtained. In some of the softer horizons sampled, this requirement meant digging out substantial volumes of rock in order to expose relatively fresh strata. Any portions of rock which included recent plant material such as surface lichen growth or penetrating rootlets, were rejected when choosing the sample material to preclude field contamination. As the samples were collected they were placed in self sealing polythene bags inside tagged linen sample bags for transfer back to the laboratory.

The separation techniques used and described below are now more or less standard in both academic and commercial palynological laboratories although details may vary with local conditions and requirements. In particular, treatment of samples differs depending on which group of acid-insoluable microfossils is being recovered. Essentially the processes used fall under three main headings.

a] dissolution and removal of the sediment matrix to release any enclosed organic material.

b] concentration and chemical treatment of organic residues to provide optimum conditions for microscopic examination of the microfossils.

c) mounting the fossil assemblages as a permanent preparation.

For the extraction of acritarchs, which may range in size from 350u down to less than 5u, the following procedures were carried out.

Dissolution

A portion of sample between fifty and two hundred and fifty grammes was taken, the size depending on the lithology of any given sample; smaller portions of favourable sediments such as mudstones or siltstones were necessary while experience showed that sandstones and many limestones required the preparation of larger volumes of rock to yield numerically sufficient acritarch populations. Where the lithology allowed, the sample was scrubbed using a nylon brush and Teepol, an industrial detergent. The sample was then rinsed thoroughly under running water and broken up into approximately pea sized fragments using a hammer and a steel pestle and mortar. This greatly increased the surface area of the sample so facilitating breakdown by acids. The fragmented sample was transferred to a rigid polythene bottle where a few drops of hydrochloric acid were added to test for the presence of carbonates. Where a positive carbonate reaction was obtained, more hydrochloric acid was added until the reaction ceased, violent effervescence being prevented by the previous addition of a small amount of water. If a large volume of hydrochloric acid was used at this stage then the bottle was allowed to stand and settle overnight, after which the supernatant liquor was decanted. Normally however the next step could be proceeded with directly. Any silicate minerals in the sample were broken down by the addition of 40% hydrofluoric acid; extreme caution was required at this stage to avoid any violent reaction. The acid was added a little at a time and only gentle agitation was used to mix it. The bottle was then stored in a water bath at 60^{o}C and the sample was stirred daily using a glass rod. The time taken for complete breakdown of the sample varied from two to ten days; at this point the resulting fine, organic rich sludge and acid liquor were transferred to a 1000ml. polythene beaker which was filled with water, ensuring thorough mixing. The beaker was allowed to stand overnight and then decanted, a procedure which was repeated until a test with litmus paper showed that the supernatant liquid was neutral. The acritarchs were then cleaned and concentrated by washing the organic residue through a 20u nylon mesh sieve. The coarse fraction retained on the sieve was transferred to a number two Buchner glass funnel with an effective pore size of 3 to 5u. The fine fraction, washed through the nylon sieve, was caught in a 1000ml. beaker and passed through a separate Buchner funnel. After this the two size fractions were treated in an identical manner. At this stage a drop of the residue was examined under a microscope and usually consisted of acid-insoluable microfossils, particulate organic debris and often heavy mineral grains and some calcium fluoride crystals. The latter were removed by heating the residue in a beaker of hydrochloric acid and then washing with water in the Buchner funnel. Organic debris was commonly abundant, obscuring the acritarchs and requiring chemical oxidation to remove it.

Oxidation and heavy liquid separation

Oxidation reactions were carried out in the Buchner funnel, great care being exercised to avoid over-oxidation since the process affects not only the organic debris but also any acritarchs present; oxidation frequently renders the acritarchs easier to observe with transmitted light since the wall is thinned. However they will be totally destroyed if the oxidising agent used is too powerful or the period of exposure is extended. The oxidising reagents used in ascending order of strength were, 70% nitric acid, Schultz solution and fuming nitric acid. Treatment was always initiated with the weakest reagent and a drop of residue was examined at frequent intervals under a microscope to ascertain the rate of reaction. This method of repeated examination was required for every sample, to determine the reagent needed and the duration of oxidation. A uniform procedure was impossible since the reactions of different residues varied widely. When optimum oxidation was achieved, the sample was washed thoroughly to remove any traces of nitric acid. If heavy minerals were present, the residue was transferred to a centrifuge tube, acidified with a drop of hydrochloric acid, topped up with zinc bromide [S.G.2.3], and shaken gently to ensure an homogenous mixture. The tube was then centrifuged for fifteen minutes at 1500 r.p.m. after which the minerals were concentrated in the bottom while the light organic fraction was retained in the upper portion of the tube. The zinc bromide containing the organic residue was returned to the Buchner funnel and the heavy liquid was allowed to drain off. The residue was then thoroughly washed with water, any precipitate of $Zn(OH)_2$ formed at this stage being dispersed by addition of a drop of hydrochloric acid. A clean, concentrated assemblage of acritarchs had now been obtained and where these were pale and transparent they were stained with the organic dye Safranin Red and washed again. The residue was then transferred to a stoppered glass tube and allowed to settle.

All reactions and storage involving acids were carried out inside suitable fume-hoods. All glass and polythene containers were sterilized with fresh chromic acid to prevent cross contamination of samples.

Mounting

Permanent microscope slides were made by removing most of the water from above the organic residue in the glass tube with a teat pipette; a few drops of cellosize solution were added to the concentrated residue and shaken, a portion was then extracted from the tube and spread evenly over a cover slip on a hotplate at 60°C; the water was evaporated off and the organic matter was left adhering to the cover slip as a strew mount. A glass slide was placed on a separate hotplate at 110°C, given a thin coating of canada balsam and then left until the solvent had been driven off. The cover slip was then inverted and carefully lowered onto the canada balsam so that no air bubbles were trapped beneath. After cooling, any excess canada balsam was removed by scrubbing the slide in methylated spirit. A minimum of six slides were prepared from each sample, coarse and fine fractions being mounted separately. All slides were labelled with the relevant sample number plus a unique number for each slide; OV/O/1-3 is thus slide number 3, prepared from sample OV/O/1.

Preparations for use in a stereoscan electron microscope were made by pipetting a portion of organic residue in a concentrated deionised aqueous solution on to a circular cover slip where it was allowed to dry at room temperature. The microfossils adhering to the cover slip were then coated with gold in a vacuum chamber. The cover slip was finally fixed to the upper surface of an aluminium stub with liquid silver DAG.

<u>Photography</u>

All transmitted light photography was carried out on a Zeiss photomicroscope with automatic exposure control. Film used was Kodak Panatomic-X and was developed using Kodak D 76 at 68^{o}F for eight minutes. Prints were produced using an Ilfaprint Processor 1502 using Kodak HC-110 developer at 68^{o}F with nitrogen agitation.

The stereoscan electron microscope used was a Cambridge Instruments Co. Stereoscan Mk II (old model).

<u>Slide Examination</u>

For each sample a count of two hundred acritarchs was made to give the relative species composition of each assemblage. After the count was completed, examination of slides was continued to ensure that any rare species present were recorded and identified. A grading system was devised to show the relative abundance of all species within any sample.

Grade	Symbol	Number Present
Very Rare	V	<5
Rare	R	5-10
Uncommon	U	10-20
Common	C	20-40
Abundant	A	>40

Routine logging of slides was carried out using X10 eyepeices with a X20 objective for the coarse fraction and a X40 oil immersion objective for the fine fraction. Detailed examinations were made with a X100 Neofluor oil immersion objective and a X100 phase-contrast oil immersion objective. Nomarski interference was used to elucidate details of surface ornamentation in some suitably preserved acritarchs.

Representative slides from all samples are housed in the palynological collections of the Department of Geology, University of Sheffield.

Chapter Three

PREVIOUS RESEARCH ON ORDOVICIAN ACRITARCHS.

Note: In this chapter a brief review is given of the history of research on acritarchs of Ordovician age and mention is made of most significant publications dealing with this group of microfossils; for convenience these various works are dealt with on the basis of the geographical location of the assemblages discussed.

Europe:

The first acritarchs of Ordovician age to be recovered and studied, were described from the Baltic region by Eisenack [1931]. This work was the first of an extensive series of publications dealing wholly or partly with Ordovician acritarchs from this area, [Eisenack 1931, 1938, 1939, 1951, 1958a, 1958b, 1962b,1965a, 1968b, 1969, 1976]; much of the early work of Eisenack was based on samples taken from glacial erratics in northern Germany. Other authors subsequently reported on the prolific and extremely well preserved microplankton assemblages which seem to be characteristic of many Ordovician strata in the Baltic region [Kjellstrom 1971a, 1971b, 1976; Tynni 1975]. The work of Kjellstrom, based on subsurface core samples with lithological correlation and megafossil control available, is of particular interest and importance.

After the pioneering studies of Eisenack, workers in France took an early interest in Ordovician microplankton and a number of papers appeared which concentrated on acritarch studies. (Deunff 1951, 1954, 1959; Chauvel, Deunff and Le Corre 1970; Le Corre and Deunff 1969; Henry 1969; Martin 1972; Paris and Deunff 1970; Rauscher 1971, 1973, 1974). Francine Martin, working in Belgium, reported on Ordovician acritarch assemblages similar in composition to those recorded from France (Martin 1966a, 1969a, 1969b, 1974, 1975; Martin, Michot and Vanguestaine 1970). A single report on acritarchs of Llandeilo/Caradoc age from Portugal was presented by Henry and Thadeau (1971). Gorka (1969) described well preserved early Ordovician acritarchs from Poland while Burmann (1968, 1970) working with poorly preserved material in thin sections, published details of acritarchs of similar age from the German Democratic Republic. Lower Ordovician acritarch assemblages were also described from Bulgaria (Kalvacheva 1969, 1972; Kalvacheva and Dimitrova 1973); in addition, a useful statistical study was carried out on species of the genus Veryhachium using populations recovered from Lower Ordovician sediments in the Iskur Gorge, Bulgaria (Kalvacheva and Chobanova 1973). A number of publications have appeared dealing mainly with early Ordovician acritarchs from Czechoslovakia (Vavrdova 1965, 1966, 1972, 1973, 1974, 1976, 1977).

Russia:

A number of papers have appeared in the Russian literature in the past three decades, dealing mainly or exclusively with Ordovician acritarchs (Timofeev 1959, 1963, 1966; Timofeev German and Mikhaylova 1976; Umnova 1975; Umnova and

Vanderflit 1971]. Unfortunately the standard of description and illustration is often poor and new taxa are frequently so inadequately erected as to be unusable. A much more serious difficulty with the Russian literature is that many publications appear to be wholly unobtainable in the West; for instance the present author is aware of several apparently major recent papers but extensive efforts at both official and personal levels to obtain copies of these works have so far failed. It must be arguable if any new taxa appearing under these conditions can even be accepted as validly published since such papers are certainly not freely available.

North America:

The first acritarchs of Ordovician age to be recorded from North America were described from the Trenton Formation (Caradoc] of Anticosti Island, Canada (Staplin, Jansonius and Pocock 1965]. Further details of Canadian acritarchs followed (McGregor and Cramer 1971] while recently early Ordovician acritarch assemblages from Newfoundland have been studied in conjunction with the contemporary macrofossil faunas (Dean and Martin 1978; Martin 1978].

The first publication dealing with acritarchs from Ordovician sediments in the United States appeared as little as ten years ago; a short paper on acritarch excystment and surface ultrastructure in which acritarchs of Llandeilo age were included. (Loeblich and Tappan 1969]. This was the forerunner of a continuing series of exemplary and superbly illustrated publications which concentrate on Middle and Upper Ordovician acritarchs from the eastern-central U.S.A. (Loeblich 1970a, 1970b; Loeblich and MacAdam 1971; Loeblich and Tappan 1970, 1971a, 1971b, 1978; Tappan and Loeblich 1971). The material dealt with in these studies is well preserved and since the interests of the authors have been essentially in the fields of classification and taxonomy, effort has been concentrated on the recording of new taxa; these are notable for the very detailed descriptions provided in association with excellent transmitted light and S.E.M. photographs. A high standard of presentation has been established in these publications which future authors would do well to emulate. Further details of Upper Ordovician acritarchs from the Kentucky region were given by Jacobson (1978). This substantial research effort has resulted in the description of over seventy new species in less than a decade and has made the United States an important area in our understanding of acritarch distribution during the Ordovician period.

Great Britain:

The first acritarchs to be described from strata of Ordovician age in the British Isles were from the late Caradoc Phosphate Beds of North Wales (Lewis 1940). These poorly preserved specimens were examined in thin section and seem to have attracted little attention amongst British palaeontologists at the time. No further work was carried out on Ordovician microplankton until as late as 1966 when Downie and Ford described a sparse assemblage of acritarchs of probable Arenig age from the Manx Slates of the Isle of Man. This was quickly followed by a series of short, essentially biostratigraphical papers on early Ordovician acritarchs from Great Britain (Wadge, Owens and Downie 1967; Lister, Burgess and Wadge 1968;

Lister, Cocks and Rushton 1969; Wadge, Nutt, Lister and Skevington 1969; Lister and Holliday 1970; Downie and Soper 1972; Downie in Durham 1973; Turner and Wadge, 1979].

Acritarchs from the Lower, Middle and Upper Ordovician of Wales and the Welsh Borderlands were mentioned, but not described in detail by Jenkins [1967], in a work devoted mainly to chitinozoans. The first detailed and systematic study of Ordovician acritarchs from Great Britain is that of Booth [1979, unpublished Ph.D.thesis], dealing with assemblages of Arenig and Llanvirn age. The present work is the first detailed investigation of Middle and Upper Ordovician acritarchs from this country.

<u>Other Areas</u>:

Few regions outside those mentioned above, have so far yielded any information about Ordovician acritarchs. A major exception is North Africa where hydrocarbon exploration drilling has given rise to a number of publications on acritarchs from sub-surface Ordovician strata [Cramer, Allam, Kanes and Diez 1974; Cramer and Diez 1976, 1977; Cramer, Kanes, Diez and Christopher 1974; Deunff 1977]. The assemblages described so far have been exclusively early Ordovician in age, the acritarchs themselves being mostly extremely well preserved.

Only a single record exists of Ordovician acritarchs from the Southern Hemisphere [Combaz and Peniguel 1972]. The assemblages described by these authors, from the Lower and Middle Ordovician of the Canning Basin, Western Australia, are also from subsurface samples; the acritarch species present show some similarity with those from Baltic populations of comparable ages.

Chapter Four

DESCRIPTIVE TERMINOLOGY AND CLASSIFICATION.

Terminology

The term 'acritarch' was first used by Evitt (1963) to describe a large group of mainly Palaeozoic microfossils whose biological affinities are unknown but which he considered, in agreement with Deflandre (1947), to be polyphyletic. Traditionally most organic-walled microfossils had been termed 'hystrichospheres' since the early work of Wetzel (1932,1933) and Deflandre (1936, 1937); Evitt (1961) was able to demonstrate the dinoflagellate affinities of many of the hystrichospheres including the genus Hystrichosphaera, the taxon on which the informal name hystrichosphere was based. The transfer by Evitt of this and many other forms to the Dinophyceae left a residue of microfossils of uncertain affinities for which the name hystrichosphere was no longer appropriate. The name acritarch (uncertain - origin) was proposed by Evitt (1963) to accomodate such forms; he emphasized that the term carried no biological implications and was not based on any taxon included in the group.

The sole criteria available for the description and classification of the acritarchs are the variations in their morphological characteristics. Over the last three decades a substantial glossary of terms has been introduced by various acritarch workers to describe aspects of the overall shape and fine structure of the widely divergent forms recorded. Many early authors tended to restrict description to gross morphology and made little or no reference to details of fine structure or ornament. Subsequently attention was given to the incidence and meaning of the diverse vesicle openings encountered in many species (Eisenack 1958a, 1963, Staplin et al. 1965); these features are now widely interpreted as features of biological significance. In recent years, some authors have placed increased emphasis on detailed study of the fine ornament borne on the vesicle and process walls of many acritarchs. In some instances specific and even generic importance has been attached to fine sculptural elements which often may only be adequately studied using a scanning electron microscope (Loeblich 1970, Tappan and Loeblich 1971, Wicander 1974).

It is apparent that morphography is of fundamental importance in the acritarcha and so it is vital for any terminology used to be clearly defined and consistently applied. Major lists of descriptive terms used by previous workers have been compiled by Lister (1970), Kjellstrom (1971a) and Eisenack et al. (1973). The principle descriptive terms used in this study are defined and illustrated in the following diagrams. In general, where an acceptable English word or phrase exists it has been used. Thus 'smooth' is preferred to the 'psilate' or 'laevigate' of other workers.

Text - Fig. 14

Vesicle shapes encountered in this study.

a	-	spherical.
b	-	fusiform.
c	-	naviform.
d	-	hemispherical.
e	-	unipolar.
f	-	bipolar.
g	-	polygonal.

Text-fig. 14

Text - fig. 15.

Vesicle and process terminology used in this study.

1) Simple processes.

a - simple, conical with acuminate termination.

b - trebeculate.

c - solid.

d - hollow, plugged at base.

e - basal plug associated with constriction.

f - hollow with infilled tip.

g - evexate distal termination.

h - flagelliform.

i - filose.

2) Complex processes.

j - bifurcate

k - ramusculose.

l - grapnel shaped.

m - capitate.

n - digitate.

o - anastomosing.

3) Ornamented processes.

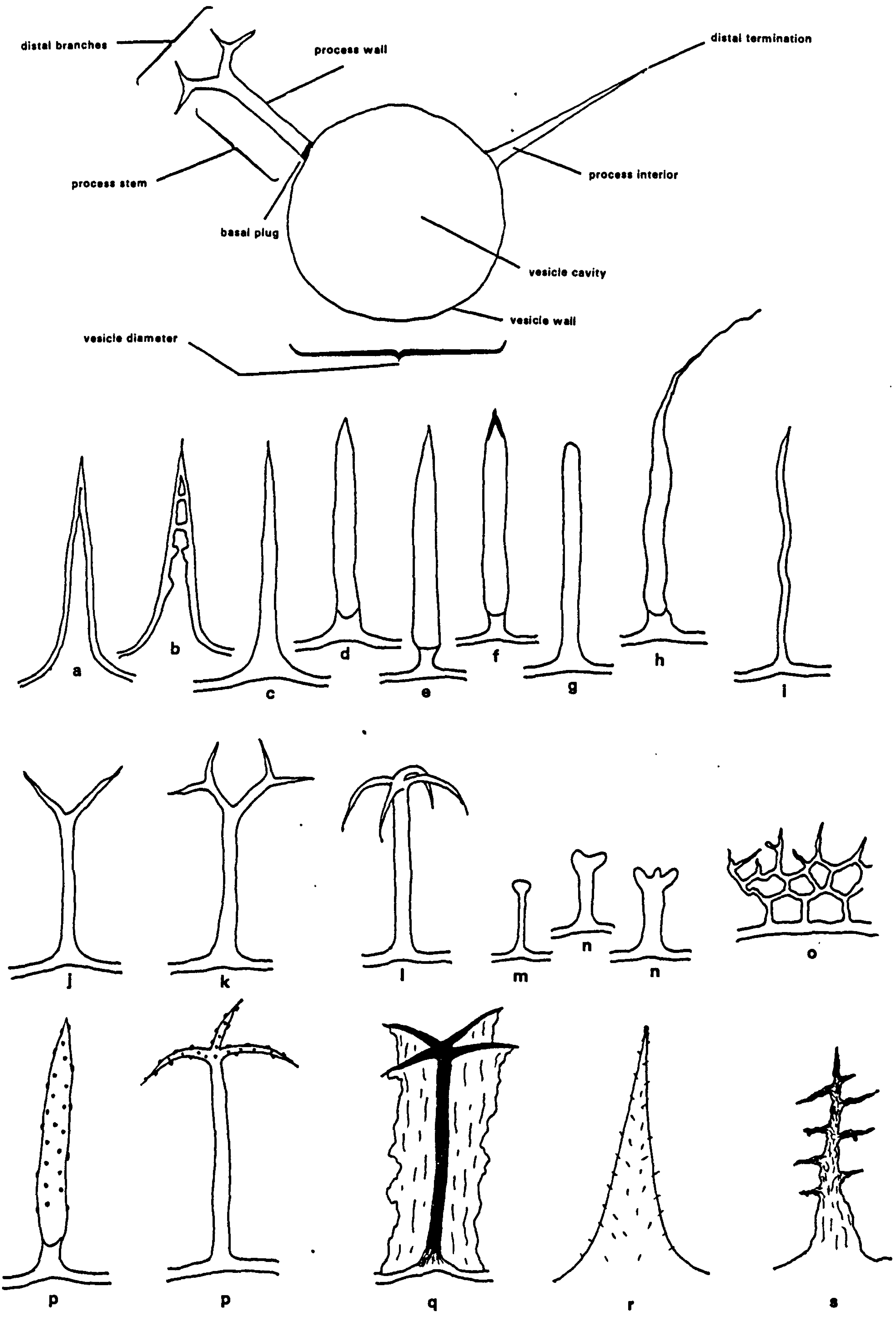
p - granulate.

q - petalloid (winged).

r - spinose.

s - echinate.

Text-fig. 15



distal branches
process wall
distal termination
process interior
process stem
basal plug
vesicle cavity
vesicle wall
vesicle diameter
a
b
c
d
e
f
g
h
i
j
k
l
m
n
n
o
p
p
q
r
s

Text - fig. 16.

<u>Vesicle openings encountered in this study</u>.

a - simple pylome.

b - pylome with thickened rim.

c - pylome with raised collar.

d - pylome with thickened collar.

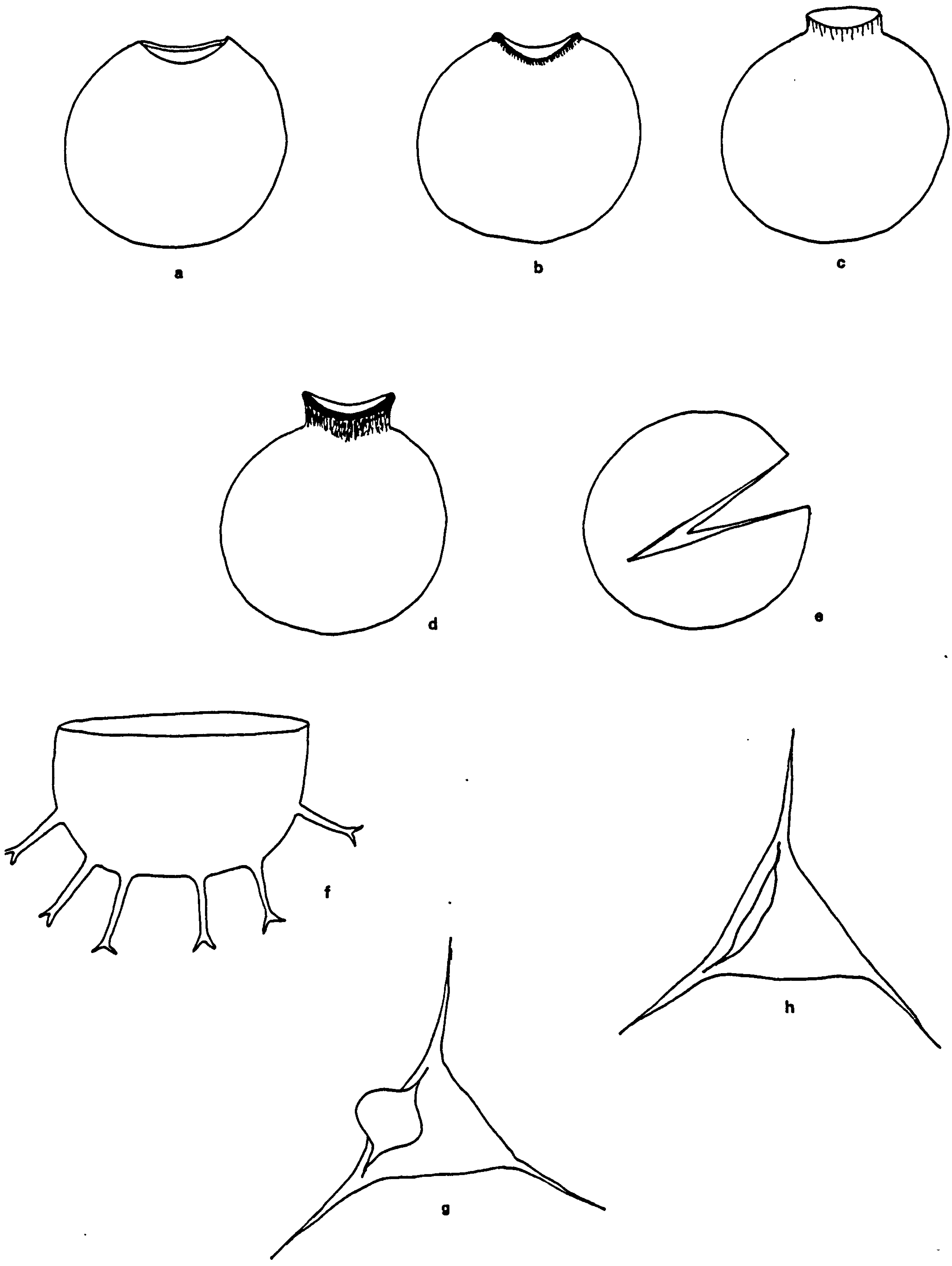
e - median split.

f - macropylome.

g - epityche [flap-type].

h - epityche [simple split].

Text-fig. 16



Text - fig. 17.

Vesicle wall ornament encountered in this study.

a - smooth.

b - granular.

c - verrucate.

d - spinose (acuminate).

e - reticulate.

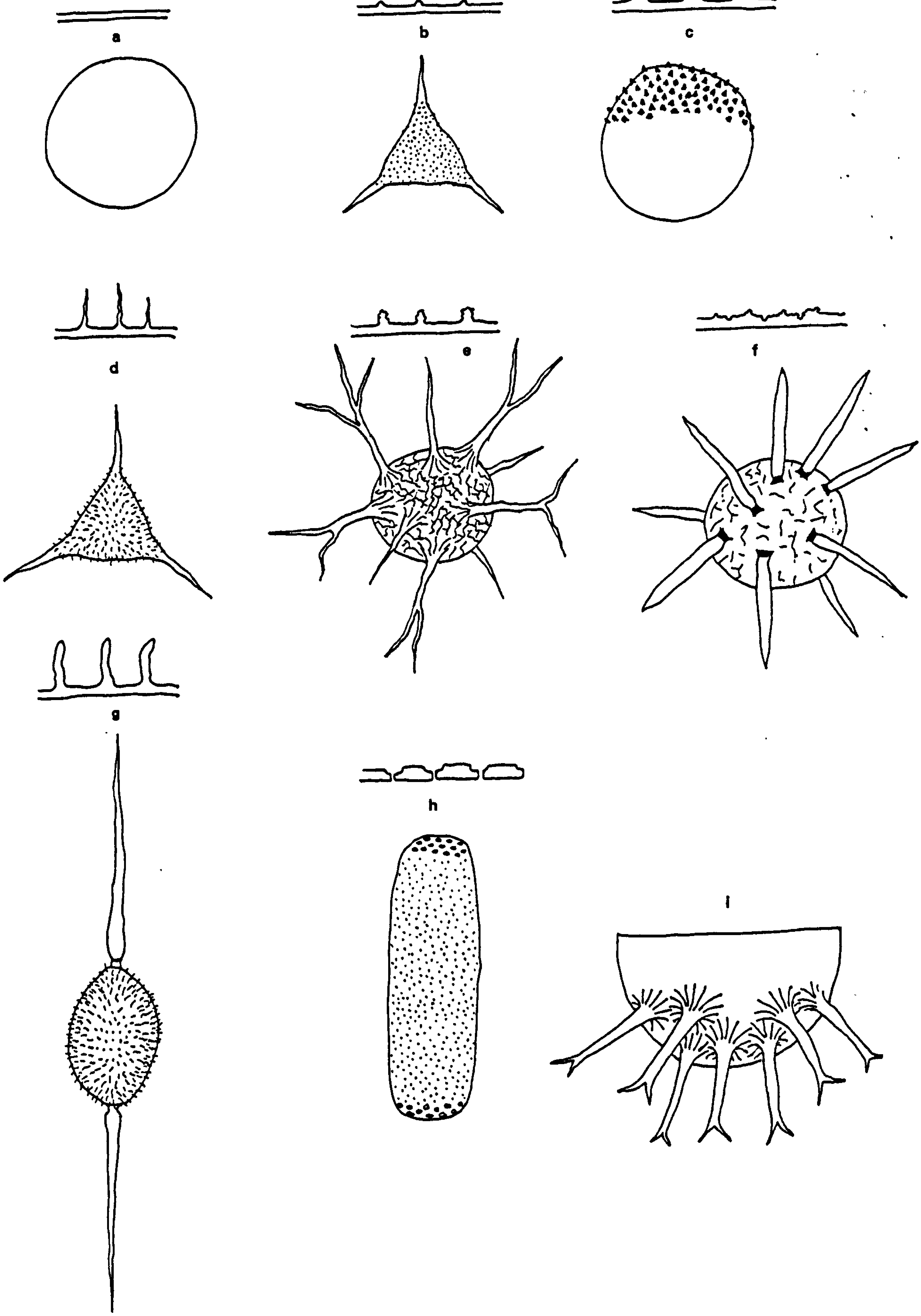
f - shagrinate.

g - spinose (evexate).

h - porate.

i - stellate.

Text-fig. 17



Process Constriction

Many species attributed to the genus Baltisphaeridium (Eisenack 1958) Eisenack 1969, exhibit a constriction of the process walls in the region of the solid proximal plug which separates the vesicle cavity and process interior (see text-fig.15e). This constriction has been described by a number of authors and in the past has been considered a consistent and therefore characteristic feature of certain species; e.g. Baltisphaeridium klabavense (Vavrdova 1965) Kjellstrom 1971b; B.constrictum Kjellstrom 1971a.

The present study has made possible the examination of individuals of various species of Baltisphaeridium, some of which were in an excellent state of three-dimensional preservation while others were partially or wholly compressed due to compaction of the enclosing sediment body. These observations have shown conclusively that process constriction is not necessarily a consistent feature of any one species (although it may be so), but can depend to some extent on the state of compression of the individuals concerned. Text-fig. 18-1a shows a hollow, thin-walled process with no basal constriction. In fig. 18-1b, after compression has taken place, the same process now shows an apparent proximal constriction in the vicinity of the solid basal plug. Fig. 18-1c, the same process in lateral view, shows the differential flattening of hollow process and solid plug which gives rise to this phenomenon; as the process is compressed, the curves of the wall of the hollow portion are flattened so that eventually the two 'sides' of the process meet, at which point they are planar and so have attained their maximum

Text-fig. 18


THREE-DIMENSIONAL
COMPRESSED
Dorso-Ventral View
Dorso-Ventral View
Lateral View
Compression
no constriction
apparent constriction
1 a
1 b
1 c
Compression
original constriction
exaggerated constriction
2 a
2 b
2 c

width. This becomes less pronounced in the vicinity of the basal plug where the process walls commonly thicken; the solid plug itself resists compression and remains almost unaltered. It is instructive to note that Text-fig. 18-1b, the process with a secondary constriction, appears almost identical to fig. 18-2a, a process with a genuine proximal constriction. It is thus apparent that although process constriction may be a useful differentiator at specific level, it can only be used with confidence where acritarchs are preserved in a more or less uncompressed state. Records where the state of preservation is not clear, either from the author's comments or from illustrations must be treated with caution. Records where the material is obviously in a compressed state must be considered ambiguous and less importance attached to the feature in such cases.

Classification

When Evitt (1963) proposed the term 'acritarch' he made it clear that what he loosely termed a 'group' had no formal status under the provisions of the Botanical Code; despite this he recommended that these microfossils should be treated as plants for the purposes of classification. Downie Evitt and Sarjeant (1963) examined the status of the acritarchs in some detail; they endorsed the concept of the acritarcha as an incertae sedis group of botanical affinity and proposed subdivision of the group into equally informal suprageneric 'subgroups'. They emphasized that these were created simply to accomodate acritarch form genera having essentially similar gross morphological characteristics. Inclusion of genera within a subgroup in no way implied any biological affinities but was merely a taxonomic convenience. Fourteen such subgroups were proposed, the name of each based on a characteristic morphological feature, with the use of any component generic name being specifically excluded [p.6]; the derivation of each subgroup name was given and a diagnosis provided. For example, the subgroup Acanthomorphitae [akantha - thorn], was defined as, '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'. The authors made it clear that they expected many genera to eventually be removed from the scheme as accumulating data made apparent their biological affinities. These proposals were adopted by many acritarch workers and Timofeev [1966] introduced a somewhat similar classification. Deflandre and Deflandre [1964] adopted a modified version of the Downie et al. scheme, substituting the term parafamily for subgroup. Henry [1969] and Gorka [1969] both used this terminology but parataxa are not recognised by the Botanical Code and this emendation has been generally rejected. Other workers were wholly opposed to the concept of informal subgroups and Eisenack [1969] adopted the term 'Hystrichophyta' [Madler 1963], for extinct algal bodies or cysts with pylomes. Eisenack suggested a 'natural classification' within the Hystrichophyta for three families that he considered could be distinguished from the acritarchs, the Baltisphaeridiaceae, Leiosphaeridiaceae and Leiofusidaceae. As pointed out by Wicander [1974, p.11] this has resulted in confusion rather than simplifying classification since at least some genera placed in the Hystrichophyta by Eisenack are firmly established as belonging to the algal Class Prasinophyceae. In addition, the partial replacement of the group acritarcha with Hystrichophyta is of dubious value since the definitions are very similar. Wicander further commented that 'Hystrichophyta' is anyway an unfortunate name since it may suggest affinity with the informal term 'hystrichosphere' which is based on the dinoflagellate genus Hystrichosphaera Wetzel 1933.

One of the failings of the scheme of subgroups proposed by Downie et al. began to be appreciated when Staplin Jansonius and Pocock (1965) proposed a new subgroup, the Baltisphaeritae, deliberately named after the genus Baltisphaeridium. The authors commented, 'it would simplify procedure .... if one genus were indicated as best representing the concept reflected by the respective subgroup'. This was totally opposed to the views of Downie et al. who intended that sub-groups should not require modification because of the eventual removal of one or more genera whose affinities had subsequently been determined. If in the future, Baltisphaeridium were to be transferred from the acritarcha, then the Subgroup Baltisphaeritae would become a substantial taxonomic problem since the genus best reflecting the concept of the taxon would no longer be attributable to it. However, since the scheme is informal, there is nothing to prevent any worker sharing the views of Staplin et al., from erecting any number of similarly ill-conceived suprageneric taxa. This informality also means that workers have total freedom to redefine the limits of any subgroup as they think necessary. Cramer (1968, 1971) adopted the scheme but included in the Acanthomorphiteae genera such as Leiofusa and Veryhachium, taxa which quite clearly do not fall within the original concept of the subgroup. Lister (1970) used Acanthomorphiteae but emended the diagnosis so that his concept of the taxon coincided with his theories concerning possible affinities between acanthomorphitic acritarchs and dinoflagellates.

Few acritarch specialists dispute the need for a flexible classification for the group, whose affinities remain obscure. Any suprageneric scheme must be informal as is shown by the potential difficulties posed by the Baltisphaeritae of Staplin et al.. These authors effectively indicated a type genus for their taxon without formally designating it so, an attempt to provide some stability which, if followed, could quickly render the scheme wholly unworkable. Conversely, if the essential requirement of informality is observed then there can be no types to which concepts may be referred; workers are thus free to interpret and emend the system as they wish. This does occur as is amply demonstrated by the examples of Lister and Cramer cited above and the results are often confusing.

It appears then, that for the acritarcha, a formal or even a semi-formal, suprageneric classification is unworkable, while any suitable informal system is inherently unstable. For these reasons it is preferred not to adopt any scheme for classification above generic rank here and instead taxa are listed alphabetically. This is in agreement with the conclusions of Wicander (1974). Loeblich and Wicander (1976) have abandoned use of the term 'acritarch' altogether and refer to 'microplankton of uncertain origin'. This appears unnecessary, unduly verbose and ignores the possibility that some acritarchs may not have been planktonic.

Problems of classification abound even at generic level, where little agreement has been reached as to which morphological features represent stable and meaningful generic indicators. This is illustrated by the different emphasis which has been placed on the significance of the various types of excystment opening; such structures are clearly considered by many authors to have generic significance since reference to excystment has been included in the diagnoses of many genera (Loeblich and Tappan 1969, Lister 1970, Playford 1977). Conversely, Eisenack Cramer and Diez (1973) regard pylomes (circular openings) as facultative and therefore trivial characters, irrelevant to taxonomy. Indeed Eisenack (1974, 1976) appears to reject as excystment structures, most non-circular openings, dismissing them as 'tension or pressure cracks'. A second example of the fundamental disagreement amongst acritarch workers is provided by Lister (1970,p.48); he considered the complexity of distal branching of processes a generic feature, a proposal totally rejected by Eisenack et al.(1973). This inability to agree as to which characters form a stable basis for generic differentiation is partly responsible for the plethora of genera currently extant, many exhibiting overlap and partial or complete synonymy. Potter (1974, unpublished Ph.D.thesis) referring to this state of affairs commented, 'The situation is generally aggravated by the large number of poorly and frequently illegally erected genera .... and there appears to be no simple solution to the problem'. Regrettably this is still true today.

For the purposes of this study, gross vesicle form, process type and distribution, type of excystment opening and fine wall ornamentation are all considered at generic level. This follows the suggestions of Downie (1973) who, in proposing the basis for a future natural classification, stressed the importance of these features.

Chapter Five

SYSTEMATICS

Note: All measurements given are in microns unless otherwise stated.

The following abbreviations are used in this section

a) I.C.B.N. = International Code of Botanical Nomenclature.

b) I.C.Z.N. = International Code of Zoological Nomenclature.

Holotypes of new taxa are designated in the text by reference to four sets of characters:-

a) Slide number.

b) location on slide by Zeiss stage co-ordinates.

c) location on slide by England Finder co-ordinates.

d) reference to illustrations by photographic plate and figure numbers.

Genus ACTINOTODISSUS Loeblich and Tappan 1978

Type species:- _Actinotodissus longitaleosus_ Loeblich and Tappan 1978.

Original Diagnosis

A diacrodian with similar processes on opposite poles, the simple, conical, hollow processes communicating with the vesicle interior.

Remarks

The history of the classification and taxonomy of the diacrodians has been complex and confusing, a situation created when many of the original species described, were assigned to a plethora of invalid genera by Timofeev 1959. The confusion was worsened by Deflandre and Deflandre - Rigaud 1961 who revised and restricted most of Timofeev's original genera; unfortunately many of their proposed emendations were either invalid or illegitimate under various provisions of the I.C.B.N. and so must be rejected. A detailed account of the present status of this group is given in Loeblich and Tappan 1978 [p.1236]; a full review is not considered justified in this study since few indigenous diacrodians were recovered.

In their paper, Loeblich and Tappan conclude [p.1237], that many Middle and Upper Ordovician forms bear little resemblance to the early Palaeozoic genera of Timofeev. In particular they point out that the type species of _Acanthodiocrodium_ Timofeev, a validly published genus, has a polar ornament of short solid processes or knobs unlike later forms which have hollow processes; consequently they propose a new genus *Actinotodissus* to accommodate species having hollow processes in free communication with the vesicle interior. The present author agrees that *Acanthodiacrodium* is too widely circumscribed and that restriction of the genus to forms bearing only solid ornament is desirable. In addition to being a step towards a more refined classification of these acritarchs, this will accentuate the limited stratigraphical range of the majority of forms bearing solid sculptural elements; this is a feature which appears to be mainly characteristic of Tremadocian assemblages.

Actinotodissus spp.

Pl.26,figs.1,2.

Description

Vesicle hollow, sub-quadrate to sub-rectangular in outline, bearing identical hollow processes on each of two opposite poles separated by a wide equatorial belt devoid of such processes; this equatorial belt may be unornamented (Pl.26, fig.2) or may bear longitudinal folds or striae (Pl.26,fig.1). The state of preservation of most specimens is too poor to allow details of process and wall sculpture to be determined, only gross morphology may be deduced with any confidence.

Dimensions

All specimens encountered were in the 25 to 35 x 20 to 30u size range.

Remarks

Because of the rarity and the carbonised and partially fragmented state of most individuals, no attempt was made to speciate these forms; it was felt that any specific determinations would certainly be suspect. However the genus is recorded here for the sake of completeness and in the hope that this observation may be of some value to future workers.

Comparisons

A number of hollow-processed forms have in the past been recorded from Tremadocian deposits and elsewhere, and have been attributed to Acanthodiacrodium [see Gorka 1967,1969: Martin 1969: Rasul 1971 M.S.]. Many of these clearly have close affinities with Actinotodissus and may stand in need of transfer to this genus.

Occurrence

Llandeilo [South Wales].

Genus ASTROPHEOS Booth 1979 M.S. emend.

Type species: Astropheos celestum [Martin 1969] Booth 1979 M.S.

Emended Diagnosis

Wall thin or of only moderate thickness and composed of a single layer. Central body hollow with a polygonal or sub-polygonal outline. Processes usually exceeding eight in number, having a simple, hollow tapering form with wide bases, curving proximal contacts and acuminate distal terminations. The process stems are decorated with small grana or spines which may develop a hair like fineness distally. The ornament may extend onto the central body surface.

Remarks.

The diagnosis is emended to include granulate as well as spinose ornamentation.

Astropheos brachyskolos sp.nov.

Pl.21,figs.4,7,8.

Derivation of name: Gr. brachys = short, skolos = thorn. Referring to the processes and their ornament.

Diagnosis

Central vesicle hollow, polygonal in outline, formed by the merging of wide process bases. Vesicle wall thin [1u or less] smooth, apparently single layered. Processes about 25 in number, hollow, communicating freely with vesicle interior, cone-shaped with wide bases, having curving proximal contact and acuminate distal terminations. Processes are randomely distributed and for any one individual are all of approximately similar dimensions. The ornament, which is restricted to the processes, consists of initially robust, thorn-like lateral spines which branch irregularly from the main stem and taper rapidly to become slender and delicate. These spines, 2 to 4u in length are most fully developed towards the distal termination and die out proximally. Process length is about half of the vesicle diameter.

Dimensions

vesicle diameter	:	20[27]32
process length	:	7[13]22
process width	:	2.5[3]4
specimens measured	:	20
specimens recorded	:	42

Holotype : slide ref. OV/LHS/1-11; 20.7/109.7; V40/3;
Pl.21,figs.7,8.

vesicle diameter	:	31
process length	:	12
process width at base	:	4
lateral spine length	:	2.5
number of processes	:	28

Description

The numerous, relatively short processes carrying a distinctive well developed ornament, combined with a smooth vesicle wall, are the distinguishing features of the species. The processes may exhibit a tendency to infill and become solid distally. No excystment structure recorded.

Remarks

The lateral spines, whilst proximally robust, become slender and delicate distally and are easily damaged during preservation. Consequently where preservation is moderate or poor, the ornament may, through breakage, appear shorter than described.

Comparisons

Astropheos celestum has fewer, broader processes bearing a more delicate ornament. *Astropheos helosa* sp.nov. has fewer longer processes with an ornament of grana rather than spines. *Micrhystridium stellatum var. intonsurans* of Lister 1970, is similar but is very much smaller and has processes ornamented with short, strongly developed barbs. *Astropheos llandeilensis* sp.nov. has less numerous processes.

Occurrence

Caradoc (Shropshire).

Astropheos celestum [Martin 1969] Booth 1979 M.S.

Pl.21,figs.1,2,3; Pl.27,figs.1,2,4.

1969	Veryhachium celestum	Martin p.89,Pl.3,fig.147; Pl.4,fig.206;Pl.6,fig.252.
1970	Baltisphaeridium echinulatum	Burmann p.309,Pl.18,fig.3.
1972	Veryhachium celestum	Martin p.26,Pl.7,fig.3.
1974	Polygonium spinosum	Jardine et al. p.117,Pl.2, fig.3.
1979	Astropheos celestum	Booth [M.S] p.245,Pl.7, figs.3-4;Pl.17,fig.1;Pl.19, fig.7;Pl.20,fig.5;Pl.21,fig.3; Pl.33,fig.7;Pl.35,fig.1.

Original Diagnosis

Central Body : diameter 20 to 38u, generally 25u, star shaped.

Processes : in number 8 to 15, slightly longer than the diameter of the central body. Form conical with flared bases and slender simple terminations.

Ornamentation : all the surface is bristling with numerous spines 1 to 2.5u in length [Transl.]

Description

The central body has a polygonal outline and is formed by the merging of the generally very wide process bases. Vesicle and process wall is thin, [1u or less] and is apparently single layered. Processes, generally 8 to 12 in number are cone-shaped, simple with acuminate distal terminations, hollow, with interiors that communicate freely with the vesicle cavity. The processes on any individual may show considerable variation in length and width. Process and [usually to a lesser extent] vesicle wall always ornamented with slender delicate spines. Generally about 2u, exceptionally these lateral spines may attain 5 to 6u in length. [see Pl.21,fig.3]. Usually processes show no symmetrical arrangement. Very rarely an individual exhibits an apparent symmetry similar to that characteristic of the genus Polygonium Vavrdova. This is not a typical feature of the species and is considered an accidental consequence of partial compression in a particular orientation during preservation. No excystment structure recorded.

Dimensions

vesicle diameter	:	20[26]33
process length	:	18[28]37
process width at base	:	7[8]13
specimens measured	:	20
specimens recorded	:	>50

Since processes merge gradually into the central vesicle, locating the base of any process is normally a subjective decision. Despite this, measurement of process bases has been attempted since very wide processes are characteristic of the species.

Remarks

This species is an important constituent of the acritarch microplankton at some horizons, forming up to 10% of the total assemblage.

Comparisons

Astropheos brachyskolos sp.nov. has shorter and more numerous processes with a more robust lateral ornament. Astropheos helosa sp.nov. has more numerous and narrower processes with an ornament of well developed grana rather than spines.

Occurrence

Caradoc (Shropshire). Llandeilo (South Wales).

Previous Records.

Silurian, Belgium (Martin 1969). Upper Llanvirn, G.D.R. (Burmann 1970). Ordovician and Silurian, Algeria (Jardine et al.1974). Llanvirn, U.K. (Booth 1979 M.S.).

Astropheos helosa sp.nov.

Pl.22,figs.9,10,11.

Derivation of name: Gr. helosa = studded, warty.

Diagnosis

Central vesicle hollow, polygonal or sub-polygonal in outline, formed by the merging of wide process bases. Vesicle wall thin, (less than 1u) and apparently single layered. Processes 12 to 15 in number, hollow, communicating freely with the vesicle interior, having the shape of slender cones flaring widely at the base. Proximal contact curved, distal terminations acuminate. Processes are randomely distributed and for any one individual are all of approximately similar dimensions. Ornamentation is of irregular grana which are always most strongly developed on the processes. These grana may extend on to the vesicle or may be restricted to the processes giving a smooth vesicle wall. Process length is approximately equal to the vesicle diameter.

Dimensions

vesicle diameter	:	21[29]40
process length	:	22[30]42
process width	:	2.5[4]6
specimens measured	:	17
specimens recorded	:	114

Holotype : slide ref. OV/AS/1-1;21.9/85.5;W14/4;Pl.22,fig.11.

vesicle diameter	:	40
process length	:	40
process width at base	:	6
ornament height	:	0.5
number of processes	:	12

Description

The processes are characteristically slender over most of their length, widening suddenly towards the proximal end to give wide bases. The ornament varies from weakly developed and difficult to detect, to a strongly granular appearance. No excystment structure was recorded. Ruptures of the vesicle wall were observed but these are thought to represent random splits caused by compression during preservation.

Remarks

Astropheos helosa, normally present in low numbers where it occurs, may become locally abundant forming up to 25% of some assemblages.

Comparisons

Astropheos celestum has fewer broader processes bearing a spinose ornament. Astropheos brachyskolos sp.nov. has more numerous shorter processes bearing well developed lateral spines.

Occurrence

Caradoc (Shropshire)

Astropheos llandeilensis sp.nov.

Pl.27,figs.3,5,6.

1979 Astropheos sp.A. Booth (M.S.) p.247,Pl.23, fig.7;Pl.26,fig.6;Pl.33, fig.8;Pl.35,fig.6.

Derivation of name: after the type-section at Llandeilo where this species is common in the lower portion.

Diagnosis

Central vesicle hollow, polygonal in outline, thin-walled (less than 1u) and apparently single-layered. Processes, about fourteen in number, are hollow, simple, homomorphic with acuminate distal terminations; process interior communicates freely with vesicle cavity; vesicle and process walls bear an ornament of fine irregular thorn-like lateral branches.

Dimensions

vesicle diameter	:	33[37]40
process length	:	14[20]27
process width	:	7[8]10
process numbers	:	12-16
specimens measured	:	15
specimens recorded	:	36

Holotype : slide ref. FF/M.a.Lst./2-2; 8.5/94.7; J24/1; Pl.27,fig.6.

vesicle diameter	:	36
process length	:	16
process width	:	7
process numbers	:	14

Description

The vesicle is formed from the wide merging bases of the conical processes, the wall is smooth to microgranular. Processes bear numerous, short, solid lateral spines which are usually most strongly developed distally, becoming less pronounced towards process bases; despite this the spines persist and normally extend onto the vesicle wall where they are reduced in size and are more widely dispersed. Process length is approximately half of the vesicle diameter but a few processes may be present which are of smaller stature than the majority. No excystment structure recorded.

Remarks

This species is common in samples from the lower portion of the type section at Llandeilo. It appears to have a relatively restricted stratigraphical range in the U.K. and may prove to be a useful biostratigraphical marker.

Comparisons

Astropheos celestum (Martin 1969) Booth 1979 (M.S.) is similar but has fewer, longer processes. A.brachyskolos sp.nov. has much more numerous, shorter processes bearing longer thorn-like lateral spines. A.helosa sp.nov. has an ornament of grana rather than solid spines.

Occurrence

Lower Llandeilo (South Wales).

Previous Record

Llanvirn, U.K. (Booth 1979).

Genus BALTISPHAERIDIUM

(Eisenack 1958) Eisenack 1969.

Type species: Baltisphaeridium (as Ovum hispidum) longispinosum Eisenack 1931. Holotype lost. Neotype: Baltisphaeridium longispinosum (as filifera) longispinosum. Eisenack 1959.

Emended Diagnosis. (Eisenack 1969)

Shell round, without tabulation, with $\pm$ numerous processes, radial, evenly distributed, in general of similar type and mostly hollow, they are closed at the ends. Usually processes are simple but occasionally there may occur branching processes; only seldom are all processes branched. The process interior does not usually communicate with the central body. Processes are evenly distributed even when they are few in number. The diameter of the body is in general more than 30u, (mostly 40-60u), and can be 70u. The overall diameter may exceed 300u. The (rare) pylomes are circular (normal pylomes) - (Trans.).

Remarks

For a full discussion of this genus see Eisenack 1969(p.249) and Lister 1971(p.50). The latter in particular gives a full account of the history of the genus and the various concepts of it conceived and utilized by different authors. For the purposes of the present study, the emended diagnosis of Eisenack 1969 is accepted and used throughout.

Comparisons

Baltisphaeridium (Eisenack 1958) Eisenack 1969 is closely similar to Baltisphaerosum gen.nov. in general morphology and particularly in process type and style. However, Baltisphaeridium develops pylomes as an excystment structure whilst Baltisphaerosum always has a median split.

Baltisphaeridium annelieae Kjellstrom 1976 emend.

Pl.4,figs.3,6,7.

1976. Baltisphaeridium annelieae Kjellstrom p.10,fig.5,

Emended Diagnosis

Baltisphaeridium sp. with moderately thin, single walled, spherical psilate vesicle. Excystment structure formed as a partial rupture. Angular proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Numerous [>60] processes, closely distributed over the entire vesicle surface, in length not exceeding the length of the vesicle diameter, echinate or verrucate, slender, homomorphic, simple with acuminate distal terminations.

Description

Pronounced proximal plug always developed, separating process interior from vesicle cavity. Process ornament commonly not strongly developed although this is a variable feature. No excystment structure recorded.

Dimensions

vesicle diameter	:	38[50]60
process length	:	9.5[15]21
process width [widest part]	:	1[2]2
specimens measured	:	10
specimens recorded	:	17

Remarks

The diagnosis is emended to include verrucate as well as echinate process ornament since it is often difficult to determine the exact type of sculptural element present when dealing with poorly preserved specimens. In addition, original echinate ornament may be reduced to verrucae by abrasion or chemical activity. A single specimen was recorded having processes which were very short relative to the vesicle diameter, [see Pl.4,fig.6]. Although it may be morphologically sufficiently different to require the creation of an infra-specific taxon, this is not considered justifiable on the basis of one individual. Consequently the specimen is herein retained within B.annelieae. Transfer to Baltisphaerosum gen. nov. is postponed pending confirmation of the excystment mechanism.

Comparisons

B.annelieae is easily distinguished from all other Baltisphaeridium spp. by the presence of numerous echinate or verrucate processes. B.accinctum Loeblich and Tappan 1978 is similar but has a granular vesicle and more numerous and much more strongly echinate processes.

Occurrence

Caradoc (Shropshire)

Previous Record

Llandeilo, Sweden (Kjellstrom 1976)

Baltisphaeridium filosum Kjellstrom 1971

1971b	Baltisphaeridium filosum	Kjellstrom p.24,Pl.1,fig.9.
1973	Baltisphaeridium filosum	Eisenack Cramer and Diez p.113.
1975	Baltisphaeridium filosum	Tynni p.11,fig.14.

Original Diagnosis

Baltisphaeridium sp. with thin, single-walled, subspherical, shagrinate vesicle. No excystment structure recorded. Angular proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Numerous processes, in length about one third to one quarter of vesicle diameter, flagelliforme, homomorphic, simple with acuminate distal terminations. Process separation very small.

<u>Baltisphaeridium</u> cf. <u>filosum</u>

Pl.5,figs.3,5,6.

<u>Description</u>

The individuals recorded here are similar to Kjellstrom's type material but the vesicle wall may be only slightly shagrinate or even smooth. In addition the processes are considerably shorter than those described by Kjellstrom while the diameter of the central vesicle is less. No excystment structure recorded.

<u>Dimensions</u>

vesicle diameter	:	48[53.5]60
process length	:	6[8.5]13
process width	:	1

<u>Remarks</u>

Considering the differences between the individuals recorded here and <u>B.filosum</u>, these specimens are not assigned unequivocally to Kjellstrom's species. Despite this the two clearly have close affinities and if more data become available from future research they may prove to be conspecific.

<u>Comparisions</u>

<u>Baltisphaeridium</u> cf. <u>filosum</u> is similar to <u>B.flagellicum</u> Kjellstrom 1971b but the latter has flagelliform processes with bulbous distal terminations. <u>B.trichophorum</u> (Eisenack 1965) Kjellstrom 1971b has more robust processes exhibiting a wide base and a curving proximal contact with the vesicle.

B.multipilosum (Eisenack 1931) Eisenack 1958 has much more numerous processes.

Occurrence

Caradoc (Shropshire)

Baltisphaeridium hirsuitoides

(Eisenack 1951) Eisenack 1958

Pl.5,figs.1,2

1931 Ovum hispidum cf. hirsutum Eisenack p.111,Pl.5,fig.19.

1938 Hystrichosphaeridium cf. hirsutum Eisenack p.13,Pl.1, fig.11.

1951 Hystrichosphaeridium hirsuitoides Eisenack p.189,Pl.3, fig.8.

non 1958 Hystrichosphaeridium hirsuitoides Downie p.335,Pl.1, figs.2,3,11,12.

1958 Baltisphaeridium hirsuitoides Eisenack p.400.

1959 Baltisphaeridium hirsuitoides Eisenack p.196.

? 1959 Hystrichosphaeridium hirsuitoides Timofeev p.52,Pl.4, fig.5.

1962 Baltisphaeridium hirsuitoides Eisenack p.359,Pl.44, figs.4,5,6,7. (pars.)

1963 Baltisphaeridium hirsuitoides Downie and Sarjeant p.90.

1964 Baltisphaeridium hirsuitoides Downie and Sarjeant p.91.

? 1965b Baltisphaeridium cf. hirsuitoides Eisenack p.259,Pl.22, fig.10.

1965a Baltisphaeridium hirsuitoides Eisenack p.135.

? 1966 Hystrichosphaeridium hirsuitoides Timofeev Pl.83,fig.17.

non 1967 Baltisphaeridium hirsuitoides Combaz Pl.3,figs.53,54.

1968 Baltisphaeridium hirsuitoides Eisenack Pl.2,fig.4.

1969 <u>Baltisphaeridium hirsuitoides</u> Eisenack p.250.

1969 <u>Baltisphaeridium hirsuitoides</u> Gorka p.29,Pl.2,figs.1,2,5,10.

? 1969 <u>Baltisphaeridium hirsuitoides</u> var. <u>hamatum</u> Lister, Cocks and Rushton p.602.

1971b <u>Baltisphaeridium hirsuitoides</u> Kjellstrom p.26,Pl.1.fig.12.

1973 <u>Baltisphaeridium hirsuitoides</u> Eisenack Cramer and Diez p.125.

1973 <u>Baltisphaeridium hirsuitoides</u> Rauscher pp.72,160,161,Pl.2, figs.8,9.

1975 <u>Baltisphaeridium hirsuitoides</u> Tynni p.12,Pl.1,fig.7.

1976 <u>Baltisphaeridium hirsuitoides</u> Kjellstrom p.20,fig.13.

<u>Original Diagnosis</u>

Vesicle spherical, processes more numerous than with <u>H.longispinosum</u>, always shorter than in this sp., about the length of the radius or less. Mostly fine and bristle-like and ending in a point. In comparison with <u>H.multipilosum</u> the processes are significantly smaller in number and also mostly longer. Forking processes up to now have not been seen. [Trans.]

<u>Description</u>

The central vesicle is hollow with a smooth, relatively rigid wall giving a spherical shape. Processes hollow, smooth, simple, homomorphic with acuminate distal terminations. Process interior separated from vesicle cavity by a solid basal plug. No proximal constriction is developed. Processes are slender, cylindrical and taper rapidly to a point. Process contact with vesicle is angular. Processes one-third to one-half of vesicle diameter in length. No excystment structure recorded.

Dimensions

vesicle diameter : 45[49]53

process length : 15[20]30

process width : 2[2.5]3

specimens measured : 5

Remarks

The distinguishing features of this species are the slender cylindrical processes having angular contact with the central vesicle.

Comparisons

B.hirsuitoides differs from B.longispinosum (Eisenack 1931) Eisenack 1959 in having much shorter more cylindrical processes with angular proximal contact. The processes of B.multipilosum (Eisenack 1931) Eisenack 1958 are very much more numerous. Baltisphaerosum christoferii comb. nov. has longer and much more slender processes.

Occurrence

Caradoc (Shropshire)

Selected Previous Records

Ordovician, Baltic (Eisenack 1931, 1938, 1959, 1965, 1968). Upper Arenig, Poland (Gorka 1969). Arenig-Llanvirn, U.K. (Lister, Burgess and Wadge 1969, Lister Cocks and Rushton 1969). Llandeilo Gotland (Kjellstrom 1971).

Baltisphaeridium latiradiatum

(Eisenack 1931) Eisenack 1959

1931 Ovum hispidum longispinosum Eisenack (pars.) p.110, Pl.5,figs.14,15.

1938 Hystrichosphaeridium longispinosum Eisenack (pars.) p.12, Pl.1,fig.1.

1951 Hystrichosphaeridium longispinosum Eisenack (pars.) p.188, Pl.1,figs.1,2.

1959 Baltisphaeridium longispinosum forma latiradiata Eisenack p.195,Pl.15,fig.4.

1963 Baltisphaeridium longispinosum forma latiradiata Eisenack p.208,Pl.19,fig.8.

1965a Baltisphaeridium longispinosum forma latiradiata Eisenack p.134.

1965 Baltisphaeridium latiradiatum Staplin Jansonius and Pocock comb.nov. p.189,Pl.20, figs.3,4,5,9.text fig.13.

? 1966 Baltisphaeridium longispinosum Timofeev Pl.84,fig.5.

1968a Baltisphaeridium longispinosum forma latiradiata Eisenack Pl.2,fig.6.

1968b Baltisphaeridium longispinosum forma latiradiata Eisenack p.90,Pl.25,fig.4.

1969 Baltisphaeridium latiradiatum Eisenack p.250.

1971b Baltisphaeridium latiradiatum Kjellstrom p.28,Pl.2,fig.1.

1972 Baltisphaeridium latiradiatum Johansson Karis and Kjellstrom p.580.

1975 Baltisphaeridium latiradiatum Tynni p.12,Pl.1,fig.9.

1976 Baltisphaeridium latiradiatum Gorbatschev Fromm and Kjellstrom p.106

Original Diagnosis

The shell is nearly always robust and therefore dark and frequently spherical. On the other hand the processes are very wide at the base and on the whole are thin-walled and delicate, hence often collapsed. Examples with unbranched processes are abundant but also some with branched processes occur. [Trans.]

Baltisphaeridium cf. latiradiatum

Pl.5,fig.4;Pl.29,figs.?1,?2.

Description

Vesicle wall thin, smooth, sometimes spherical but more usually distorted during compaction. Processes about seven in number, equal to or longer than the diameter of the central vesicle; they are very thin-walled and delicate and are usually folded and crumpled. Smooth, homomorphic, simple with acuminate distal terminations, the processes have wide bases below which is a pronounced proximal constriction. Process interior separated from vesicle cavity by a solid plug.

Dimensions

vesicle diameter	:	50[51]55
process length	:	62[64]67
process width [widest part]	:	10[12]13
specimens measured	:	3
specimens recorded	:	7

Remarks

The rare individuals of this species recorded here are very similar to the type material from the Baltic described by Eisenack (1938,1951,1959). Kjellström 1971 described the species as having a shagrinate vesicle, an observation also based on material from the Baltic. This feature was not observed in the present specimens.

Comparisons

Baltisphaeridium constrictum Kjellstrom 1971b has a similar overall morphology but the vesicle wall is always granular. B.trophirhapium Loeblich and Tappan 1978 has a granular vesicle wall and bluntly rounded process terminations.

Occurrence

Caradoc (Shropshire)

Selected Previous Records

Ordovician, Baltic (Eisenack 1938, 1959, 1963). Middle Ordovician, Baltic, (Kjellstrom 1971).

Baltisphaeridium longispinosum subsp. delicatum subsp.nov.
Pl.1,figs.1,2,4; Pl.29,figs.3-6.

Derivation of name: Latin - delicatus = soft, delicate, with reference to the thin walled, flexible processes.

Diagnosis

Vesicle spherical to sub-spherical, smooth, bearing a variable number of long, slender, simple, smooth, hollow, homomorphic processes with acuminate distal terminations; process walls are usually very thin and fragile so that processes are flexible and easily folded; process bases plugged, apparently with solid wall material so that the process interior does not communicate with the vesicle cavity; process length about equal to, or longer than, vesicle diameter.

Dimensions

vesicle diameter	:	35[44]50
process length	:	30[41]60
process width	:	2.5[3]5
specimens measured	:	30
specimens recorded	:	>200

Holotype : slide ref. NS/4-1; 16.1/100.9; Q30/4; Pl.1,fig.2.

vesicle diameter	:	48
process length	:	47
process width	:	2.5
process numbers	:	22

Description

Vesicle wall thin to moderately thick [0.5 to 1.5u]. Processes are very slender and without proximal constriction, the process wall is normally very thin [0.5u or less] but even when thickened the processes retain their extreme flexibility. [Pl.1, fig.4]; very rarely a small secondary branch arises from the stem of a process; processes, from six to about twentyfive in number, vary in length, normally they are about equal to the vesicle diameter but may occasionally greatly exceed this; processes may exhibit a tendency to become infilled. No excystment structure recorded.

Remarks

The fragility and flexible nature of the processes is considered sufficient justification to erect a new sub-species to accomodate this morphotype.

Comparisons

Baltisphaeridium longispinosum longispinosum (Eisenack 1959) Staplin Jansonius and Pocock 1965 has the same overall morphology, but the processes are thicker-walled, stiff, and never flexible as with the present material. B.pachyacanthum Eisenack 1965 has a larger vesicle and much thicker walls. B.ingerae Kjellstrom 1976 differs in having a granulate vesicle and echinate processes. B.hirsuitoides (Eisenack 1951) Eisenack 1958 has shorter cylindrical processes having angular proximal contact with the vesicle wall.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan, Ayrshire).

Baltisphaeridium pauciechinus sp. nov.

Pl.5,figs.7,8.

Derivation of name: Latin - paucus = few, little; echinatus = spiny, referring to the processes.

Diagnosis

Vesicle wall smooth to shagrinate or granulate, moderately thick (1-1.5u) giving a rigid spherical shape which is usually well maintained during preservation. Processes about fifteen in number, short, generally less than one half the vesicle diameter, simple, homomorphic with acuminate distal terminations. Processes carry very short (1-2u) lateral branches which become more strongly developed distally. Processes hollow, the interior separated from the vesicle cavity by a solid basal plug. No proximal constriction is developed.

Dimensions

vesicle diameter	:	45(49)53
process length	:	14(17.5)23
process width	:	1.5(2)2.5
specimens measured	:	4
specimens recorded	:	8

Holotype : slide ref. OV/LHS/2a-1;6.8/110.3;G40/4;Pl.5,figs.7,8.

vesicle diameter	:	53
process length	:	15
process width	:	1.5
length of lateral spines	:	0.8
separation of processes	:	20 approx.

Description

Processes may show a tendency to infill and become solid. No excystment structure recorded.

Remarks

Although only a low number (8) of individuals were recorded, they are sufficiently morphologically consistent and distinct that the creation of a new species is considered justified. The sparsely distributed, short, echinate processes are the distinguishing feature.

Comparisons

Baltisphaeridium annelieae Kjellstrom 1976, is similar but has much more numerous processes. Baltisphaeridium uncinatum (Downie 1958) Martin 1965, has similar process ornament but is smaller and has free communication between the process interior and the vesicle cavity.

Occurrence

Caradoc (Shropshire)

Baltisphaeridium pauciverrucosum Kjellstrom 1971

Pl.3,fig.3; Pl.4,fig.1.

1971a Baltisphaeridium pauciverrucosum Kjellstrom p.17,fig.9.

1973 Baltisphaeridium pauciverrucosum Eisenack, Cramer and Diez p.167.

1975 Baltisphaeridium pauciverrucosum Tynni p.16,Pl.2,fig.2.

Original Diagnosis

Baltisphaeridium sp. with thin, single walled, sub-spherical, shagrinate vesicle. No excystment structure recorded. Curved proximal process junction with the vesicle. Separation of the interior of the process from the vesicle cavity. Processes, about twenty two in number, in length almost equal to the vesicle diameter, broad bases, verrucate, conical, simple with acuminate whip-like distal terminations.

Description

Central vesicle spherical to sub-spherical with thin apparently single wall which is sometimes crumpled irregularly during compaction and preservation. . Processes about twenty in number always ornamented with widely spaced grana or verrucae. Hollow, slender, tapering gradually to the whip-like distal termination. Prominent basal plug is always developed. Vesicle wall is smooth to shagrinate. No excystment structure recorded.

Dimensions

vesicle diameter	:	40[46]50
process length	:	38[52]65
process width [widest part]	:	3[3]5
specimens measured	:	5

Remarks

The specimens recorded compare closely with the type material of Kjellstrom but the size of the vesicles is considerably smaller here than in the Baltic material. Kjellstrom indicates a size-range of 68-75u for his examples.

Comparisons

B.pauciverrucosum is similar to Baltisphaeridium calicispinae Gorka 1969 but is easily recognised by having more widely spaced process ornament and whip-like distal terminations.

Occurrence

Caradoc [Shropshire]

Previous Records

Llandeilo, Sweden [Kjellstrom 1971] Ordovician, Baltic [Tynni 1975]

Genus BALTISPHAEROSUM gen.nov.

Derivation of name: to show the close affinities with <u>Baltisphaeridium</u> (Eisenack 1958) Eisenack 1969.

<u>Diagnosis</u>

Vesicle spherical to sub-spherical, relatively thick-walled (1-2u); bearing radiating processes which are hollow, distally closed, usually simple or rarely branching and which do not communicate with the vesicle interior; process and vesicle walls may be smooth or ornamented. Process bases always plugged, apparently with solid wall material. Excystment is by the development of a median split.

Type species: <u>Baltisphaerosum</u> <u>christoferii</u> comb.nov. = <u>Baltisphaeridium</u> <u>christoferii</u> Kjellstrom 1976. p.16,fig.9.

<u>Remarks</u>

This genus is distinguished from <u>Baltisphaeridium</u> by always exhibiting excystment by the development of a median split; that is, a rupture in the vesicle wall which actually does, or which tends to, divide the vesicle into two approximately equal segments along a straight suture. In all other respects, representatives of this genus are like <u>Baltisphaeridium</u> (Eisenack 1958) Eisenack 1969, and indeed, have until now been referred to Eisenack's taxon. The varying types of excystment structures are widely accepted amongst acritarch workers as features of generic significance, (see Loeblich and Tappan 1969, Lister 1970). It seems unreasonable therefore to perpetuate the present situation where the genus

Baltisphaeridium has two quite distinct methods of excystment. Eisenack [1974 pp.275,276], has criticised the interpretation of splits as excystment structures and refers to them as 'tension or compression cracks'. In the present author's opinion there is little possibility of the splits currently under discussion being random breakages due to expansion or compression, although such breakages do undoubtedly occur. The splits referred to here appear to have a number of constant characteristics which combine to suggest that they are genuine excystment structures.

a] The splits always occur in an approximately median position thus tending to divide the vesicle into halves.

b] Splits always occur along straight sutures or 'cryptosutures' [Lister 1970, p.24]

c] Median splits and pylomes appear to be mutually exclusive; the author has not seen a single individual from the Ordovician of Britain, in which both occur. Kjellstrom [1971b,Pl.2,fig.5] figures an individual of Baltisphaeridium multipilosum [Eisenack 1931] Eisenack 1969 that appears to possess both types of opening, although only the 'partial rupture' is mentioned in the text. Since pylomes are well known from this species [Eisenack 1974 p.276], it is probable that this split represents a random breakage; it may be significant that the figure is clearly of a very thick-walled specimen which might be expected to split open on compression rather than respond by folding.

In addition it should be pointed out that median splits of the kind discussed above, are well known in other acritarch genera and are widely interpreted as excystment structures, for example, Orthosphaeridium [Eisenack 1968] emend. and

Ordovicidium Tappan and Loeblich 1971.

Comparison

Actipilion Loeblich (1970) is similar but has a double wall, a vesicle which is always ornamented and filmy processes which are easily detached. *Orthosphaeridium* has a low number of processes which are regularly distributed.

Remarks

Baltisphaerosum gen.nov. and *Orthosphaeridium* clearly have close affinities and future research may show them to be congeneric.

Baltisphaerosum bystrentos comb. nov. emend.
Pl.2,figs.4-6; Pl.3,fig.5; Pl.29,figs.?7,?8.

1978 *Baltisphaeridium bystrentos* Loeblich and Tappan p.1248, Pl.5,figs.1-3.

Emended Diagnosis

A species of *Baltisphaerosum* having flexible processes with rare bifurcations, surface ornamented with prominent irregularly sized and spaced grana; vesicle wall thick, from 2.0u in interprocess area to twice as thick opposite process junction; vesicle ornament varies from prominent irregularly spaced grana, through sparse barely distinguishable grana to a completely smooth wall surface.

Description

Central vesicle spherical, hollow; bearing eight to twenty, hollow, granulate processes having little or no proximal constriction; a pronounced basal plug separates process interior from vesicle cavity, the plugs projecting into the vesicle; processes slender, widest just above the base and have sides which are parallel for part of their length, converging distally; processes simple, with evexate or more usually acuminate distal terminations, commonly solid at tip; process length equal to or slightly less than vesicle diameter, rarely process length may greatly exceed vesicle diameter. Excystment is by development of a median split.

Dimensions

vesicle diameter	:	39[50]58
process length	:	28[46]85
process width	:	2[3.5]5
specimens measured	:	20
specimens recorded	:	>100

Remarks

The diagnosis is emended to include vesicle ornamentation varying from prominent grana to a smooth wall surface, and also to effect the transfer to Baltisphaerosum gen.nov. Specimens were recorded which were identical to the original North American material of Loeblich and Tappan 1978, having coarsely granulate process and vesicle walls; however, in addition a complete gradation was observed, from these forms through individuals with reduced vesicle ornamentation to specimens having a completely smooth vesicle wall. Process ornament is always strongly developed. Since separation of these varied but clearly intimately associated morphotypes is impossible on an objective basis, the species circumscription is here widened to include them; this is considered justified since the original description is apparently based on a low number of specimens, possibly no more than three (Loeblich and Tappan, 1978, p.1248). The transfer to Baltisphaerosum gen.nov. is required since this genus is characterised by excystment through development of a median split while Baltisphaeridium (Eisenack 1958) Eisenack 1969, has a pylome.

Comparisons

Baltisphaerosum bystrentos comb.nov. is similar to Baltisphaeridium calicispinae Gorka 1969, which was described as having perforate vesicle and process walls; (Gorka's illustrations, whilst clearly showing the granular or echinate wall ornament, fail to show these pores). Baltisphaerosum bystrentos is distinguished by the absence of pores, the striking basal process plugs which bulge into the vesicle interior and by having rare secondary processes developed.

Occurrence

Caradoc (Shropshire) ? Llandeilo (South Wales).

Previous Record

Llandeilo (Mountain Lake Member, Bromide Formation, Oklahoma).

Baltisphaerosum christoferii comb. nov.

Pl.1,figs.3,5,6; Pl.4,fig.2.

1976 Baltisphaeridium christoferii Kjellstrom p.16,fig.9.

Original Diagnosis

Baltisphaeridium sp. with moderately thin, single walled, subspherical to spherical, psilate vesicle. Separation of the interior of the process from the vesicle cavity. Well-defined proximal process plug formed by the separation of ectoderm at the inside of the basal process cavity. Numerous processes, about thirty, in length not exceeding the vesicle diameter, psilate, conical, slender, homomorphic, simple with acuminate distal terminations.

Description

The specimens encountered were very similar to the type material of Kjellstrom, but the number of processes, always about twenty here, is less than that in the Baltic examples. Excystment is by a median split.

Dimensions

vesicle diameter	:	43[49]55
process length	:	35[38]40
process width (widest part)	:	2[2.5]3
specimens measured	:	4
specimens recorded	:	19

Remarks

Although bearing slightly fewer processes than indicated in the original diagnosis, the specimens recorded here clearly have the same distinctive process style as Kjellstrom's material. Since the original diagnosis uses the imprecise term 'about thirty' to describe process numbers, emendation is not considered necessary.

Comparisons

B.christoferii is easily distinguishable from all other Baltisphaerosum spp. in having numerous, slender, smooth processes.

Occurrence

Caradoc (Shropshire)

Previous Records

? Llandeilo (Lower Viruan, Sweden, Kjellstrom 1976)

Baltisphaerosum dispar sp.nov.

Pl.2,figs.1-3; Pl.3,figs.1,2,4.

Derivation of name: Latin : dispar, unlike - dissimilar, referring to the different ornamentation of vesicle and process walls.

Diagnosis

Vesicle spherical to sub-spherical, wall of moderate thickness (1u or less), vesicle surface ornamented with sparse scattered micrograna; vesicle bears a low number (6-14) of stiff radiating, homomorphic, simple, hollow processes; the process interior does not communicate with the vesicle cavity; processes always ornamented with prominent, irregularly sized and shaped grana.

Dimensions

vesicle diameter	:	39(50)58
process length	:	28(51)63

process width	:	5[7.5]10
specimens measured	:	18
specimens recorded	:	>100

Holotype : slide ref. OV/AS/1-1; 18.3/103.1; S33/3; Pl.2,fig.3.

vesicle diameter	:	54
process length	:	48
process width	:	6
process numbers	:	12

Description

Vesicle wall fairly rigid but tends to fold on compression; the sparse micrograna on the vesicle surface are a constant feature, only rarely does an individual appear to have an almost smooth vesicle wall. Processes are constricted proximally and have a basal plug apparently of solid wall material; processes are widest just above this constriction and then gradually taper to a rounded or more usually evexate distal termination; process tips always infilled and solid. The granular ornament of the process wall often becomes more pronounced distally and frequently is best developed on the solid distal portion; process length is equal to, or slightly less than, vesicle diameter. Excystment is by the development of a median split.

Remarks

This species is common in samples from sediments of middle and late Caradoc age from Shropshire. The diagnostic features are the dissimilar sized granular ornament of the vesicle and process walls and the rounded or evexate, solid process terminations.

Comparisons

Baltisphaeridium calicispinae Gorka 1969 has a similar gross morphology but differs in having densely echinate vesicle and process walls which are finely perforated. Baltisphaeridium klabavense (Vavrdova 1965) Kjellstrom 1971a, has densely echinate vesicle and process walls. Baltisphaeridium aliquigranulum Loeblich and Tappan 1978 has a smooth vesicle wall and fewer, long slender processes with acuminate distal terminations. Baltisphaeridium oligopsakium Loeblich and Tappan 1978 differs in possessing a pitted granular vesicle wall and numerous processes ornamented with widely separated, sparse, grana and spinules.

Occurrence

Caradoc (Shropshire)

Baltisphaerosum onniensis sp. nov.

Pl.4,figs.4,5; Pl.30,figs.1,2.

Derivation of name: after the classic Onny Valley section in which the species is common.

Diagnosis

Vesicle spherical, moderately thick-walled (1-1.5u), smooth, bearing a low number (10 - 15) of radiating, simple, smooth, hollow processes with acuminate distal terminations; the process interior does not communicate with the vesicle cavity; processes have a basal plug, apparently of solid wall material but are without proximal constriction; process length is between half and two thirds of vesicle diameter.

Dimensions

vesicle diameter	:	43[49]57
process length	:	28[35]45
process width	:	3[4]5
process numbers	:	9-15
specimens measured	:	15
specimens recorded	:	>50

Holotype : slide ref. OV/LHS/2b-2; 17.8/88.4; S18/3; Pl.4,fig.4.

vesicle diameter	:	48
process length	:	36
process width	:	4
process numbers	:	9

Description

Processes, although always of one style, often vary considerably in length on a single individual. Vesicle and process walls are smooth but rarely a specimen is observed which appears to have a shagrinate vesicle surface; since this usually occurs in less well preserved assemblages it may be simply a preservational feature. Excystment is by the development of a median split.

Remarks

The diagnostic features of this species are the smooth processes which may be of varying length but are always less than the vesicle diameter, and the smooth vesicle wall. Median splits allowing excystment were common in the Shropshire assemblages.

Comparisons

Baltisphaerosum christoferii comb. nov. has similar overall morphology but is distinguished by having much more slender processes of a consistent length. Baltisphaeridium longispinosum delicatum subsp.nov. has much longer more delicate processes and does not excyst by means of a median split. B.hirsuitoides [Eisenack 1951] Eisenack 1958 has narrower, more cylindrical processes having angular proximal contact.

Occurrence

Caradoc [Shropshire], Llandeilo [South Wales].

Genus BARAKELLA Cramer and Diez 1977.

Type species: Barakella fortunata Cramer and Diez 1977.

Original Description

Flat to prismatic diacrodians characterized by a hemimorphic process topography. The first order processes are homomorphic, unbranched or simply bifurcate, slender and tapering to whiplike processes at both apical and antapical poles. Second order process-like structures are present at the antapical pole in the form of a generally minor filamentous construction composed of a patch or crown of slender filose elements which anastamose peripherally to the structure and which also may be linked across the structure. Longitudinal diacrodian folds are generally present.

Remarks

This distinctive genus, originally described from North African sub-surface sediments of early Ordovician age, has not been recorded from elsewhere in the world until now.

Barakella fortunata Cramer and Diez 1977.

Pl.34,fig.5.

1977 *Barakella fortunata* Cramer and Diez p.345,Pl.5, figs.3,12. text fig.3:23.

Original Description

Rectangular *Barakella* with a basally relatively thick, rapidly tapering, sharp tipped process at each corner, and a patch of peripherally and radially interconnected and anastomosing filamentous elements at the short side corresponding with the antapical pole. Five to ten longitudinal diacrodian folds are present on each face.

Description

Vesicle hollow, compressed, rectangular, similar in overall outline to *Veryhachium lairdi* [Deflandre 1946] Deunff ex Downie 1959; however it differs from this species in having an anastomosing patch of fine, short, filamentous sculptural elements between the bases of the processes at one end of the vesicle; in addition each face of the vesicle bears a number of longitudinal folds or striations. No excystment structure recorded.

Dimensions

vesicle length	:	29
vesicle width	:	19
process length	:	21
process width at base	:	3.5
specimens measured	:	1
specimens recorded	:	1

Remarks

The single individual recovered here is almost identical to the North African examples of Cramer and Diez and indeed bears a very strong resemblance to their holotype. This close similarity is remarkable when one considers not only the widely separated points of origin but the substantial difference in apparent ages. The Moroccan material is dated as late Arenig in age compared with the Llandeilian age of this specimen. Cramer and Diez admit [p.340] that the ages assigned to their subsurface material have no direct megafossil control, and are derived by extrapolating quantatative changes in acritarch and chitinozoan assemblages from megafossil correlated surface exposures. No details are given of these quantitative data so it is impossible to assess how reliable their suggested late Arenig age may be.

The individual recorded here is badly corroded and somewhat broken but remains clearly identifiable; the possibility that it may be reworked is not overlooked but is considered unlikely since it is not accompanied by any of the distinctive and restricted species which are well known from the British Arenig [Booth 1979 M.S.]

Comparisons

Barakella felix Cramer and Diez 1977 is the only similar species described but this has an inflated vesicle and more numerous primary processes.

Occurrence

Lower Llandeilo [South Wales]

Previous Record

Upper Arenig, Morocco [Cramer and Diez 1977]

Genus CHELEUTOCHROA Loeblich and Tappan 1978.

Type species: Cheleutochroa gymnobrachiata Loeblich and Tappan 1978.

Diagnosis

Vesicle spherical with simple conical, hollow, laevigate processes that are solid distally, processes communicate freely with vesicle interior, vesicle wall relatively thick, ornamented with muri forming a reticulate pattern which breaks up into elongate parallel or converging ridges near the processes, directed toward but not extending on to the processes, processes laevigate; excystment by rupture of the vesicle wall.

Remarks

Abnormally an individual may have processes which are hollow throughout their length.

Cheleutochroa meionios sp. nov.
Pl.7,figs.1,2,3.

Derivation of name: Greek : meion, smaller-less.

Diagnosis

Central vesicle hollow, spherical to sub-spherical in outline, having a reticulate surface formed by low muri producing a reticulum with small luminae; the reticulum breaks up in the vicinity of the processes so that muri form near parallel converging ridges directed towards the process bases; process surface is smooth. Processes are simple, hollow and communicate freely with vesicle interior.

Dimensions

vesicle diameter	:	12[16]19
process length	:	8[16]21
process numbers	:	10-15
specimens measured	:	13
specimens recorded	:	38

Holotype : slide ref. OV/A/26-1; 17.2/96.6; S27/0; Pl.7,figs.1,2,3.

vesicle diameter	:	18
process length	:	18
process numbers	:	14

Description

Processes are simple, conical, straight to somewhat flexible and sinuous; process length generally about the same as the vesicle diameter but a few shorter processes are usually present. Processes taper only gradually to an acuminate distal tip which is normally solid; rarely, infilling of this portion of the process is incomplete giving rise to a trabeculate structure. Vesicle and process walls are approximately 1u thick. Vesicle wall ornamented with a reticulum formed from low muri less than 0.5u high and having luminae less than 1u in diameter. The degree of development of this ornament varies between individuals. In the vicinity of process bases the reticulation is replaced by nearly parallel converging ridges directed towards each process base, but not extending onto the processes. Excystment is by the development of a median split.

Remarks

Cheleutochros meionios is morphographically identical to *Cheleutochros gymnobrachiata* Loeblich and Tappan 1978, but is placed in a new species here because of the very great disparity in size between the two forms. *Cheleutochroa gymnobrachiata* is based on a record of only three specimens (Loeblich and Tappan 1978, p.1254), and it is recognised that new data derived from future research may show these two forms to be conspecific. At present the size-difference and differing stratigraphic occurrences of the two forms is considered sufficient justification for the creation of a new species.

Comparisons

Cheleutochroa meionios is morphographically identical to *Cheleutochroa gymnobrachiata* but is one-half the size of this species.

Occurrence

Caradoc (Shropshire)

Genus DIAPHOROCHROA Wicander 1974

Type species: *Diaphorochroa ganglia* Wicander 1974.

Original Diagnosis

Vesicle spherical, wall thin, granulate; numerous processes, laevigate, hollow, open into and communicate freely with vesicle interior; tips of processes multifurcate; excystment by splitting of vesicle wall.

Diaphorochroa diaphorosos sp. nov.

Pl.7,figs.4,5,6.

Derivation of name: Greek : diaphoros, different, referring to the two types of process always present.

Diagnosis

A species of *Diaphorochroa* having a hollow vesicle, spherical to sub-spherical in outline, wall relatively thin bearing a granular ornament. Processes hollow, communicating freely with vesicle interior and always of two distinct types on any one specimen; some processes divide distally whilst others are simple with an acuminate distal termination; the wall of both kinds of precesses is always smooth.

Dimensions

vesicle diameter	:	12[16]20
process length	:	14[18]21
process numbers	:	10-14
specimens measured	:	12

specimens recorded : 22

Holotype : slide ref. OV/OS/4-1; 20.3/93.4; V22/2;Pl.7,fig.6.

vesicle diameter : 13

process length : 16

process numbers : 12

Description

The vesicle wall is always relatively thin but the granular ornament makes precise measurement difficult; process walls are thin and delicate, less than 0.5u. The granular vesicle ornament does not extend onto the process walls which are entirely smooth; some specimens show the vesicle wall ornament being replaced in the vicinity of process bases by nearly parallel converging ridges directed towards each base. Process length is never less than, and generally slightly in excess of, vesicle diameter. Each individual bears processes of two different kinds, some are simple with an acuminate distal termination whilst others bifurcate distally; a single bifurcation is normal but rarely second order bifurcations occur. The ratio of bifurcate to simple processes varies widely but no individual was recorded without at least one of both process types. No excystment structure was recorded.

Remarks

The differentiation of vesicle and process wall and the possession of heteromorphic processes is characteristic of this species. The pronounced similarities between this form and Diaphorochroa homoios sp.nov. suggests close affinities between these species. Indeed, since in the Onny section, _Diaphorochroa diaphorosos_ only comes in after the disappearance of _Diaphorochroa homoios_, it seems likely that the former is directly derived from the latter. The small size and occasional occurrence of radiating ridges at process bases suggests some affinities with _Cheleutochroa meionios_ sp.nov.

Comparisons

Diaphorochroa homoios sp.nov. is closely similar but only bears bifurcating processes which are usually more abundant than in this species.

Occurrence

Late Caradocian (Shropshire)

Diaphorochroa homoios sp. nov.

Pl.7,figs.7,8,9,10.

Derivation of name: Greek : homoios, same-like-similar, referring to the homomorphic processes.

Diagnosis

A species of _Diaphorochroa_ having a hollow vesicle, spherical to sub-spherical in outline, wall relatively thin, bearing a granular ornament. Processes hollow; communicating freely with vesicle interior and dividing distally; process wall is always smooth.

Dimensions

vesicle diameter	:	16(18)20
process length	:	16(17)19

process numbers : 10-20

specimens measured : 14

specimens recorded : 27

Holotype : slide ref. OV/HS/1-1; 21.0/117.9; W48/2; Pl.7,figs.7,8.

vesicle diameter : 18

process length : 16

process numbers : 20

Description

The vesicle wall is always relatively thin but the dense granular ornament makes precise measurement difficult; process walls are generally very thin and delicate, [less than 0.5u]. The granular ornament of the vesicle does not extend onto the process walls which are entirely smooth. In rare specimens the vesicle grana may be arranged in ridges or interconnecting ridges to give a rugulate or reticulate appearance to the wall. Some specimens show the vesicle wall ornament being replaced in the vicinity of process bases by nearly parallel converging ridges directed towards each base. Process length is approximately equal to the vesicle diameter, each process dividing distally by simple bifurcation up to the third order; the number of processes is variable but as processes are reduced in number on a specimen they appear to become stouter and more robust. Excystment is by the development of a median split.

Remarks

The differentiation between the granular vesicle wall and the smooth bifurcating processes is the characteristic feature of this species. The small size and occasional presence of radiating ridges at process bases, suggests some affinities with Cheleutochroa meionios sp.nov.

Comparisons

Diaphorochroa homoios is similar to Diaphorochroa diaphorosos sp.nov. but always bears similar bifurcating processes whilst the latter species has simple and bifurcating processes together. Diaphorochroa ganglia Wicander 1974 is much larger (32-35u) and has a more complex process branching pattern. Baltisphaeridium neaghe Cramer 1971 is much larger and has a rugulate rather than a granular vesicle wall. Lister (1968, Pl.6,fig.17) figures a specimen from the Ludlovian of Shropshire which appears superficially similar to Diaphorochroa homoios but no description is given.

Occurrence

Caradoc (Shropshire)

Genus DICHASPHAIRA Potter 1974 M.S.

Type species: Dichasphaira roscida Potter 1974 M.S.

Original Diagnosis

Body hollow, outline circular to subcircular, form globular in the uncompressed state, wall consists of a single layer, usually relatively thin; surface smooth to granular otherwise without ornament; opening by equatorial or sub-equatorial splitting, partial or complete; forms without opening bear no indication of the future line of parting, being indistinguishable from other simple leiospheres.

Remarks

Potter 1974[M.S] proposed the genus Dichasphaira to accomodate simple spherical forms in which excystment occurred by the development of a median split; such forms may be differentiated from Leiosphaeridia [Eisenack 1958] Downie and Sarjeant 1963, which, when excysting, develops a pylome. It is fully appreciated that difficulties do arise with these two taxa since the majority of specimens recovered have no opening at all; despite this the type of excystment opening is a fundamental feature and it is considered justifiable to separate these at a generic level where possible. Thus forms which fall into recognisable species, individuals of which exhibit median splits, are referred to Dichasphaira. Sphaeromorphs having pylomes or alternatively those in which excystment has not been reported are retained in Leiosphaeridia.

Dichasphaira caradocium sp. nov.

Pl.25,figs.6,8.

Derivation of name: after the Caradoc Series in which the species is common in Shropshire, the type area.

Diagnosis

Vesicle hollow, spherical, microgranular, moderately thick-walled [0.75-2.0u]; the wall apparently consists of a single layer and is fairly rigid. Excystment is by the development of a median split.

<u>Dimensions</u>

vesicle diameter	:	42[53]70
specimens measured	:	15
specimens recorded	:	>100

Holotype : slide ref. NS/4-6; 7.5/125.0; T21/3; Pl.25,fig.6.

vesicle diameter : 44

<u>Description</u>

This species is normally preserved in a partly three-dimensional state since the thick vesicle wall tends to resist compression during sediment compaction; where flattening does occur, any resultant folding of the wall is usually minor. Sometimes the lips of an excystment split are folded over and into the opening itself, giving the vesicle an elliptical outline.

<u>Remarks</u>

The vesicle wall is normally microgranular but rarely an almost smooth individual is seen; specimens of this kind, if they lack an excystment opening, are indistinguishable from specimens attributed to <u>Leiosphaeridia ketcheniata</u> sp.nov. <u>D.caradocium</u> probably intergrades into the abundant, undifferentiated small sphaeromorph acritarchs which are frequently found in the same assemblages.

<u>Comparisons</u>

<u>Leiosphaeridia wenlockia</u> 1959 is similar but has a smooth vesicle wall, in addition excystment openings have never been described from this Silurian species. <u>Leiosphaeridia</u>

ketcheniata sp.nov. is generally smaller, always has a smooth vesicle wall and develops a large pylome rather than a median split.

Occurrence

Caradoc (Shropshire) Caradoc (Girvan)

Dichasphaira form group C Potter 1974 M.S.

Pl.26,figs.7,8.

Original Description

The body is hollow with a subcircular to irregular outline. The wall is thin, single layered, with a smooth to faintly shagreen texture. All specimens exhibit equatorial splits. The size is 35u or less (11-33u).

Description

The present material is identical to that described by Potter from the Middle Cambrian of Britain.

Dimensions

vesicle diameter varies from 19 to 40u.

Remarks

This relatively rare form was recorded only from the Llandeilo of South Wales and unlike the material of Potter, was associated with otherwise identical individuals which lacked equatorial splits. Since no sphaeromorphs having pylomes were encountered at this stratigraphical level, all thin-walled spherical specimens from these horizons are tentatively assigned to this form group; it is possible that representatives of other genera have been included under this informal taxonomic name, but because of poor preservation and lack of morphological features allowing further sub-division, more refined identification was not possible.

The present specimens are also closely comparable with Hemisphaerium ? sp.A of Vanguestaine 1978, [p.271,Pl.4,figs.2, 3] from the Cambrian of Belgium. It is not considered likely that the individuals recovered from the Llandeilo are reworked Cambrian forms since there are no additional data suggesting this to be so. It is probable that forms such as these are very widespread and stratigraphically long ranging; however this is difficult to demonstrate since many acritarch workers appear not to record data on sphaeromorphs or at least rarely publish any details.

Comparisons

The genus Leiosphaeridia [Eisenack 1958] Downie and Sarjeant 1963 contains species superficially similar to this group but these develop pylomes as an excystment structure, never a median split. D.caradocium sp.nov. is generally larger and always has a thicker microgranulate wall.

Occurrence

Llandeilo [South Wales]

Genus EPISTOMIUM gen.nov.

Derivation of name: Greek - epistomium = bung or stopper; with reference to the basal process plugs.

Diagnosis

Central vesicle hollow, polygonal, compressed, wall thin to thick (0.5-2.0u), smooth or ornamented; each angle of the vesicle bears a hollow simple process which arise in the same plane as the vesicle and taper distally to a closed termination; processes are slender, cylindrical, smooth or ornamented; the process interior is always separated from the vesicle cavity by a proximal plug apparently of solid wall material, this plug is not associated with basal constriction of the process. Excystment is by the development of an epityche.

Type species: *Epistomium trirhethium* sp.nov.Pl.17,figs.8-11.

Remarks

This new genus is similar in overall morphology to *Veryhachium* Deunff 1954 ex Downie 1959 but is distinguished by the processes always exhibiting solid proximal plugs; in addition the processes in *Epistomium* do not widen gradually towards the base to finally merge imperceptibly into the vesicle as do processes of typical representatives of *Veryhachium*; here the slender, cylindrical processes are parallel sided or nearly so until a point just below the basal plug and then expand directly into the vesicle wall.

Epistomium trirhethium gen.et.sp.nov.

Pl.17,figs.8-11.

Derivation of name: Greek - trion = three; rhethos = limb. with reference to the three processes characteristic of the species.

Diagnosis

Central vesicle hollow, triangular, wall thin to moderately thick (0.5-1.5u), smooth to microgranular. Each angle of the vesicle bears a hollow, simple, slender, cylindrical, smooth or microgranular process which all arise in the same plane as the vesicle and taper distally to an acuminate or evexate termination; the process interior is always separated from the vesicle cavity by a proximal plug apparently of solid wall material. Excystment is by the development of an epityche.

Dimensions

vesicle height	:	32(36)40
vesicle and process height	:	105(113)122
process length	:	74(80)90
process width	:	2(2.5)3
height of plugs	:	6 to 20
specimens measured	:	7
specimens recorded	:	14

Holotype : slide ref. OV/A/la-1; 15.2/117.4; Q48/1; Pl.17,fig.8.

vesicle height	:	40
vesicle and process height	:	116
process length	:	78
process width	:	2.4
height of plugs	:	10

Description

The triangular vesicle is inflated in outline. Processes are without basal constriction, the length being at least twice the vesicle height, commonly more; distal tips are usually infilled and solid and processes are parallel-sided or nearly so for much of their length, this feature is maintained proximally until a point just below the basal plug where the process walls flare rapidly to merge into the vesicle wall.

Remarks

The very long, slender, cylindrical processes with proximal plugs are the diagnostic feature of this species. Rarely an individual may exhibit thickening of the vesicle and process walls so that the processes have a tendency to become infilled.

Comparisons

Veryhachium trisulcum (Deunff 1951) Deunff 1959 ex Downie 1959 is similar in overall morphology but is readily distinguished by having hollow processes which widen gradually towards the base and are in free communication with the vesicle cavity. Orthosphaeridium ternatum (Burmann 1970) Eisenack Cramer and Diez 1976 is larger, has a spherical central vesicle and excysts by the development of a median split.

Occurrence

Lower Caradoc (Shropshire)

Genus EUPOIKILOFUSA Cramer 1971. emend.

Type species: Eupoikilofusa striatifera (Cramer 1964) Cramer 1971.

Emended Diagnosis

Vesicles fusiform, elongated. At each pole there may be a simple pointed process. Within the same species the length of polar processes may vary greatly. The vesicle wall is unilayered, and sculpture distribution symmetry is holomorphic with elements arranged in a pattern parallel to, or rotational around, the longitudinal axis, and with a decreasing size, number and complexity of elements towards the poles. The ectoderm surface is ornamented with elements of the striate kind : rugulae, striae, fossulae or micro-echinate elements in longitudinally or helically oriented rows. The vesicle may open by splitting along the axis at approximately an equatorial position. The vesicle axis may be straight or curved, even in the same species.

Remarks

The generic diagnosis is emended to exclude polar processes as an obligatory feature and to recognise helical as well as longitudinal striate ornament ornamentation. This in no way alters the overall concept of the genus and indeed was obviously the intention of the original author since in the same paper he included in this genus forms such as E.cabotti [Cramer 1971, p.87]. The present author agrees that this species has very close affinities with other taxa assigned to Eupoikilofusa and consequently the diagnosis is emended to embrace these forms.

Eupoikilofusa was originally proposed by Cramer 1971 [p.83] to clarify the confusing taxonomic situation arising from the partial synonomy of Poikilofusa Staplin Jansonius and Pocock

1965 and Dactylofusa Brito and Santos 1965. Poikilofusa as first described, embraced forms with a wall ornament of 'small spines or muri'. Dactylofusa included forms with 'claviform processes which are regularly distributed in longitudinal rows'. Cramer 1971, recognising that forms with processes in longitudinal rows are circumscribed by both generic descriptions, restricted Dactylofusa, limiting it to individuals having 'separate sculptural elements arranged in longitudinal rows'. The diagnosis of Poikilofusa was emended to include only specimens with 'striae, rugulae or uninterrupted rows of interconnected smaller sculptural elements'; the name Poikilofusa was changed by addition of the prefix 'Eu' since the emended genus is substantially different from the original concept of Staplin et al. 1965. At the same time Cramer restricted Leiofusa Eisenack 1938 to include only fusiform acritarchs which are smooth or irregularly microgranular.

Eupoikilofusa cabottii Cramer 1971

Pl.20, figs.6,9.

1971	Eupoikilofusa cabottii	Cramer p.87, Pl.4, figs.66,67, text-fig.25h.
? 1973	Moyeria uticaensis	Thusu p.142, Pl.2, figs.18-22.
1974	Eupoikilofusa cabottii	Hill p.170, Pl.24, figs.9,10. [M.S
1974	Schizaesporities sp.I.	Martin p.32, Pl.4,115,116,123; Pl.7, figs.233,236.
1976	Eupoikilofusa cabottii	Eisenack Cramer and Diez p.259.

Original Diagnosis

Vesicle hollow, varying from ellipsoidal to fusiform in outline. Vesicle axis straight or crescent-shaped. No processes at poles. The vesicle wall contains about twenty thicker, longitudinally oriented parallel muri. These muri form a more or less helicoidal pattern, with the longitudinal vesicle axis as rotation centre. The vesicle wall is about 0.5 microns thick at the intermural areas, and about 1u at the muri. The vesicle wall appears to be unilayered. No preferential splitting patterns or other pylome structures known.

Description

Vesicle hollow, elliptical in outline, sometimes elongate or slightly crescent-shaped; no processes; vesicle wall thin, about 0.5u in thickness, ornamented with thicker, raised, solid muri which emanate from two common points, one at each end of the vesicle and have a helical arrangement; this gives the appearance of a net-like mesh of muri when individuals are compressed so that opposite walls are in juxtaposition. No excystment structure recorded.

Dimensions

vesicle length	:	47[50]57
vesicle width	:	39[41]43
height of muri	:	1
specimens measured	:	5
specimens recorded	:	10

Remarks

The specimens recorded here appear to be identical in morphology and size to the material described from the Ashgill and Llandovery of Belgium (Martin 1974), and that from the Llandovery of Britain (Hill 1974, M.S.). Morphographically all three records are closely similar to Cramer's species E.cabottii, but their dimensions are approximately one half of those indicated by Cramer for his species; however close examination of Cramer 1971 shows a large disparity between the dimensions of E.cabottii quoted in the text (p.87) and the apparent size of the specimens illustrated, (Pl.4,figs.66, 67). In the description, the dimensions are given as 'Length of vesicle 100 to 200 microns'. The figures, said to be at a magnification of X1000, have a length of 5cms which at this magnification would be equivalent to an actual size of 50u, approximately the same as the records for similar forms from other sources. Clearly either the text or the magnification indicated is wholly inaccurate. Consequently the size-range given for E.cabottii is considered unreliable and is not taken into account; on this basis the present specimens are indistinguishable from those of Cramer and are thus attributed to his species.

The material from the L'Ilion Shale, New York, described by Thusu 1973 is similar in gross morphology but appears to have finer and more numerous muri; this may represent a separate species although more data are required to demonstrate this. The genus Moyeria Thusu 1973 is a junior synonym of Eupoikilofusa Cramer 1971.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan).

Previous Records

Llandovery, New York (Cramer 1971). Ashgill-Llandovery, Belgium (Martin 1974). Llandovery, U.K. (Hill 1974, M.S.).

Genus EXCULTIBRACHIUM
Loeblich and Tappan 1978 emend.

Type species: Excultibrachium concinnum Loeblich and Tappan 1978.

Emended Diagnosis

Vesical circular in outline, ornamented with numerous stiff hollow processes that do not communicate with the vesicle interior but are closed proximally with a short solid plug; processes divide distally into flexible branches in a single plane, branches hollow at point of branching, but distally are filled and solid, where they taper to a fine point; vesicle wall laevigate, process wall scabrate.

Remarks

The diagnosis is emended by deleting the phrase 'four to six' with reference to the number of distal flexible branches in a single plane. This in no way alters the overall concept of the genus but removes from the generic diagnosis reference to a minor morphological feature which is demonstrably not of generic significance.

Excultibrachium oligoklados sp.nov.
Pl.15,figs.4,5,6.

Derivation of name: Greek : oligo = few; klados = branch, twig, after the reduced number of distal branches with reference to the type species.

Diagnosis

Vesicle hollow, spherical to subspherical in outline, bearing numerous stiff hollow processes that do not communicate with the vesicle interior; distally processes divide into three or four branches in a single plane, branches are long, flexible and taper to a filament-like termination.

Dimensions

vesicle diameter	:	42[47]58
process length	:	16[28]52
process numbers	:	16 - 26
specimens measured	:	9
specimens recorded	:	12

Holotype : slide ref. NS/4-5; 19.3/85.0; U14/0; Pl.15,fig.6.

vesicle diameter	:	54
process length	:	26
process numbers	:	21

Description

Processes stiff, arising at approximately 90° to vesicle wall, tapering only slightly to the point of furcation where they divide into three, or rarely, four, flexible branches in a single plane; branches are relatively long, up to 15u, tapering to fine filament-like terminations which at X1200 in transmitted light appear acuminate; the flexible branches are often recurved down towards the vesicle to give the processes a grapnel-like appearance. Proximally processes are plugged with solid wall material so that there is no connection between process interiors and the vesicle cavity; process length varies from 60% to 100% of vesicle diameter. At X1200 in transmitted light both vesicle and process walls appear smooth. Excystment is by the development of a median split.

Remarks

Excultibrachium oligoklados sp.nov. is characterized by having stiff processes which divide distally into three flexible branches in a single plane. This form clearly has very close affinities with Excultibrachium concinnum Loeblich and Tappan 1978 but differs in that the latter is restricted by original diagnosis to individuals possessing four or six distal branches; in addition the vesicle dimensions in the present form are somewhat less than those quoted for the North American species.

Comparisons

Excultibrachium oligoklados sp.nov. appears to be superficially similar to Peteinosphaeridium trifurcatum subsp.longiradiata Eisenack 1965a; however this taxon normally has vela or wings down the axis of each process, although, 'wings on the processes may be only weakly developed or missing' [Trans.] Eisenack 1965a [p.138]. No trace of wings is present in the form under discussion. In addition Eisenack's sub-species appears to have much shorter more robust distal branches.

Occurrence

Caradoc [Shropshire].

Genus GONIOSPHAERIDIUM Eisenack 1969 emend.

Type species: *Goniosphaeridium polygonal* ex *Ovum hispidum polygonale* Eisenack 1931; Holotype lost, neotype Eisenack 1959 p.199,Pl.16,fig.8.

Emended Diagnosis

Vesicle hollow, polygonal or sub-polygonal, greater than 20u in diameter, wall smooth, thin [0.5 - 0.75u], bearing eight or more evenly distributed, hollow, simple, homomorphic processes having acuminate distal terminations; process interiors communicate freely with the vesicle cavity. There is no apparent differentiation between process and vesicle walls, which merge imperceptibly via a curving contact.

Remarks

Eisenack 1969 [p.256] proposed *Goniosphaeridium* to accomodate forms having simple unbranching hollow processes in communication with the vesicle cavity; unfortunately Eisenack omitted any reference to size in his original diagnosis so that the genus was indistinguishable from *Micrhystridium* [Deflandre 1937] Downie and Sarjeant 1963. In 1971 Kjellstrom rectified this situation by restricting *Goniosphaeridium* to forms having a vesicle diameter greater than 20u [see *Micrhystridium*, this study]. However at the same time, Kjellstrom introduced into his emended diagnosis, reference to the vesicle shape, viz.... 'spherical to polygonal vesicle'.... [p.43]. This inclusion of spherical vesicles rendered *Goniosphaeridium* sensu Kjellstrom a partial junior synonym of *Solisphaeridium* Staplin Jansonius and Pocock 1965. Consequently further emendation is proposed here, restricting the genus to polygonal or sub-polygonal forms having a vesicle diameter of more than 20u; in addition a purely arbitrary minimum number of eight processes is considered characteristic of the genus to allow separation from Veryhachium [Deunff 1954] ex Downie 1959.

In 1966 Vavrdova introduced the genus Polygonium, a taxon very similar to Goniosphaeridium in gross morphology. Significantly however, Vavrdova described the processes of her genus as having a consistent concentric arrangement and she clearly considered this a diagnostic feature of the genus. The present author has seen specimens from the Tremadocian and early Ordovician of Britain exhibiting such a concentric arrangement of processes but they are almost invariably associated with otherwise identical individuals having randomely distributed processes; thus it is possible that examination of large populations of Polygonium would show that the regular process arrangement reported by Vavrdova is coincidental and is not in fact a persistent feature. If this were shown to be so, then reference to concentric processes might be deleted from the diagnosis; Goniosphaeridium would then become a junior synonym of Polygonium causing the former name to be abandoned. However such a drastic emendation of Polygonium would certainly radically change the genus from the concept of the original author and cannot be justified without examination of the type material; for this reason Goniosphaeridium is retained here as a seperate taxon.

Veryhachium is similar in the style of the processes but these are always few in number and usually lie in a single plane. Solisphaeridium is restricted to those forms which have a spherical or sub-spherical vesicle. The genus Astropheos Booth 1979 [M.S.] emend. has an identical basic structure but here the processes always carry a surface ornament of grana or lateral spines. Estiastra Eisenack 1959 is larger by several magnitudes and lacks curving bases to the processes.

Goniosphaeridium connectum Kjellstrom 1971a.

Pl.22,figs.1,2.

1971b Goniosphaeridium connectum Kjellstrom p.44,Pl.3,fig.5.

1973 Goniosphaeridium connectum Eisenack Cramer and Diez p.483.

Original Diagnosis

Goniosphaeridium sp. with thin, single-walled, polygonal, psilate vesicle. No excystment structure recorded. Curved proximal process contact with the vesicle. Free communication between the process interior and the vesicle cavity. Processes, about ten in number, in length not exceeding the vesicle diameter, psilate, broad bases, conical, homomorphic, simple with evexate and/or bulbous distal terminations.

Description

The individuals encountered during this study are very similar, morphographically, to the original description of the species; however they vary in generally having fewer processes than the 'about ten' reported by Kjellstrom; in addition the size-range here is smaller than that of the Baltic specimens. Despite these differences the process style is so striking and characteristic that there is little doubt that only a single species is involved and that the differences observed are due merely to infra-specific variation.

Dimensions

vesicle diameter	:	19[22]28
process length	:	18[22]29
overall diameter	:	47[63.5]88
process numbers	:	6
specimens measured	:	4
specimens recorded	:	5

Remarks

This species although extremely rare, appears to be restricted to sediments of Caradocian age.

Comparisons

Goniosphaeridium splendens comb.nov. is similar but always has hollow conical processes with acuminate distal terminations.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan).

Previous Record

Caradoc, Sweden (Kjellstrom 1971a).

<u>Goniosphaeridium</u> <u>elongatum</u> sp.nov.

Pl.23,figs.5-12.

Derivation of name: Latin - elongare = long; with reference to the processes.

<u>Diagnosis</u>

A species of <u>Goniosphaeridium</u> having a hollow vesicle which is smooth, thin-walled (<0.5u), polygonal to sub-polygonal in outline; bearing a variable number of smooth, simple, hollow, homomorphic processes having wide bases which taper rapidly to form a slender conical stem; this stem then tapers gradually to an acuminate distal termination which may become hair-like. The interior of the processes communicates freely with the vesicle cavity. Process length is equal to, or longer than the vesicle diameter.

<u>Dimensions</u>

vesicle diameter	:	19(23)26
process length	:	19(24)31
process numbers	:	9 to 30
specimens measured	:	102
specimens recorded	:	>200

Holotype : slide ref. N5/3-3; 6.2/96.0; F25/4; Pl.23,fig.5.

vesicle diameter	:	23
process length	:	30
process numbers	:	24

Description

The vesicle diameter of forms attributed to this species only rarely falls below the 20u limit, thus allowing the species to be differentiated from the genus Micrhystridium (Deflandre 1937) Downie and Sarjeant 1963. The process length is always at least equal to the vesicle diameter but in most individuals is considerably greater. There is no differentiation between vesicle and process walls which merge imperceptibly via a curving contact. No excystment structure recorded.

Remarks

This species includes a number of morphological types, which however, may only be recognised by subtle changes in continously variable characters such as process length and process numbers; thus, although end-members may look substantially different, examination and measurement of a large number of specimens shows that complete intergradation exists. Since no objective grounds could be found for sub-dividing these forms, all are assigned here to a single new species. This form appears to be both widespread and abundant in sediments of Caradocian age but was not recorded at all from the Llandeilo.

Comparisons

G.splendens comb.nov. is similar in its basic structure but always has shorter, much more robust processes which are usually fewer in number. The genus Micrhystridium contains a number of essentially similar species but these always have a mean vesicle diameter of less than 20u. Goniosphaeridium sp.A always has fewer very much stouter processes and a larger vesicle.

Occurrence

Caradoc [Shropshire]. Caradoc [Girvan].

Goniosphaeridium splendens comb.nov.

Pl.23,figs.1-4; Pl.28,figs.1-3.

1931	Ovum hispidum polygonale	Eisenack p.113,Pl.4,figs. 18,19,[pars.]
1970	Veryhachium splendens	Paris and Deunff p.27,Pl.1, fig.4,text-fig.1.
1973	Goniosphaeridium cf. polygonale	Rauscher p.165,Pl.10, figs.14,15.
1976	Goniosphaeridium polygonale	Eisenack p.196,Pl.5,fig.1.
? 1979	Polygonium gracile	Booth [M.S.][pars.] Pl.11, fig.3[?]; Pl.13,fig.4[?]; Pl.15,fig.10[?];Pl.31,fig.5[?].

Original Diagnosis [as V.splendens]

An organism with a very small shell. The processes, nine in number are extensions of the shell and are therefore hollow. They communicate with the vesicle cavity; the wall is apparently without ornament. The processes are conical and are longer than the vesicle radius [Trans.].

Description

Vesicle hollow, polygonal, smooth, thin-walled [about 0.5u], bearing a variable number of hollow, smooth, simple, conical, homomorphic processes, the interiors of which are in free communication with the vesicle cavity; the robust processes taper only gradually towards the tip where they end in an acuminate termination. There is no differentiation between vesicle and process walls which merge imperceptibly via a curving contact. No excystment structure recorded.

Dimensions

vesicle diameter	:	19[27]35
process length	:	11[18]32
process numbers	:	11[19]24
overall diameter	:	48[59]80
specimens measured	:	30
specimens recorded	:	>400

Remarks

Examination of the taxonomic history of this form reveals a complex nomenclatural problem. The form was first described by Eisenack 1931 [p.113] under the name Ovum hispidum polygonale, a holotype being designated and illustrated [Pl.4,fig.19]; this holotype was unfortunately later lost. In the same paper Eisenack figured a dissimilar form which he referred to as Ovum hispidum cf. polygonale [Pl.5,fig.18]; this form was much larger, had a very thin wall and possessed infilled process tips; other specimens were also figured [Pl.4,figs.16,?17,20] under the name Ovum hispidum polygonale, which appear to be much more like the authors [Eisenack's] O.hispidum cf.polygonale. Since the holotype had been lost, Eisenack 1959 designated a neotype [Pl.16,fig.8] under the name Baltisphaeridium polygonale. This neotype is clearly unlike the original holotype and is in fact the form which Eisenack 1931 referred to as O.hispidum cf. polygonale. It seems that Eisenack had concluded that all the variations on this basic morphological theme are indivisible on objective grounds and should therefore all be included within a single highly variable species. This inference is supported by the appearance of a later publication, (Eisenack 1976, p.196) where he combines Goniosphaeridium connectum and G.conjunctum, both Kjellstrom 1971, into the species polygonale, now the type species of the genus Goniosphaeridium Eisenack 1969. Thus the species G.polygonale sensu Eisenack 1976 circumscribes large and small forms with smooth or shagrinate walls and acuminate, evexate or bulbous process terminations which may or may not be infilled. The present author considers this wholesale 'lumping' of different forms to be totally unjustified since the differences between them are substantial, they are based on variations in characters widely accepted as being of specific value in the acritarcha and finally they appear to be consistent. To include all of these variations in a single species as advocated by Eisenack tends to legitamise biological relationships which as yet remain assumed rather than proven. In addition potentially useful stratigraphical information may be lost; consequently the form under discussion here is considered a distinct and separate species. The position now arises where the use of the original specific name given to this form, that is polygonale, must be fixed by reference to the type, (here the neotype) under the provisions of the code, (I.C.B.N. Art. 7.1.); however the present form is considered not to be conspecific with the neotype and therefore the name polygonale cannot be applied and a different name must be used. Paris and Deunff 1970 figured and described a new species from the Llanvirn which they called Veryhachium splendens (p.27). This species clearly falls within the confines of the present form; no figure was given for the number of specimens examined but the wording of the description suggests that the species may have been based on a single individual. The abundant specimens examined here include some which are almost identical to the holotype of V.splendens (see Pl.23,fig.3); thus it appears that V.splendens is the first name validly applied to this form since the concept behind the name polygonale was altered by the designation of a neotype unlike the holotype. The species name splendens must therefore be applied and since it is characterised by a relatively high number of processes evenly distributed over the vesicle surface, the species is here transferred from Veryhachium to Goniosphaeridium.

Comparisons

G.polygonale is distinguished by the large size, very thin wall and infilled process tips. Several species of the genus Tectitheca Burmann 1968 resemble G.splendens comb.nov. but they are all readily distinguished by possessing a single, frequently enlarged, apical process. Polygonium gracilis Vavrdova 1966 has, by definition, processes arranged in a consistent concentric pattern.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan). Llandeilo (South Wales).

Selected Previous Records

Ordovician erratics, Baltic (Eisenack 1931). Llanvirn, France (Paris and Deunff 1970). Ordovician, France (Rauscher 1973).

Goniosphaeridium sp. A.

Pl.22,figs.3-5; Pl.28,fig.?4.

Description

Central vesicle hollow, polygonal in outline, smooth, thin-walled [about 0.5u], bearing a low number of hollow, smooth, simple, homomorphic processes which are robust and have particularly wide bases; the processes taper gradually to an acuminate distal termination and the interiors of the processes are in free communication with the vesicle cavity; process length is always equal to or greater than the vesicle diameter. There is no differentiation between vesicle and process walls, the two merging imperceptibly via a broadly curving contact. No excystment structure recorded.

Dimensions

vesicle diameter	:	20[23]33
process length	:	21[29]50
process numbers	:	6[8]9
specimens measured	:	11
specimens recorded	:	16

Remarks

This species is characterised by the long, very broad processes which are few in number; it is rare, and the possibility exists that this is merely an extreme form of *G.splendens* comb. nov. However no intermediate examples were observed and so the two are described separately here. Allocation of this form to the genus *Goniosphaeridium* is somewhat arbitrary since specimens with only six or seven processes could be considered transitional to Veryhachium (Deunff 1954) ex Downie 1959; indeed some authors might prefer to place such individuals within Veryhachium. The specimens encountered in the present study do not have all major processes developed in a single plane with smaller additional accessory processes on the faces; here all processes are of approximately equal size and are distributed in a regular manner over the entire vesicle, consequently reference to the genus Goniosphaeridium is considered the most appropriate.

Comparisons

G.splendens comb.nov. is somewhat similar but always has more numerous, shorter and more slender processes. There is a striking similarity between Goniosphaeridium sp.A and Astropheos celestum Booth 1979 (M.S.). The latter species is however readily identified by always having a surface ornament of short delicate spines. Despite the classificatory significance which has been attached to this difference in surface ornament, the essential morphological similarity in structure of these two forms is so pronounced that the possibility of a close biological relationship should not be overlooked, (compare Pl.22, fig.3 with Pl.21, figs 1,3). It must be remembered that the classification currently applied to the acritarcha is a wholly artificial one, based as it is, on variations in shape and on differences in ornamentation. It is conceivable that species currently assigned to quite different genera may eventually prove to be closely related in a biological sense.

This form was recorded only rarely in the present study and the creation of a new species is not considered justifiable until more data become available. A single questionable occurrence was recorded from the Lower Llandeilo [Pl.28,fig.4], but it is doubtful if this specimen is in fact conspecific with the present taxon.

Occurrence

Caradoc [Shropshire].

Goniosphaeridium sp. B.

Pl.28,figs.7-9.

Description

Central vesicle hollow, polygonal in outline, apparently smooth, thin-walled [about 0.5u], bearing numerous, hollow, smooth, simple, conical, homomorphic processes which have wide bases and taper gradually to an acuminate distal termination; the vesicle itself is formed by the merging of process bases. Process interiors are in free communication with the vesicle cavity and the length of the processes is approximately equal to one-half of the vesicle diameter. There is no apparent differentiation between the process and vesicle walls. No excystment structure recorded.

Dimensions

vesicle diameter	:	22[24]25
process length	:	9[10]11
process numbers	:	30 to 40
specimens measured	:	6
specimens recorded	:	11

Remarks

This rare form was only recorded from the Lower and Middle Llandeilo; only eleven specimens were recovered and the creation of a formal new species is not considered justifiable until more data become available.

Comparisons

Some specimens of Goniosphaeridium elongatum sp.nov. are somewhat similar but they always have fewer and considerably longer processes. G.splendens comb.nov. has a larger central vesicle and many fewer processes. Micrhystridium aremoricanum (Paris and Deunff 1970) Booth 1979 (M.S.) is morphographically almost identical but always has a vesicle diameter of less than 20u, usually substantially less.

Occurrence

Lower and Middle Llandeilo.

Genus LEIOFUSA (Eisenack 1938)
emend. Cramer 1971.

Type species: Leiofusa fusiformis (Eisenack 1934) Eisenack 1938.

Restricted Diagnosis (Cramer 1971)

Vesicle hollow, fusiform with simple pointed processes at each pole. Processes varying in length from less than one tenth to as much as five 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.

Remarks

The diagnosis of this genus was restricted by Eisenack 1965, emended by Combaz et al. 1967 and further restricted by Cramer 1971. The diagnosis adopted here is that of the latter author which essentially restricts Leiofusa to fusiform acritarchs which are smooth or at most irregularly microgranular; similar but ornamented forms were transferred to Dactylofusa (Brito and Santos 1965) Cramer 1971 and Eupoikilofusa Cramer 1971.

Comparisons

Navifusa Combaz et al. 1967 has vesicle sides which are parallel or nearly so and poles which lack simple pointed processes but instead have broadly rounded terminations. Dactylofusa has an ornament of separate sculptural elements arranged in longitudinal rows. Eupoikilofusa is decorated with striae or continous sculptural elements arranged in longitudinal rows. Anamaloplaisium Tappan and Loeblich 1971 has a Leiofusid-like shape but both processes bear an ornament of short thorn-like lateral branches.

Leiofusa fusiformis

(Eisenack 1934) Eisenack 1938.

Pl.20,figs.1-3.

1934	Ovum hispidum fusiformis	Eisenack p.65,Pl.4,fig.19.
1938	Leiofusa fusiformis	Eisenack p.28,Pl.4,fig.10.

1964	<u>Leiofusa fusiformis</u>	Downie and Sarjeant p.123.
1964a	<u>Leiofusa fusiformis</u>	Cramer pp.34,37,Pl.1,fig.6.
1965a	<u>Leiofusa fusiformis</u>	Eisenack p.140.
1965	<u>Leiofusa fusiformis</u>	Vavrdova p.352.
1966	<u>Leiofusa fusiformis</u>	Vavrdova p.410.
1967	<u>Leiofusa fusiformis</u>	Combaz Lange and Pansart p.298,Pl.1,figs.?C,?H,J; text-fig.1.
1968	<u>Leiofusa fusiformis</u>	Eisenack p.6,Pl.3,figs.?1,?2.
1970	<u>Leiofusa fusiformis</u>	Burmann p.316,Pl.13,fig.3.
1971	<u>Leiofusa fusiformis</u>	Cramer p.78,Pl.2,fig.35; text-fig.22-H.
1971	<u>Leiofusa fusiformis</u>	Sheshegova p.47,Pl.12,fig.16.
1972	<u>Leiofusa fusiformis</u>	Vavrdova p.86.
1973	<u>Leiofusa fusiformis</u>	Thusu p.803,Pl.104,figs.3,13.
1974	<u>Leiofusa fusiformis</u>	Rauscher p.100,Pl.5,fig.27.
1974	<u>Leiofusa fusiformis</u>	Hill p.172,Pl.25,fig.1.[M.S.].
1977	<u>Leiofusa fusiformis</u>	Vavrdova p.111,Pl.4,fig.1I.

<u>Original Diagnosis</u>

The body of this cyst is spindle-shaped and is drawn out into two thin fine spines. The wall is light yellow and very thin. The total length is about 320u of which the spindle-shaped body occupies about seven-tenths. The width measures 50u.[Trans.]

<u>Description</u>

Central vesicle hollow, smooth, elongate, fusiform with a long, hollow, simple, smooth process at each pole, the processes tapering distally to an acuminate termination; process interiors have free communication with the vesicle cavity.

Vesicle and process walls are thin [<0.5u], apparently single-layered and are undifferentiated. No excystment structure was recorded.

Dimensions

overall length	:	235[295]390
vesicle width	:	21[25]30
specimens measured	:	7.
specimens recorded	:	11

Remarks

Only the overall length was measured since in most specimens no obvious boundary exists between the vesicle and the processes [see Pl.20,fig.1] where processes are readily discernible, one is frequently longer than the other.

A single specimen was recorded having a clearly defined vesicle bearing very slender processes [Pl.20,fig.2]; specimens similar to this have been recorded from the Lower Llandovery of Brasil[Combaz et al. 1967, Pl.1,fig.H;Eisenack 1968, Pl.3, figs.1,2] and compared with <u>L.fusiformis</u> Cramer 1971 Pl.2,fig. 35 figures a comparable individual and assigns it to this same species.

Comparisons

<u>L.filifera</u> Downie 1959 is very similar in gross morphology but from the illustration [Pl.11,fig.7] this species appears to have an ornament of sparse striae. <u>L.thomissa</u> Loeblich 1970 is distinguished by bearing an ornament of scattered pits whilst <u>L.simplex</u> [Combaz 1967] Eisenack et al. 1976 lacks any

clearly defined polar processes.

Occurrence

Caradoc (Shropshire).

Selected Previous Records

Ordovician, Baltic (Eisenack 1934, 1938). Arenig, Bohemia (Vavrdova 1972). Upper Llanvirn, G.D.R. (Burmann 1970). Llanvirn, France (Rauscher 1974). Caradoc and Ashgill, Bohemia (Vavrdova 1965, 1966). Lower Llandovery, Brasil (Combaz et al. 1967). Wenlock, Rochester Formation, Canada (Thusu 1973). Lower Gedinnian, Spain (Cramer 1964a - possibly reworked).

Leiofusa sp. A.

Pl.26,figs.3-6.

1979	Leiofusa sp.A.	Booth (M.S.) p.232,Pl.20, fig.3;Pl.27,figs.13,14.

Description

Vesicle hollow, smooth, elliptical to inflated-fusiform in outline, thin-walled (<0.5u); each pole bears a single, hollow, smooth, simple, slender, flexible process tapering distally to an acuminate termination; process interior has free communication with the vesicle cavity. No excystment structure recorded.

Dimensions

vesicle length	:	13(15)17
vesicle width	:	9(10)11

process length	:	10.5[14]17
process width at base	:	1.0 - 1.5
specimens measured	:	4
specimens recorded	:	8

Remarks

Most of the specimens encountered are carbonised and processes are so dark that they appear solid; however a single much less carbonised individual was recovered [Pl.26,fig.3], showing clearly that the processes are hollow. Minor internal growth of pyrite is commonly associated with this form but rarely leads to significant distortion. Since so few individuals were recorded and the general preservation is poor, creation of a new species to accomodate these forms is deferred until more data become available.

Comparisons

Leiofusa ampulliformis Martin 1966 is similar but has a larger vesicle and much shorter processes.

Occurrence

Lower and Middle Llandeilo [South Wales].

Previous Record

Lower Llanvirn, Shropshire [Booth 1979 M.S.].

Genus LEIOSPHAERIDIA

[Eisenack 1958] Downie and Sarjeant 1963 emend.

Type species: *Leiosphaeridia baltica* Eisenack 1958.

Emended Diagnosis

Spherical to ellipsoidal bodies without processes, often collapsed or folded, with or without pylomes. Walls granular, punctate or unornamented, thin or thick, without divisions into fields and without transverse or longitudinal furrows or girdles.

Remarks

The diagnosis is emended to remove reference to an exclusively thin wall. This is considered necessary since the type species L.baltica Eisenack 1958 has a wall between 3 and 8u in thickness; although relatively thin when compared with some specimens of Tasmanites Newton 1875, this is an extremely thick wall by acritarch standards and use of the term 'thin' in this context is incorrect and potentially misleading. In all other respects the generic description of Downie and Sarjeant 1963 is accepted.

The history of the classification of sphaeromorph acritarchs has been complex and a number of reviews of this sub-group have been published, perhaps the most notable being included in Downie and Sarjeant 1963 and Staplin et al. 1965. Only a brief treatment of Leiosphaeridia is given here; for additional information on other proposed sphaeromorph genera see the above publications. Potter 1974 [M.S.] also contains a useful summary of many sphaeromorph taxa not encountered in the present study.

Leiosphaeridia as originally described and subsequently emended, is restricted to forms with or without pylomes; no mention is made of other modes of excystment; it is accepted that pylomes may or may not be developed by individuals of a single species and also that other species belonging to the genus may never exhibit pylomes, (Downie and Sarjeant 1963, p.88). There appears to be no objective way of dividing these simple forms and both those with and without pylomes should be retained within the one genus, Leiosphaeridia. However other sphaeromorphs occur which never have pylomes but commonly develop median splits as excystment openings; these cannot be considered as congeneric with Leiosphaeridia and where forms with this type of opening are recorded they are assigned to the genus Dichasphaira Potter 1974 (M.S.). Examination of samples from the Middle and Upper Ordovician of Britain showed the presence of many thousands of variable but essentially similar sphaeromorph acritarchs, often forming the bulk of some total assemblages. As noted by Hill 1974 (M.S.) these forms are difficult to speciate since the differences are limited to variations in body size and wall thickness, characters which for the most part seem to be continously variable; despite this, four taxa are described in detail here since they appear to form distinctive and consistent species recognisable either by their large size or by the possession of particular excystment structures. This leaves a large residue of simple spherical acritarchs ranging from 10 to 100u in diameter which are objectively indivisible (see Pl.34,fig.7); no description of these forms is attempted since they are long-ranging and are thus of little biostratigraphical interest.

Leiosphaeridia ketcheniata sp.nov.

Pl.25,figs.1,2,4.

Derivation of name: Greek - ketchenos = gaping, yawning; with reference to the large pylome.

Diagnosis

Vesicle hollow, spherical, smooth, moderately thick-walled [1.0-1.5u], fairly small. Excystment is by the development of a very large pylome which often has a thickened smooth rim.

Dimensions

vesicle diameter	:	34[39.5]44
pylome diameter	:	18[23.5]28
specimens measured	:	14
specimens recorded	:	23

The pylome normally occupies between 60% and 70% of the vesicle diameter.

Holotype : slide ref. NS/3-6; 12.1/131.2; N62/1; Pl.25,fig.4.

vesicle diameter	:	40
pylome diameter	:	19

Description

This species is usually preserved in a more or less three-dimensional state since the relatively thick wall resists compression and generally prevents folds developing. Where flattening has taken place, any resultant folding is always minor although random rupturing of the wall may occur. Pylomes without a thickened rim are sometimes observed, [Pl.25,figs.1,2].

Remarks

This form is relatively rare but is easily identified by the large pylome which is developed; even when lacking a pylome, specimens may normally be recognised by the fairly thick unfolded vesicle wall.

Comparisons

L.wenlockia Downie 1959 is similar in overall morphology but pylomes have never been described from this species.

Occurrence

Lower Caradoc [Shropshire].

Leiosphaeridia tenuissima Eisenack 1958.

Pl.25,figs.3,5.

1958b	Leiosphaeridia tenuissima	Eisenack p.341,Pl.1,figs.2,3.
1958a	Leiosphaeridia tenuissima	Eisenack p.8,Pl.2,figs.1,2.
1963	Leiosphaeridia tenuissima	Downie and Sarjeant p.95.
1964	Leiosphaeridia tenuissima	Downie and Sarjeant p.125.
1966	Leiosphaeridia tenuissima	Combaz p.32,Pl.1,fig.2.
1979	Leiosphaeridia tenuissima	Eisenack Cramer and Diez p.337.

Original Diagnosis

Wall extremely thin and delicate, transparent, glass-clear; preserved only as flattened almost circular discs. No pylome observed. [Trans.].

Description

Vesicle hollow, spherical, smooth, thin-walled [<0.25u], usually colourless or pale-yellow but always transparent. No processes or ornamentation of any kind; found only in a flattened state so that the wall always has a number of major folds due to compression. No excystment structure recorded.

Dimensions

vesicle diameter	:	100[127]170
specimens measured	:	10
specimens recorded	:	73

Remarks

Splits in the vesicle wall are commonly present but seem to be arbitrary in position and development and are considered to be random ruptures brought about by compression. It is probable that L.tenuissima intergrades into similar but smaller unspeciated sphaeromorphs and possibly also into the thicker-walled form L. cf. voigti.

Comparisons

L.tenuissima is identical in size-range, shape and folding characteristics of the wall to L. cf. voigti; the latter may usually be distinguished by the thicker less transparent wall. Occaisionally intermediate forms are encountered and a detailed study of this group might show these two taxa to be conspecific.

Occurrence

Lower Caradoc [Shropshire].

Previous Records

Tremadoc, U.S.S.R. [Eisenack 1958]. Undivided Palaeozoic, North Africa, [Combaz 1966].

Leiosphaeridia voigti Eisenack 1958

1958b	Leiosphaeridia voigti	Eisenack p.392, Pl.1,figs.4-6.
1958a	Leiosphaeridia voigti	Eisenack p.8,Pl.2,figs.3,4.
1962	Leiosphaeridia voigti	Eisenack p.71.
1963	Leiosphaeridia voigti	Downie and Sarjeant p.95.
1964	Leiosphaeridia voigti	Downie and Sarjeant p.125.
1966	Leiosphaeridia voigti	Combaz p.32,Pl.2,fig.11.
1968	Leiosphaeridia voigti	Eisenack p.4,Pl.1,fig.2.
1979	Leiosphaeridia voigti	Eisenack Cramer and Diez p.341.

Original Diagnosis

Wall thin without wall pores, only preserved as nearly circular flattened discs or also as specimens rolled up into a spindle shape. Diameter about 260u. Small, double-rimmed pylomes are common; they are 10u in diameter, or 20u including the rim. [Trans.].

Remarks

The dimensions for the type material quoted by Eisenack 1958 were very large [190 to 310u], however, the morphologically identical North African specimens figured by Combaz 1966, were only about 100u in diameter. It is evident then, that there is a very large size-range within this species.

Leiosphaeridia cf. voigti

Pl.25,fig.7.

Description

Vesicle hollow, smooth, originally spherical but found only as flattened elliptical or disc-shaped bodies which are always folded. Wall moderately thick (0.5 - 1.0u), translucent rather than transparent, no processes or ornamentation of any kind. No excystment structure recorded.

Dimensions

vesicle diameter	:	104(132)173
specimens measured	:	28
specimens recorded	:	>500

Remarks

Although appearing identical to L.voigti in gross morphology, the dimensions of this form are substantially less than those of the type material of Eisenack, (holotype diameter = 252u); in addition, despite a careful search, no pylomes were recorded here, although the original author describes them as occurring commonly in his material. For these reasons it was not considered justifiable to assign this form to L.voigti with any degree of confidence.

L. cf. voigti commonly occurs in great abundance in the Caradocian sequence of Shropshire and in some samples may make up as much as 50% of the total assemblage. It is possible that L. cf. voigti intergrades with L.tenuissima Eisenack 1958 and also with the plethora of smaller sphaeromorph acritarchs which are usually abundant in the same samples; these latter forms have not been differentiated since they lack features which would allow objective speciation. Preservation is often poor due to distortion caused by compression and internal mineral growth plus corrosion of the outer wall surface.

Comparisons

L.tenuissima is similar to L. cf. voigti but has a thinner more delicate wall which is always transparent. L.fastigatirugosa Staplin 1961 is apparently identical and may be conspecific.

Occurrence

Caradoc (Shropshire).

Genus LOPHOSPHAERIDIUM

(Timofeev 1959) Downie 1963.

Type species: Lophosphaeridium rarum Timofeev 1959; designated by Downie 1963 (p.630).

Original Diagnosis

Vesicle thick, tuberculose. (Trans. Norris and Sarjeant 1965).

Description

Vesicle hollow, spherical or sub-spherical, no processes, wall bearing a generally dense ornament of solid grana or tubercules.

Remarks

Lophosphaeridium is distinguished from Leiosphaeridia (Eisenack 1958) Downie and Sarjeant 1963 emend. by possession of a wall ornament of strongly developed, solid sculptural elements. The genus was proposed by Timofeev 1959 but he failed to designate a type species so the genus was invalid [I.C.B.N. Art.38]. Downie 1963 [p.630] designated L.rarum as the type species thus validating the genus. Lister 1970 [p.61] emended the diagnosis to limit Lophosphaeridium to forms having a solid wall ornament. This feature was implicit in the original description and figure of Timofeev 1959, and in addition was clearly stated by Downie 1963.

Comparisons

Leiosphaeridia has a smooth or microgranulate wall, always lacking the strongly developed solid ornamentation of Lophosphaeridium. Buedingiisphaeridium [Schaarschmidt 1963] Lister 1970 has an ornament of hollow tubercles sometimes thickened at the tip.

Lophosphaeridium spp.

Pl.34,fig.8.

Remarks

Only rare individuals attributable to Lophosphaeridium were recovered from the Llandeilo, all of which were carbonised, folded, and sometimes distorted by the internal growth of Pyrite. The size-range of the specimens encountered was 20-30u but no speciation was attempted because the paucity and poorly preserved state of these forms means that any specific identifications would be tentative at best. The genus is recorded here for the sake of completeness.

Genus MICRHYSTRIDIUM

[Deflandre 1937] Downie and Sarjeant 1963.

Type species: Micrhystridium inconspicuum Deflandre 1937
as Hystrichosphaera inconspicua Deflandre 1935.

Emended Diagnosis

Hystrichospheres with spherical or oval shells not divided into fields or plates, bearing processes with closed tips, most often simple, rarely branching or ramifying, without distal connections of any kind. The processes are generally of one type only. Mean and modal diameter of shell less than 20u.

Remarks

The original diagnosis of Deflandre 1937 emphasized that Micrhystridium has a size-range which in general is less than 20u. This size restriction was criticized, notably by Staplin 1961 who considered the 20u upper limit to be wholly arbitrary and proposed that it be abandoned. Downie 1958 presented results from a size-frequency study of a Tremadocian population which suggested that the 20u boundary represents a real discontinuity and is of biological significance. Downie and Sarjeant 1963 pointed out that the proposals of Staplin to abandon the 20u upper size-limit would render Micrhystridium indistinguishable from Baltisphaeridium Eisenack 1958; they therefore rejected Staplin's proposal but agreed with him that the genus should be restricted to forms having simple closed spines; they added that species with a vesicle surface divided into fields and those having tubular processes should be transferred into other genera. Staplin Jansonius and Pocock 1965 published a further emendation which included the vague statement 'of small to moderate size'. Rasul 1971 [M.S.] and Potter 1974 [M.S.] working respectively with Tremadocian and Lower and Middle Cambrian material, both concluded that the 20u size probably represents a significant boundary.

Other authors have considered the mode of excystment and the wall structure to be features of significance [Sarjeant 1967; Lister 1970]. Sarjeant maintained that many Mesozoic species of Micrhystridium have a double wall and that whilst pylomes are not a feature of the genus, other excystment openings do occur. Lister [p.78] agreed with Sarjeant's findings in part but made it clear that in his opinion double walls were a feature never found in Palaeozoic Micrhystridia. The present author endorses this conclusion having examined many hundreds of Ordovician examples which without exception proved to have a single-layer wall structure. Lister [p.77] further emended the diagnosis to include 'excystment by cryptosuture, dehiscence gradual by stages'. No unequivocal excystment structures were recorded in this study and the generic diagnosis of Downie and Sarjeant 1963 is followed here.

For a more detailed review of the history of this group see Sarjeant 1967, Lister 1970 and Eisenack Cramer and Diez 1979. It should be noted that the diagnosis of Micrhystridium given by the latter authors [p.383] and prefixed by the statement 'as proposed by Sarjeant 1967' is in fact incorrect and seriously misquotes Sarjeant; he clearly stated in his proposed diagnosis 'size small, mean and modal diameter of shell generally less than 20u'. Eisenack et.al. have deleted this reference from the diagnosis in what may be a typographic omission since no formal change is proposed.

It is realized that as diagnosed at present, Micrhystridium probably contains what will ultimately prove to be a number of acritarch genera; however, recognition and adequate delimitation of such genera will require a major research effort covering much of the stratigraphical column and is a project beyond the scope of this study.

Micrhystridium acum Martin 1969.

1969	Micrhystridium acum	Martin p.68,Pl.6,fig.273; text-fig.21.
1979	Micrhystridium acum	Eisenack Cramer and Diez p.387.

Original Diagnosis

Central body more or less globular in form, diameter 10-13u; the processes form a dense cover over the central body. Process length 4 to 7u. They are in the shape of slender hair-like cylinders whose extremities are distinctly capitate. [Trans.].

Micrhystridium acum var. brevispinum var.nov.

Pl.24,figs.4-6; Pl.32,figs.10,11.

Derivation of name: Latin - brevis, short, with reference to the short processes.

Diagnosis

Vesicle hollow, spherical; wall smooth, thin [0.5u or less], single-layered, bearing numerous short, slender, smooth cylindrical, hollow, homomorphic processes having capitate distal terminations which are solid. The process interior communicates freely with the vesicle cavity.

Dimensions

vesicle diameter	:	15[18]22
process length	:	2.5[3]4
process width	:	<1
process numbers	:	30-60
specimens measured	:	13
specimens recorded	:	29

Holotype : slide ref. OV/LHS/2a-9; 14.7/98.6; P28/4; Pl.24,Fig.6.

vesicle diameter	:	15
process length	:	3
process numbers	:	about 60

Description

The processes have slightly expanded bases and a curving proximal contact with the vesicle; they taper rapidly to an extremely slender, hair-like stem which is apparently hollow for most of its length; distally the process stems may become solid but generally they are so fine that even with high powered optics this feature cannot be determined with certainty; the capitate tips however are cleary solid. Processes are evenly distributed over the vesicle surface and there is no differentiation between process and vesicle walls. Processes are always very short, generally less than one quarter of the vesicle diameter in length. No excystment structure recorded.

Remarks

This rare species is found intermittently throughout the Llandeilo and Caradoc, a distribution pattern which suggests that the Caradocian record is a true one and that M.acum var. brevispinum var.nov. is not reworked into these horizons.

This species could be considered assignable to the genus Helosphaeridium Lister 1970; however Lister considered 'excystment by cryptosuture' to be a diagnostic feature of his taxon (p.76); no such structures were recorded here and consequently the species is retained in Micrhystridium; it is realized that additional data from future research on the mode of excystment may result in the transfer of this form to Helosphaeridium. A single individual was recovered which was closely similar to M.acum Martin 1969 (Pl.24,fig.10).

Comparisons

M.acum is similar in overall morphology but is distinguished by having a smaller vesicle and proportionately longer proceses. M.? triangulatum Potter 1974 (M.S.) appears superficially similar but has fewer, longer and more robust processes which expand distally into apparently triangular terminations. M.notatum Volkova 1969 has an ornamented wall surface and thicker processes.

Occurrence

Llandeilo (South Wales). Caradoc (Shropshire)?

Micrhystridium aremoricanum

(Paris and Deunff 1970) Booth 1979 M.S.

Pl.24,figs.7-9,11-13; Pl.32,figs.1,3.

1970 *Micrhystridium inconspicuum* subsp. *aremoricanum* Paris and Deunff p.32,Pl.2,fig.20.

1979 *Micrhystridium aremoricanum* Booth (M.S.) p.112,Pl.3,figs. 10-12; Pl.6,fig.7; Pl.8,fig.8; Pl.11,fig.4; Pl.12,figs.5-7, 10(?); Pl.14,fig.9; Pl.16, fig.14;Pl.18,fig.9(?);Pl.30, fig.10(?); Pl.34,fig.10(?).

1979 *Micrhystridium aremoricanum* Turner and Wadge p.407,Pl.20, fig.4.

Original Diagnosis

Acritarchs with a spherical central body, exhibiting conical spines which measure approximately one third of the diameter of the vesicle. The processes are numerous and robust. (Trans.).

Description

Vesicle hollow, circular or sub-circular in outline, wall thin (about 0.5u), smooth, single-layered; there is no differentiation between vesicle and process walls. Processes are numerous, smooth, simple, hollow, homomorphic, conical, with wide bases and they taper distally to an acuminate termination; the process interior communicates freely with the vesicle cavity.

Processes have a curving contact with the vesicle wall and are generally somewhat flexible, they are distributed evenly over the vesicle surface. No excystment structure recorded.

Dimensions

vesicle diameter	:	9[17]20
process length	:	5[7]9
process width at base	:	1-2
process numbers	:	30-50
specimens measured	:	12
specimens recorded	:	>50

Remarks

This species is common in the Lower and Middle Llandeilo of South Wales but occurs only intermittently in the type Caradoc section of Shropshire. The Caradocian record of the species must be regarded as uncertain since the same samples also yield numerous reworked Lower Ordovician acritarchs and it is possible that M.aremoricanum is itself reworked here. Booth 1979[M.S.] noted that in the Arenig and Lower Llanvirn of Britain M.Aremoricanum always appears to have a microgranulate wall; this feature was not observed in the present material where all of the specimens examined in detail exhibited smooth wall surfaces. Booth further commented that M.inconspicuum subsp. aremoricanum Paris and Deunff 1970 bears little resemblence to M.inconspicuum Deflandre 1937, and he proposed that the Ordovician form should be elevated to specific rank; this assessment is accepted and the new combination of Booth is adopted here.

Comparisons

M.henryi Paris and Deunff 1970 may be distinguished by possession of shorter and more delicate processes.

Occurrence

Lower and Middle Llandeilo (South Wales). ? Caradoc (Shropshire).

Previous Records

Llanvirn, France (Paris and Deunff 1970). Arenig and Llanvirn, U.K. (Booth 1979 M.S.). Arenig, U.K. (Turner and Wadge 1979).

Micrhystridium equaspinosum sp.nov.

Pl.24,figs.1-3; Pl.32,figs.7-9.

Derivation of name: Latin : equaa = equal, with reference to the processes which in length are approximately equal to the vesicle diameter.

Diagnosis

Vesicle hollow, sub-spherical to sub-polygonal, wall smooth, thin (about 0.5u), single-layered. Vesicle bears numerous hollow, simple, smooth, homomorphic processes which communicate freely with the vesicle cavity.

Dimensions

vesicle diameter	:	9(17)20
process length	:	11(15)18
process numbers	:	about 30
specimens measured	:	15
specimens recorded	:	>100

Holotype : slide ref. OV/LHS/2a-7; 10.2/85.9; K15/3; Pl.24,figs.1,2.

vesicle dimensions : 16 x 10

process length : 11

process numbers : 30

Description

The processes have slightly expanded bases and taper rapidly to a slender, somewhat flexible stem which has an acuminate distal termination; processes are hollow for most of their length but may sometimes be solid towards the tip. In length the processes are always equal to, or slightly shorter than the vesicle diameter and are evenly distributed over the vesicle surface. There is no differentiation between the vesicle and process walls. No excystment structure recorded.

Remarks

This is one of the few Micrhystridium species to be recovered from samples ranging from the basal Llandeilo through to the top of the Caradoc. This distribution strongly suggests that the Caradocian record is a true one and that M.equaspinosum sp.nov. is indigenous and not reworked into these horizons.

Comparisons

M.shinetonensis Downie 1958 has a spherical vesicle and typically has fewer shorter processes. M.radians Stockmans and Williere 1963 has very much shorter processes. M.stellatum var. salopiense Lister 1970 is very similar in overall morphology but commonly has minutely capitate process tips. M.profusum Wicander 1974 is distinguished by having a spherical vesicle which bears more numerous and shorter processes.

Occurrence

Llandeilo (South Wales). Caradoc (Shropshire).

<u>Micrhystridium</u> <u>henryi</u> Paris and Deunff 1970.
Pl.32,figs.2,4-6.

1970	<u>Micrhystridium</u> <u>henryi</u>	Paris and Deunff p.31,Pl.2, figs.2,10,14,15,18; Pl.3,fig.7.
? 1973	<u>Micrhystridium</u> <u>henryi</u>	Rauscher p.97,Pl.5,figs.9,10.
1979	<u>Micrhystridium</u> <u>henryi</u>	Booth p.123,Pl.12,figs.3,4,8; Pl.13,fig.11.

Original Diagnosis

This species .... possesses short conical spines with simple tips, thinning rapidly. The spines which are between 2 and 4u in length, meet each other at the base. The vesicle is spherical and varies in diameter from 17 to 24u. The number of spines is greater than one hundred and twenty. (Trans.).

Description

Vesicle hollow, spherical to sub-spherical in outline, wall thin, (about 0.5u), smooth, single-layered; there is no differentiation between vesicle and process walls. Processes are numerous, smooth, simple, hollow, homomorphic with relatively narrow flaring bases and they taper rapidly to a slender stem which has an acuminate distal termination; the process interior communicates freely with the vesicle cavity. Processes have a curving contact with the vesicle and are distributed evenly over the vesicle surface. No excystment structure recorded.

Dimensions

vesicle diameter	:	15[16]17.5
process length	:	2.5[3]4.0
process width at base	:	1 - 1.5
process number	:	50 - 70
specimens measured	:	9
specimens recorded	:	27

Remarks

The vesicle shape is more varied here than in the material described by Paris and Deunff; in addition the original diagnosis cites the number of processes as, 'greater than one hundred and twenty', whilst the present specimens typically bear approximately half this number; despite this they are assigned to M.henryi for two reasons,

a) The overall size, process style and process length are all closely similar to the type material.

b) Although the original authors quote one hundred and twenty as the minimum number of processes, all of their figured specimens, including the holotype, appear to have substantially fewer processes than this.

The specimens figured by Rauscher 1973 [Pl.5,figs.9,10] and referred to M.henryi only bear about twenty to thirty widely spaced processes and the validity of the assignment to this species is doubtful.

Specimens attributable to M.henryi occur rarely at certain levels in the Caradocian of Shropshire but always in samples containing numerous reworked Lower Ordovician acritarchs; this Caradocian record of the species is considered unreliable since M.henryi may itself be reworked into these horizons.

Comparisons

M.aremoricanum (Paris and Deunff 1970) Booth 1979 (M.S.) is distinguished by having longer, much more robust processes with a more conical form.

Occurrence

Lower and Middle Llandeilo (South Wales). ? Caradoc (Shropshire).

Previous Records

Llanvirn, France (Paris and Deunff 1970). Arenig, U.K. (Booth 1979 M.S.).

Genus MULTIPLICISPHAERIDIUM

(Staplin 1961) Lister 1970.

Type species: Multiplicisphaeridium ramispinosum Staplin 1961, Pl.48,fig.24.

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.

Remarks

The genus Multiplicisphaeridium was first proposed by Staplin 1961, to include all acanthomorphic acritarchs bearing processes which branch and are closed distally; this proposal met with considerable criticism (Eisenack 1962, Downie and Sarjeant 1963), on the grounds that such a genus would clearly include many unrelated forms. The genus was emended by Staplin Jansonius and Pocock 1965 and again by Eisenack 1969, the main changes proposed being to restrict the genus to forms with proximally open processes. Lister 1970 (p.83) discussed Multiplicisphaeridium in detail and proposed further emendation concerning the heteromorphic nature of the processes and the method of excystment. The proposals of Lister are accepted by the present author and are followed here.

As pointed out by Booth 1979 (p.133), the reference in Eisenack Cramer and Diez 1973, effectively further alters the concept of the genus although no formal emendation is offered. The proposals of these authors, which include the recognition of no less than four distinct methods of excystment within the one genus, are rejected.

Multiplicisphaeridium continuatum
Kjellstrom 1971.

1971b	Multiplicisphaeridium continuatum	Kjellstrom p.46, Pl.3, fig.7.
1973	Multiplicisphaeridium continuatum	Eisenack Cramer and Diez p.571.

Original Diagnosis

Multiplicisphaeridium sp. with thin, single-walled, polygonal psilate vesicle. No excystment structure recorded. Curved proximal process contact with the vesicle. Free communication between the process interior and the vesicle cavity. Processes, about eight in number, in length exceeding the vesicle dimension, psilate, cylindrical, homomorphic, furcate with acuminate distal terminations.

Multiplicisphaeridium cf. continuatum

Kjellstrom 1971.

Pl.6,fig.6.

Description

Central vesicle hollow, spherical to sub-spherical, wall thin [<0.5u] and smooth; vesicle bears a low number of smooth processes which branch distally in an irregular manner and have free communication with the vesicle cavity; the secondary branches may arise alternately, by bifurcation, or less commonly by trifurcation; process tips have acuminate distal terminations. The process wall is identical to and merges imperceptibly with the vesicle wall. No excystment structure was recorded.

Dimensions

vesicle diameter	:	10[14]18
process length	:	15[18]21
process numbers	:	7-10
specimens measured	:	6
specimens recorded	:	7

Remarks

The present form is very similar in size and general morphology to the species described by Kjellstrom; the specimens recorded here however, have a wider range of process branching style than reported from the Baltic material. The diagnosis of Kjellstrom's species states, 'polygonal .... vesicle', but the illustration suggests that in the holotype at least, this is due to distortion probably resulting from compression.

Comparisons

M.continuatum is easily distinguished from other similar members of the genus by the very small vesicle size.

Occurrence

Caradoc (Shropshire).

Multiplicisphaeridium irregulare

(Staplin Jansonius and Pocock 1965)

Loeblich and Tappan 1978.

Pl.6,figs.1-5,7.

1965 Multiplicisphaeridium irregulare (pars.) Staplin et al. p.183,Pl.18,fig.18.

1973 Multiplicisphaeridium irregulare Eisenack Cramer and Diez p.663.

1975 Multiplicisphaeridium irregulare Tynni p.29,Pl.3,fig.10.

1978 Multiplicisphaeridium irregulare Loeblich and Tappan, p.1277,Pl.14,fig.3.

Emended Diagnosis

A species of Multiplicisphaeridium ornamented with hollow flexible processes of two types, the majority being simple and conical,, but others are alternately branched (rarely) or dichotomously branched; wall thin, of equal thickness in both vesicle and process, both also with laevigate surface.

Description

Central vesicle hollow, spherical to sub-spherical, rarely somewhat angular; vesicle and process walls appear identical, they are thin (<0.5u), smooth and merge imperceptibly. The processes, ten to fifteen in number are always of two types; simple, hollow, conical processes with acuminate or slightly rounded distal terminations are always intermingled with processes which branch irregularly; secondary branches may arise alternately on either side of the process stem or by bifurcation. All processes communicate freely with the vesicle interior. No excystment structure was recorded.

Dimensions

vesicle diameter	:	14(19)26
process length	:	7(14)20
process numbers	:	11-22
specimens measured	:	31
specimens recorded	:	86

Remarks

The present material shows a slightly smaller size-range than the measurements given by Staplin et al.

The re-examination of the type material (including the holotype) by Loeblich and Tappan 1978 has unquestionably resulted in a re-diagnosis and more comprehensive description of this species; despite this the latter authors make no claim to a formal emendation.

Occurrence

Caradoc (Shropshire).

Previous Records

Llandeilo-Caradoc, Anticosti Island, Canada (Staplin et al.1965).
Middle Ordovician, Baltic (Tynni 1975).

Multiplicisphaeridium ramusculosum
(Deflandre 1945) Lister 1970.

1942 Hystrichosphaeridium ramusculosum Deflandre p.476,text-figs.2-6,(nom.nud.).
1945 Hystrichosphaeridium ramusculosum Deflandre p.63,Pl.1, figs.8-16.
1970 Multiplicisphaeridium ramusculosum Lister p.92.
For a comprehensive synonomy list see Lister 1970 (p.92)

Original Diagnosis

Globular vesicle, in some cases ellipsoidal or sub-spherical, ornamented with processes which are usually greater in length than half the shell diameter, and perhaps equal to this diameter. The processes are of two types. Some are simple and pointed. The others, very characteristic, are ramified in an irregular manner and in addition often carry spines on the main trunk of the process [Trans. Lister 1970].

Remarks

In 1972, Cramer and Diez [p.156] introduced a number of new varieties attributed to M.ramusculosum but under the generic name Baltisphaeridium. Eisenack Cramer and Diez 1973 transferred all of these varieties to Multiplicisphaeridium including M.ramusculosum ramusculosum of Cramer and Diez 1972. This variety was quite unlike the holotype of the species, [Deflandre 1945 Pl.1,figs.8-10], and therefore cannot be interpreted as containing the nomenclatural type of the species, although repetition of the specific epithet implies that this is so, [I.C.B.N. Art.26]; under this article of the code, repetition of the specific epithet is required for the infra-specific taxon containing the nomenclatural type of the species. This being so, M.ramusculosum ramusculosum Cramer and Diez 1972 was invalidly published and must be rejected.

Multiplicisphaeridium cf. ramusculosum

Pl.31,figs.4-7.

Description

Central vesicle hollow, spherical to elliptical, thin-walled [<0.5u], apparently smooth. Processes are broad-based, hollow, heteromorphic, apparently smooth, closed distally and have free communication with the vesicle cavity; they all taper distally and are either simple with acuminate distal terminations or branch with up to fourth order bifurcation. No excystment structure was recorded.

Dimensions

		spec.1.	spec.2.	spec.3.
vesicle dimensions	:	23 x 19	18 x 18	14 x 15
process length	:	15	13	12
process numbers	:	13	11	6
specimens measured	:	3		
specimens recorded	:	4		

Remarks

This was an extremely rare form and three of the four specimens recovered had suffered considerable mechanical damage, particularly to the process tips; this is a preservational feature which makes specific allocation difficult.

Comparisons

The specimens recorded have the same basic morphology as *M.ramusculosum* but differ in not bearing short spines on the process stem and in having a more complex process branching style.

Occurrence

Llandeilo (South Wales).

Multiplicisphaeridium raspa
(Cramer 1964) Lister 1970.
Pl.31,figs.1-3.

1963 *Baltisphaeridium raspa* (pars.) Cramer p.216,Pl.2,figs. 16-19,(nom.nud.).

1964 *Baltisphaeridium raspa* Cramer p.301,Pl.4,figs. 1-6,11.

1965	Micrhystridium raspa	Deflandre and Deflandre-Rigaud, cards 2483-2487.
? 1965	Micrhystridium raspa	Rauscher, Doubinger and Manche-Bain p.312,Pl.4, figs.8,9,11.
1966	Micrhystridium raspa	Martin p.7,text-fig.5.
1969	Micrhystridium raspa	Martin p.77,Pl.3,figs. 145,146,157;Pl.5,figs.241, 242;Pl.8,figs.377,384.
? 1969	Micrhystridium raspa	Konzalova-Mazancova p.82, Pl.15,figs.?10,14,15.
1970	Multiplicisphaeridium raspa	Lister p.84.
1973	Multiplicisphaeridium raspa	Eisenack Cramer and Diez p.767.
1973	Multiplicisphaeridium raspa	Rauscher p.85,text-fig.29.
? 1974	Multiplicisphaeridium raspa	Martin p.11,Pl.4,figs.117,118.
1974	Micrhystridium raspa	Stockmans and Williere p.30.
1979	Multiplicisphaeridium raspa	Booth p.136,Pl.3,fig.13;Pl.6, figs.5,6;Pl.11,fig.6;Pl.16, fig.13;Pl.18,fig.8;Pl.20,fig.2. Pl.27,figs.6,7;Pl.29,fig.12. [M.S.].

Original Diagnosis

Central body and processes hollow, with uniform walls. The central body is roughly spherical, has a moderately thin wall and is moderately transparent. The wall is psilate at X1200 magnification.

The processes are simply bifurcated at the tips with branches of the second to third order. Number of processes ten - thirty five in optical section. Processes 25% or more of Øi. The number and length of the processes are rather variable.

Description

Central vesicle hollow, thin-walled [<0.5u], and apparently smooth, outline is spherical to elliptical. Numerous smooth, hollow, heteromorphic processes are present which are distally closed but have free communication with the vesicle cavity; processes may be simple with acuminate distal terminations or may branch up to second or third order bifurcations; the process length varies widely but is commonly about a quarter of the vesicle diameter, rarely processes may be considerably longer than this. Process width also varies, even on a single individual; some are very slender whilst others have wide bases and are generally more robust. No excystment structure recorded.

Dimensions

vesicle dimensions	:	14[18]24 x 10[16]22
process length	:	4[5.5]8
process width	:	1.5[2]2.5
process numbers	:	15-40
specimens measured	:	14
specimens recorded	:	>50

Remarks

The material recorded here closely resembles the type material of Cramer 1964, both in size and in overall morphology.

Comparisons

Multiplicisphaeridium lobeznum (Cramer 1964) Eisenack et al. 1973, is larger and has longer processes with a more complex branching style. M.picorricum (Cramer 1964) Lister 1970 is distinguished by having generally fewer and longer processes.

Occurrence

Llandeilo (South Wales).

Selected Previous Records

Siegenian to Emsian, Spain (Cramer 1964). Ordovician-Silurian, France (Martin 1966, 1969). Ashgill, France (Rauscher 1973). Arenig-Llanvirn, U.K. (Booth 1979).

Genus NAVIFUSA

Combaz Lange and Pansart 1967.

Type species: Navifusa navis ex Leiofusa navis Eisenack 1938. p.28,Pl.4,fig.11.

Original Diagnosis

Shell having the form of a more or less elongate ellipse, or rod-like with rounded extremities without processes. Wall simple, smooth or ornamented. (Trans.).

Remarks

It is clear that the original authors of the genus Navifusa, differentiated it from Leiovalia Eisenack (1965a) by virtue of its exhibiting a much more elongate outline. The present author regards this genus as being characterized by having a high length to breadth ratio and sides which are parallel or nearly so for a significant part of their length. Broadly rounded poles and no processes are the other diagnostic morphological features.

Navifusa ancepsipuncta Loeblich 1970

Pl.9,figs.1-8.

1970 Navifusa ancepsipuncta Loeblich p.730,fig.240.

1978 Navifusa ancepsipuncta Loeblich and Tappan p.1277, Pl.13,figs.6,7.

Original Diagnosis

Naviform cyst, with sides parallel nearly to the tips, then broadly rounded, no polar processes; wall thin, about 0.5u in thickness, smooth and very finely punctate over most of body, but strongly punctate for a distance of about 30-40u at each end; no pylome observed. Length ranges from 126-175u and breadth from 42-55u.

Description

The specimens recorded conform closely to Loeblich's original diagnosis but exhibit a slightly greater size-range than his material. Under an S.E.M. the pores penetrating the wall are clearly seen. The outer surface of the wall in the inter-porate areas is smooth at magnifications up to X10,000 (see Pl.9,fig,7). No excystment structure recorded.

Dimensions

vesicle length : 108(139)176

vesicle width : 42[56]72

specimens measured : 6

specimens recorded : 32

Remarks

In some of the sequences examined in this study, this species commonly occurs in association with Navifusa similis comb.nov. In residues having less than perfect preservation, great care is required to differentiate between the two forms. Frequently this is all but impossible without high powered, high quality optics coupled to a phase-contrast facility.

Comparisons

Navifusa similis comb.nov. is similar in overall shape but has an impunctate wall. N.navicula [Eisenack 1951] Combaz et al. 1967 has less broadly rounded polar terminations and an impunctate wall. N.brasiliensis lingula [Brito and Santos 1965] Combaz et al. 1967 has an impunctate wall which bears a surface ornament of verrucae.

Occurrence

Caradoc, [Shropshire].

Previous Records

Upper Ordovician Sylvan Shale, U.S.A. Loeblich [1970], Loeblich and Tappan [1978].

Navifusa similis Eisenack 1965a comb.nov.

Pl.10,figs.1,2,4.

1965a	Leiovalia similis	Eisenack p.139,Pl.12,figs.5,6.
1967	Leiovalia similis	Combaz Lange and Pansart p.295.
1972	Leiovalia similis	Combaz and Peniguel p.131, Pl.1,figs.22,24.
1975	Leiovalia similis	Tynni p.23,Pl.3,fig.1.

Original Diagnosis

Elongate shell with a thin smooth wall and good rounded poles. [Trans.].

Description

The hollow vesicle has an elongate egg-shaped outline with sides which are parallel or nearly so for most of their length. Both poles are broadly rounded, one pole commonly being larger than the other but not exclusively so. Wall is thin, [0.5u or less], delicate, commonly folded or wrinkled, always without surface ornament, usually slightly thickened at each pole. There are no processes.

Individuals are recorded having a split in the vesicle wall across a line halfway between the poles. Rarely a specimen is encountered which has divided into two separate halves, but usually rupture is only partial. Any split developing in this way is always in a median position and always takes the form of a straight line normal to the long axis. This feature may represent an excystment mechanism but more data are required to demonstrate this unequivocally.

Dimensions

vesicle length	:	63[99]186
vesicle width	:	25[32]60
specimens measured	:	67
specimens recorded	:	>200

Remarks

The present specimens are closely similar to the type material of Eisenack [1965a]; however the present author feels that the possession of a relatively elongate outline and sides which are parallel for much of their length, justifies the transfer of this species to the genus Navifusa. This species is abundant in strata of Caradoc age from Shropshire and Girvan.

Comparisons

Navifusa similis is similar to N.ancepsipuncta [Loeblich 1970], N.indianensis and N.punctata [Loeblich and Tappan 1978] in overall morphology, but the latter species are readily distinguished by having a vesicle wall which is punctate whilst that of N.similis is smooth and unbroken. Leiovalia ovalis, [Eisenack 1965a] has a more oval outline and is very much larger.

Occurrence

Caradoc [Shropshire].. Caradoc [Girvan].

Previous Records

Upper Ordovician, Baltic [Eisenack 1965a], Llandeilo, Australia [Combaz and Peniguel 1972] ? Upper Ordovician, Baltic [Tynni 1975].

Genus NEXOSARIUM gen.nov.

Derivation of name : Latin - nexosus = involved, complicated, with reference to the complex morphology of the taxon.

Diagnosis

Central vesicle hollow, spherical to sub-spherical, wall ornamented with grana or verrucae, sometimes apparently reticulate; wall moderately thick but difficult to measure because of ornament. Vesicle bears a low number of radiating hollow, heteromorphic processes all having basal plugs; process interior does not communicate with vesicle cavity; process length is approximately equal to vesicle diameter. Some processes are simple with acuminate distal terminations; others bifurcate up to the second order, rarely a trifurcate process occurs. Excystment is by the development of a median split.

Type species : Nexosarium parva sp.nov. Pl.8,figs.1-7.

Remarks

This genus is similar to Oppilatala Loeblich and Wicander 1976 but differs in always having simple and branching processes developed together on a single vesicle. In addition Oppilatala commonly exhibits basal constriction of the processes and a double-layered vesicle wall, features not seen in Nexosarium. Cheleutochroa Loeblich and Tappan 1978 differs in always having free communication between the process interiors and the vesicle cavity.

Nexosarium parva sp.nov.

Pl.8,figs.1-7.

Derivation of name : Latin - parva = little, with reference to the small size of the taxon.

Diagnosis

Ventral vesicle spherical to sub-spherical, hollow, ornamented with dense grana or verrucae, sometimes apparently reticulate; the wall is moderately thick but is difficult to measure because of the surface ornament. The vesicle bears radiating, hollow, heteromorphic processes, always with basal plugs apparently of solid wall material; there is little or no proximal constriction; the processes, about twelve in number, are in length slightly more than the vesicle diameter. Excystment is by the development of a median split.

Dimensions

vesicle diameter	:	17[19]22
process length	:	19[23]29
process width	:	1.5
process numbers	:	9[12]14
specimens measured	:	11
specimens recorded	:	16

Holotype : slide ref. OV/O/2-1;14.9/86.7;P16/O;Pl.8,Figs.3,6.

vesicle diameter	:	20
process length	:	19
process width	:	1.5

process numbers : 11

Description

The exact nature of the vesicle wall ornament is exceedingly difficult to determine using transmitted light. The form of the basal process plugs is very distinctive, the distal portion of the plug being penetrated by a deep internal depression having the shape of an inverted cone; in transverse section this gives the plugs the appearance of being more or less planar on the lower, proximal, surface, while the upper part of the plug has a deeply incised V-shaped indentation; the distal portion of the plug merges imperceptibly into the process wall (Pl.8,figs.3,6.). Two types of process are always present, simple processes with acuminate distal terminations and those having up to 2nd order bifurcations, rarely a trifurcate process occurs; secondary branches are commonly but not invariably very long and always have acuminate distal terminations. Frequently one or two processes of either type are developed which are very much smaller than the majority. All processes have thin (<0.5u) delicate walls which are entirely smooth; some however have an ornament of nearly parallel converging ridges on the vesicle adjacent to their bases.

Remarks

This taxon was only recorded from a single sample from the Onny Shales. A detailed search of other samples was made in an effort to accumulate additional data about the distribution of this form, but was unsuccessful. This very limited occurrence is difficult to explain satisfactorily, since in the sample in which it occurs, N.parva is relatively common;

This species appears to have some affinities with Diaphorochroa diaphorosos sp.nov.

Comparisons

Cheleutochroa meionios sp.nov. has a similar vesicle ornament but always has simple processes which communicate freely with the vesicle cavity. Diaphorochroa diaphorosos sp.nov. has a similar vesicle ornament and heteromorphic processes but these always communicate freely with the vesicle cavity.

Occurrence

Upper Caradoc, (Shropshire).

Genus NOTHOOIDIUM Leoblich and Tappan 1976.

Type species : Nothooidium mordidum (Cramer Allam Kanes and Diez 1974) Loeblich and Tappan 1976.

Original Diagnosis

Vesicle pear-shaped in outline, truncated at one pole and with a large cyclopylome at the truncated end; wall thin, entire vesicle surface verrucate; excystment by cyclopylome, character of operculum unknown.

Remarks

The type species Nothooidium mordidum was first described from the early Ordovician of North Africa by Cramer et al. 1974 (p.186) and was attributed to the genus Ooidium Timofeev 1957. Loeblich and Tappan 1976 (p.303) considered that this species had little affinity with Ooidium and transferred it to a new genus, Nothooidium, at the same time designating it as type species for the genus.

? Nothooidium sp.A.

Pl.31,figs.7-9.

Description

Vesicle hollow, fairly thin-walled, smooth to possibly microgranular, having an elongate pear-shape with a large opening at the narrow pole; the margins of the polar opening appear to be slightly irregular. The vesicle bears a ubiquitous, dense ornament of short, slender, flexible, homomorphic, probably solid spines which have acuminate distal terminations. Excystment is by means of a polar opening [= cyclopylome of Loeblich and Tappan ?].

Dimensions

		spec.1.	spec.2.	spec.3.
vesicle dimensions	:	61x39	47x29	56x43
width of polar opening	:	17	18	13
length of spines	:	6	5	5
number of processes	:	>200		
specimens measured	:	3		
specimens recorded	:	6		

Remarks

The dense nature of the ornament makes the exact structure of the vesicle wall difficult to observe. This acritarch is very rare and only three individuals in a reasonable state of preservation were recovered; despite this a full description is felt justified since the morphology is striking and the taxon is readily identifiable even when preservation is poor. This form is not unequivocally attributable to *Nothooidium* Loeblich and Tappan 1976, since by original diagnosis that genus has a verrucate rather than a spinose vesicle wall; however the present specimens clearly have affinities with *Nothooidium* and until more data become available they are tentatively assigned to this genus.

The sparse data currently available for *Nothooidium* and associated forms, tend to suggest that both vesicle size and length of body ornament increase from the early to the middle Ordovician; however, at present, records of the genus are so few that this observation must still be regarded as speculative.

Comparisons

Nothooidium mordidum Cramer et al. 1974 is smaller, has a dense ornament of flat-crested verrucae and a dark rimmed polar pylome. *Nothooidium* sp.A of Booth 1979 (M.S.) is less elongate and bears much shorter spines.

Occurrence

Lower and Middle Llandeilo (South Wales).

Genus ORDOVICIDIUM
Tappan and Loeblich 1971.

Type species : *Ordovicidium elegantulum* Tappan and Loeblich 1971.

Original Description (no diagnosis made)

Vesicle spherical, having numerous hollow rigid processes that do not communicate with the vesicle, taper very little distally, and are multifurcate; rarely simple processes occurring with the multifurcate ones; wall double-layered, the processes arising from the outer layer and being easily detached to leave a rimmed scar or hole exposing the inner layer; vesicle wall rather thick, laevigate to microgranulate; inner wall layer in some species also microgranulate; process walls thin, hyaline, smooth or microgranulate; excystment by rupture or splitting of the vesicle wall.

Remarks

The double-layered wall and a tendency for processes to become detached were not observed in specimens recorded from the British sequences examined in this study.

Ordovicidium elegantulum
Tappan and Loeblich 1971
Pl.13,figs.1-4; Pl.14,figs.4-7;
Pl.33,figs.3,5.

1971 Ordovicidium elegantulum Tappan and Loeblich p.398, Pl.7,figs.1-7.

Original Description [no diagnosis made]

Vesicle spherical, with hollow processes formed from the outer wall layer and thus not communicating with the vesicle interior; processes easily detached, each leaving a rimmed scar that is floored by the inner wall layer; processes tapering slightly distally where they may trifurcate or bifurcate and then bifurcate again; process branches terminating in fine, almost hair-like tips that commonly are broken off. Rarely, one or two of the processes on a specimen are simple, lack any bifurcation, and terminate in a point. Vesicle wall double-layered, rather thick, about 1.5u in thickness; hyaline walls of processes thinner, slightly less than 0.5u in thickness; both vesicle and process walls microgranulate, with small, scattered granules extending out on the processes and their branches, to the beginnings of the hair-like branch tips; excystment by a splitting and rupture of the vesicle wall.

Description

Vesicle spherical to sub-spherical, wall smooth to microgranular, thick [1-2u], bearing fairly numerous, stiff, radial, hollow processes which do not communicate with the vesicle interior and are distally multifurcate; process walls relatively thin [0.5u], always microgranular or granular; development of ornament varies between individuals but is commonly most pronounced on the distal furcae; process length 30-50% of vesicle diameter; smaller simple processes with acuminate distal terminations rarely present [see Pl.14,fig.7]. Excystment is by the development of a median split.

Dimensions

vesicle diameter	:	29[47]53
process length	:	15[18.5]24
process numbers	:	12-25
specimens measured	:	14
specimens recorded	:	>100

Remarks

A double-layered wall and a tendency for processes to become detached, features described by Tappan and Loeblich (1971) were not observed. The specimens recorded here are smaller than the size-range reported from the Oklahoma material by Tappan and Loeblich. Excystment structures formed by median splits in the vesicle wall are quite common in populations from the Caradocian of Shropshire; these splits are always median, that is tending to divide the vesicle into two approximately equal parts and consequently it is considered very unlikely that they are random ruptures caused by compression.

Comparisons

Peteinosphaeridium nudum (Eisenack 1959) Eisenack 1969, is very similar in gross morphology but differs in always having entirely smooth vesicle and process walls.

Occurrence

Caradoc, (Shropshire). ? Llandeilo, (South Wales).

Previous Records

Llandeilo/Caradoc, Oklahoma (Bromide Fm. - Tappan and Loeblich 1971).

Ordovicidium heteromorphicum

(Kjellstrom 1971) Loeblich and Tappan 1978. comb.nov.

Pl.15, figs.9,10.

1971b Peteinosphaeridium heteromorphicum Kjellstrom p.53, Pl.4, fig.2.

1973 Peteinosphaeridium heteromorphicum Eisenack Cramer and Diez p.901.

? 1975 cf. Peteinosphaeridium heteromorphicum Tynni p.32,Pl.4,fig.5.

1979 Peteinosphaeridium heteromorphicum Booth p.153,Pl.21,fig.1.

Original Diagnosis

Peteinosphaeridium sp. with thin, single walled, spherical psilate vesicle. Excystment structure formed as a partial rupture. Angular proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Processes, about twentyfive in number, in length about one third of vesicle diameter, psilate, conical, heteromorphic, simple, always with bulbous distal terminations and bifurcate with acuminate furca-tips.

Description

The present specimens agree closely with Kjellstrom's description of material from the Baltic; a minor difference is seen in that simple processes may have only slightly bulbous or even acuminate distal terminations. No excystment structure was recorded.

Dimensions

vesicle diameter	:	35[43]52
process length	:	7[10]16
process width	:	4
process numbers	:	12-29
specimens measured	:	4
specimens recorded	:	4

Remarks

This species is transferred to the genus Ordovicidium Tappan and Loeblich 1971 because of the excystment structure - 'a partial rupture' included in the diagnosis by Kjellstrom (1971b, p.53); this is a diagnostic feature of Ordovicidium, whilst Peteinosphaeridium Staplin et al. 1965 emend. Eisenack 1969, incorporates the concept of excystment by means of a pylome. (Eisenack 1969 p.253).

Occurrence

Caradoc, Shropshire.

Previous Records

Viruan, (Llandeilo), Baltic (Kjellstrom). ? Caradoc, Baltic, (Tynni). Lower Llanvirn, Shropshire, (Booth).

Genus ORTHOSPHAERIDIUM

(Eisenack 1968, Kjellstrom 1971) emend.

Type species : Orthosphaeridium rectangulare ex Baltisphaeridium rectangulare Eisenack 1963, p.211,Pl.20,figs.1,2, 3,10.

Emended Diagnosis

Vesicle hollow, rectangular to spherical in outline, bearing a low number (2 - 8) of long, hollow processes distributed in a regular manner. These processes are normally simple, tapering to a sharp point but may branch distally. The process cavity is always separated from the vesicle interior by a solid proximal plug. Excystment is by development of a straight split or suture in a median or equatorial position.

Remarks

The diagnosis is emended to include forms with a spherical vesicle as well as the 'oval to nearly rectangular' vesicles circumscribed in the original diagnosis (Eisenack 1968, p.91). Despite the contention that Baltisphaera Burmann 1970 is a junior synonym of Orthosphaeridium (Eisenack 1968) Kjellstrom 1971 'in letter and in spirit' (Eisenack Cramer and Diez, 1976 p.93), examination of Eisenack's original generic diagnosis shows that this is not wholly so. In his 1968 paper, Eisenack states in the diagnosis of Orthosphaeridium (p.91), 'central shell ...... more or less rectangular, in cross section oval to nearly rectangular' (Trans.). The material described by Burmann contained forms with spherical vesicles which cannot, objectively, be claimed as junior synonyms of Orthosphaeridium in letter, although they undoubtedly are so in spirit.

The affinities of three morphographically similar genera, Orthosphaeridium, Baltisphaera and Baltisphaeridium (Eisenack 1958) Eisenack 1969, were examined in detail by Rauscher 1973 (pp.83,84); he compared vesicle shape, process numbers and method of dehiscence and in addition pointed out that all three genera have a similar process style. By inference Rauscher concluded that Orthosphaeridium should be retained on the basis of the distinctive vesicle shape. Baltisphaera was considered a junior synonym of Baltisphaeridium since both have similar vesicles and taxa attributed to Baltisphaeridium exhibited median splits as well as pylomes. The present author, while accepting the validity of Rauscher's argument, has transferred forms with median splits from Baltisphaeridium (see Baltisphaerosum gen.nov.), thus restricting this genus to forms having pylomes; in addition the author differs from Rauscher in not considering subtle variations in vesicle shape as features of generic significance; consequently Baltisphaera is here considered a junior synonym of Orthosphaeridium, and the transfer of Burmann's species (Eisenack Cramer and Diez 1976) are accepted retroactively.

Orthosphaeridium is distinguished from Baltisphaerosum gen.nov. by having a low number of processes, which are not randomely distributed.

Rauscher 1973 (p.84) commented that forms having two or three processes evidently have close affinities and should not be separated. The present author feels that combining these very distinctive forms would be premature at the present time; it is recognised that they may indeed be revealed as conspecific by future research but more data are required to show this; in particular details of the stratigraphical distribution of the two morphotypes would be of interest. There is some evidence to suggest that O.bispinosum sp.nov. has a more restricted stratigraphical range than the tri-radiate forms, at least locally in the British Isles. Few data are available from elsewhere as yet.

Orthosphaeridium bispinosum sp.nov.

Pl.12,figs.1,3-7.

Derivation of name: after the two polar spines always present.

? 1959 Veryhachium macroceros (pars.) Deunff Pl.3,fig.37.

? 1969 Veryhachium n.sp.aff. macroceros Henry p.88,Pl.7,figs.51,56.

? 1971 Veryhachium deunffi (pars.) Henry and Thadeu p.1346, Pl.2,fig.9.

? 1973 Baltisphaeridium ternatum (pars.) Rauscher pp.83,96, Pl.10,fig.1.

? 1974 Baltisphaeridium (pars.) Rauscher Pl.2,fig.4.

? 1978 Baltisphaeridium ternatum Kalvacheva p.306,Pl.1,fig.20.

Diagnosis

Central vesicle very large, sub-spherical to oval, hollow, thick-walled (1.5-2.5u); wall bears a dense ornament of short, robust spines with rounded terminations. The processes, always two in number and occupying polar positions, are extremely long, slender, simple, homomorphic and have acuminate distal terminations; they posses basal plugs apparently of solid wall material but have little or no proximal constriction; the process interior does not communicate with the vesicle cavity; process walls are ornamented with spines identical to those on the vesicle wall.

Dimensions

vesicle dimensions	:	from 56x75 to 62x84
process length	:	from 92 to 152
process width	:	from 5 to 9
specimens measured	:	9
specimens recorded	:	26

Holotype : slide ref. OV/AS/1-5;8.3/129.6;J60/1;Pl.12,fig.1.

vesicle dimensions : 54x76

process length : 120x148

process width : 6.5

height of ornament : up to 0.8

Description

The dense ornament appears to be echinate in bright field illumination but the scanning electron microscope shows it to consist of short, thick, solid, conical spines with broadly rounded tips; these spines cover the entire vesicle surface and extend onto the process walls, typically becoming sparser and more dispersed distally; rarely they may die away altogether, leaving this portion of the process walls entirely smooth. The process wall is much thinner [<0.5u] and more delicate than the vesicle wall and is frequently folded; the distal tips of processes are infilled and solid. Excystment is by development of a median split, a feature often resulting in the vesicle splitting into entirely separated halves [Pl.12,fig.5].

Remarks

Excystment openings were abundant in the material studied. The specimen figured by Deunff 1959 [Pl.3,fig.37], and attributed to *Veryhachium macroceros*, is unlike the holotype of that species in having only two processes; in addition it is also unlike the rest of the figured specimens since it possesses much more slender processes which do not expand proximally. In size and gross morphology this specimen is similar to the present material. The specimens figured by Henry 1969 [Pl.7,figs.51,56] and assigned to *Veryhachium* n.sp. aff. *macroceros* also appear very similar to *O.bispinosum* sp.nov.;

however, no description is given by Henry of his new species (which was anyway invalid under I.C.B.N.Art.37) and the illustrations are not sufficiently good for synonomy to be established with certainty. Henry and Thadeu 1971 (Pl.2,fig.9) illustrated another very similar specimen, attributing it to a new species Veryhachium deunffi; again this specimen is unlike the holotype of their new species and clearly has affinities with the present material. The specimen illustrated at low magnification by Rauscher 1973 (Pl.10,fig.1), 1974 (Pl.2, fig.4) is not described in sufficient detail to include any ornamentation; consequently absolute identification of this form with O.bispinosum sp.nov. is not possible.

Comparisons

The conclusion and recommendation of Rauscher 1973 (pp.83,84), that forms similar to, and possibly identical with, O.bispinosum sp.nov. should be attributed to the genus Baltisphaeridium Eisenack 1969, is rejected. Baltisphaeridium characteristically develops pylomes as excystment structures whereas the present taxon excysts via a median split.

Occurrence

Upper Caradoc (Shropshire).

Previous Records

? Ordovician, Brittany (Deunff 1959). ? Lower Caradoc, Finistere (Henry 1969). ? Llandeilo - Caradoc, Portugal (Henry and Thadeu 1971). ? Caradoc, France (Rauscher 1973,1974).

Orthosphaeridium chondrododora

Loeblich and Tappan 1971

Pl.10,figs.3,5,6.

1971	Orthosphaeridium chondrododora	Loeblich and Tappan p.184,figs.2-6.
1975	Orthosphaeridium chondrododora	Tynni p.31,Pl.4,fig.2.

Original Diagnosis

Central vesicle ovate with inflated sides between the four long hollow processes; wall of vesicle 1..3u in thickness, surface ornamented with low grana clearly visible in the light microscope, but the scanning electron microscope shows the sculpture to consist of grana of various sizes and outline, from low conical to slightly elongate ones, with the area between these showing smaller granules and a minutely rugulate pattern; processes with walls about 0.6u in thickness, only slightly constricted at the junction with the vesicle where it is plugged for a distance of about 4u, hollow except for the plug and an area at the distal sharp tip which is solid for a distance of 2.6u, process surface ornamented by prominent grana throughout the entire length; excystment by a median splitting into two halves at right angles to the long dimension of the central vesicle.

Description

The vesicle dimensions are slightly smaller than those quoted by Loeblich and Tappan 1971, [p.185] but since their measurements refer to a single individual only, this cannot be considered significant. Vesicle shape is also more varied than suggested by the original authors, but again this is not surprising since their concept of the species appears to be based on one and a half individuals! The specimens encountered in this study vary from vesicles with straight sides and an almost rectangular outline (Pl.10,fig.6) to inflated vesicles similar to the holotype (Pl.10,fig.5). The ornamentation appears to be very close to that described in the type material, but some, particularly that on the vesicle wall, may be difficult to interpret in bright field illumination. Between individuals, development of grana may very from strong to barely visible. There is considerable range in process length and width.

Dimensions

vesicle sides	:	48(54)60 x 46(52)57
process length	:	88(106)130
process width	:	4(6)8
specimens measured	:	6
specimens recorded	:	6

Remarks

From the specimens studied it is clear that this species has a greater range of morphology than is suggested in the original record.

Comparisons

Orthosphaeridium vibrissiferum Loeblich and Tappan 1970 has a vesicle ornament of short, hair-like spines and process sculpture of small grana. Orthosphaeridium quadrinatum (Burmann 1970) Eisenack Cramer and Diez 1976, has a spherical or sub-spherical vesicle and may have a verrucate ornament or be smooth. Orthosphaeridium quadricornis (Burmann 1970) Eisenack Cramer and Diez 1976, has an elongate vesicle and four processes arranged in pairs in polar positions.

Occurrence

Caradoc (Shropshire).

Previous Records

Upper Ordovician, Eden Formation, U.S.A. Loeblich and Tappan 1971.

Orthosphaeridium quadrinatum

(Burmann 1970) Eisenack Cramer and Diez 1976.

Pl.11,figs.1,2; Pl.12,fig.2.

? 1965 Baltisphaeridium cf.eisnackianum (pars.) Vavrdova p.352, Pl.2,figs.2,3.

1970 Baltisphaera quadrinata Burmann 1970 p.306,Pl.8,fig.1.

1976 Orthosphaeridium quadrinatum Eisenack Cramer and Diez p.527.

Original Diagnosis

Central body nearly circular in outline with a regular quadruradial arrangement of identical, long processes which are distinctly differentiated by somewhat thinner basal constrictions. The processes are hollow, relatively thin and taper more strongly distally than proximally. Processes and central body may be smooth or covered by verrucae (Trans. Eisenack et al.).

Description

Central vesicle spherical to sub-spherical, wall moderately thick (0.5-1.5u), bearing a dense ornament of verrucae or short solid spines. Processes, always four in number, are more or less regularly distributed, either in a single plane or nearly so. Process walls are thin (<0.5u), delicate and processes are often folded or damaged; processes are long, simple, slender, hollow and have acuminate distal terminations, they bear an ornament identical to that on the vesicle wall but on the processes it is typically sparser and more dispersed, especially distally; this ornament may die away altogether distally, leaving this portion of the process entirely smooth; rarely a specimen is encountered where the process ornament is more strongly developed than that of the vesicle (Pl.12,Fig.2). Distal tips are infilled and solid. Process length is two to three times the vesicle diameter, the processes having basal plugs apparently of solid wall material; the process interior does not communicate with the vesicle cavity; proximal constriction varies from slight to pronounced. Excystment is by the development of a median split.

Dimensions

vesicle diameter	:	42(51.5)62
process length	:	80(113)176
process width	:	6(6.6)11
specimens measured	:	12
specimens recorded	:	22

Remarks

A single individual was recorded having three processes bearing the normal ornament whilst the fourth was entirely smooth; thus it appears that considerable variation of secondary features is possible within this species.

The two specimens illustrated by Vavrdova 1965 probably belong to this taxon but neither the material or the illustrations are good enough for synonomy to be established with certainty.

Comparisons

Orthosphaeridium chondrododora Loeblich and Tappan 1971 differs in having a quadrate to inflated-quadrate central vesicle. O.vibrissiferum Loeblich and Tappan 1971 is similar to O.quadrinatum but bears a spinose ornament rather than verrucae. O.rectangulare (Eisenack 1963) Eisenack 1968 has entirely smooth vesicle and process walls.

Occurrence

Caradoc (Shropshire).

Previous Records

? Upper Caradoc - Ashgill, Bohemia (Vavrdova 1965). Upper Llanvirn, G.D.R. (Burmann 1970).

Orthosphaeridium ternatum

(Burmann 1970) Eisenack Cramer and Diez 1976.

Pl.11,fig.3.

1970 Baltisphaera ternata Burmann p.306,Pl.7,fig.1; Pl.9,fig.4.

1972	_Baltisphaera ternata_	Martin p.7,Pl.7,fig.6.
1973	_Baltisphaeridium ternatum_	Rauscher pp.82,96,Pl.10, figs.1-4.
1975	_Baltisphaeridium ternata_	Tynni fig.10.
1976	_Orthosphaeridium ternatum_	Eisenack Cramer and Diez p.529.
1979	_Baltisphaera ternata_	Booth p.82,Pl.19,fig.9;Pl.20, fig.4;Pl.22,fig.6;Pl.34,fig.8.

Original Diagnosis

Central body circular in outline with a tri-radial arrangement of long unbranched processes which are distinctly differentiated from the central body by a somewhat thinner basal constriction. The processes are hollow and taper more rapidly at the distal end than at the proximal. They are placed regularly, about 120^{o} apart. Processes and central body may be smooth or may be covered by verrucae. No pylome can be seen; the vesicle opens by splitting of the central body into two smooth-rimmed halves [Trans. Eisenack et al.].

Description

Vesicle spherical to sub-spherical, wall moderately thick, [0.5-1.5u] bearing a dense ornament of verrucae or short solid spines with rounded tips. Processes, always three in number, are arranged at approximately 120^{o} angles in a single plane; process walls are thin [<0.5u], delicate and processes are frequently folded or damaged; processes are long, simple, slender, hollow and have acuminate distal terminations; they bear an ornament identical to that on the vesicle wall, but on the processes it is typically sparser and more dispersed especially distally; this ornament may die away altogether distally leaving this portion of the process entirely smooth. Distal tips are infilled and solid. Process length is two to five times the vesicle diameter, the processes having basal plugs apparently of solid wall material; the process interior does not communicate with the vesicle cavity; proximal constriction varies from slight to pronounced. Excystment is by the development of a median split.

Dimensions

vesicle diameter	:	42[50]58
process length	:	80[135]192
process width	:	4[8]18
specimens measured	:	8
specimens recorded	:	37

Remarks

The width of processes is to some extent dependent upon the state of preservation of individual specimens; those preserved in three-dimensions appear to have narrow processes with little proximal constriction when compared with compressed individuals which generally seem to have broad processes with a pronounced proximal constriction; this occurs because the flattening process leads to maximum lateral extension of the original cylindrical process [text-fig.18]. It is a feature most easily observed in these very large forms.

A single specimen was recorded having a completely smooth vesicle wall.

Very poorly preserved individuals, wholly carbonised and badly fragmented, but possibly attributable to this species, were recorded from the Llandeilo of South Wales.

Comparisons

Orthosphaeridium bispinosum sp.nov. has a larger oval vesicle and always has two processes in polar positions. *O.quadrinata* always has four processes in a single plane, or nearly so.

Occurrence

Caradoc (Shropshire). ? Llandeilo (South Wales).

Previous Records

Upper Llanvirn, G.D.R. (Burmann 1970). Arenig-Llanvirn, France (Martin 1972). Llanvirn, France (Rauscher 1973). Llanvirn, ? Arenig, U.K. (Booth 1979).

Genus PALAIOSPHAERIDIUM Rasul 1977.

Type species: *Palaiosphaeridium kamax* Rasul 1977.

Original 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 usually forked. The inner space of the processes communicates with the body cavity.

Palaiosphaeridium sp.A.

Pl.24,figs.14,15.

Description

Vesicle hollow, spherical to elliptical in shape, wall smooth, thin (about 0.5u), apparently single-layered. Processes are numerous, hollow for most of their length, heteromorphic, smooth and taper slightly to a distal termination which may be evexate, bifurcate or trifurcate; furcae are always very short, robust and are themselves evexate; the distal tips usually appear hollow but may sometimes be solid although this cannot be determined with certainty because of their small size. Process length is normally between one fifth and one tenth of the vesicle diameter, the interior of each process communicating freely with the vesicle cavity; there is no differentiation between vesicle and process walls, the two merging proximally by means of a curving contact. No excystment structure recorded.

Dimensions

vesicle diameter	:	15(19)31
process length	:	3(3.5)5
process width	:	1(1.5)2
furcae length	:	0.75(1)1.5
specimens measured	:	7
specimens recorded	:	19

Remarks

This rare form was only recovered from four widely separated samples from the Caradocian sequence of Shropshire and was always accompanied by reworked Tremadocian and Lower Ordovician acritarchs; for this reason it is possibly a reworked form of Tremadocian, Arenigian or Llanvirnian age and may not represent an indigenous Caradocian species; although this must be considered as a real possibility, it should be pointed out that no identical acritarch species has yet been described from the Tremadoc, Lower Ordovician or elsewhere in the stratigraphical column. Thus Palaiosphaeridium sp.A may represent a hitherto undescribed species of Tremadocian - early Ordovician age or alternatively it may be a new taxon of Caradocian age. There is no way of deducing the true provenance of this form from the data currently available but a full description is given here for the benefit of future workers.

Comparisons

Palaiosphaeridium kamax Rasul 1977 is similar but differs in being generally larger, having longer processes and in exhibiting much less frequent and less regular distal process furcae. Some specimens of Evittia florigera Vavrdova 1977 appear superficially similar but this species always has lobulate rather than furcate process terminations.

Occurrence

Recovered from the Caradocian of Shropshire but the original age of this form remains uncertain at present.

Genus PETEINOSPHAERIDIUM

Staplin Jansonius and Pocock 1965 emend.

Eisenack 1969.

Type species : Peteinosphaeridium trifurcatum trifurcatum ex. P.bergstromii Staplin Jansonius and Pocock 1965.

Emended Diagnosis (Eisenack 1969)

Shell spherical, fairly sturdy, always having numerous radial, elongate, solid or hollow, similar, uniformly distributed processes; process terminations closed and here they divide into two three or more irregularly formed prongs. These vary from outward slanting to almost tangentially directed prongs. Small scale secondary branches may also be developed. The branches, as with the process stems, may develop more or less broad membranes which run down the stems. These wings may be reduced or even disappear altogether or conversely be so strongly developed as to enfold the terminal branches. Pylomes (normal or raised) common. (Trans.).

Remarks

Forms with bifurcating processes lacking fins were originally excluded from the genus by Staplin et al. (1965). Forms having hollow processes without fins and an excystment structure formed by development of a median split were placed in a new genus Ordovicidium by Tappan and Loeblich (1971,1978).

The genus Peteinosphaeridium constitutes a complex taxonomic problem as pointed out by Booth 1979 (unpublished Ph.D.thesis). The first published morphotypes now attributed to this taxon were originally described by Eisenack under the name Ovum hispidum trifurcatum (Eisenack 1931); a valid redescription appeared later changing the binomial to Hystrichosphaeridium trifurcatum (Eisenack 1938), when the holotype was re-illustrated alongside other specimens considered by the author to belong to the same species. In the text of this work Eisenack describes his original choice of holotype as unfortunate and indicates another specimen, (Pl.2,fig.5) as being more typical of the species. In 1959, Eisenack transferred the species to Baltisphaeridium Eisenack 1958 and divided it into two sub-species and three forms, viz.

Baltisphaeridium trifurcatum subsp. nudum.

Baltisphaeridium trifurcatum subsp. paucifurcatum

Baltisphaeridium trifurcatum forma longiradiata

Baltisphaeridium trifurcatum forma typica

Baltisphaeridium trifurcatum forma breviradiata.

A neotype was designated in this paper (Pl.17,fig.3) to replace the now lost holotype; unfortunately the neotype was not similar to the holotype; it is clear that the author not only appreciated this but that it was intentional since the neotype was attributed to the forma typica while the now lost holotype was referred to the forma breviradiata. Since the neotype was unlike the holotype it may be considered incorrect and rejected (I.C.B.N. Art.8); the holotype then continues as nomenclatural type for the species and must still be referred to the forma breviradiata. Booth (1979) has argued that the situation then arises where Baltisphaeridium trifurcatum forma typica Eisenack (1959), transferred and emended to Peteinosphaeridium trifurcatum trifurcatum Staplin et al. (1965) to conform to the Code, (I.C.B.N. Art.24), does not in fact contain the nomenclatural type of the species although the repetition of the specific epithet implies that this is so, [I.C.B.N. Art.26]. He further points out that in this case Peteinosphaeridium trifurcatum forma breviradiata [Eisenack 1959] Staplin et al. 1965 does contain the nomenclatural type of the species although the specific epithet is not repeated as required by the Code [I.C.B.N. Art. 26]. Booth thus maintains that both Peteinosphaeridium trifurcatum trifurcatum [Eisenack 1959] Staplin et al. 1965 and Peteinosphaeridium trifurcatum breviradiatum [Eisenack 1959] Staplin et al. 1965 are inadmissable names under the Code. He advocates that the former Peteinosphaeridium trifurcatum forma breviradiata must become Peteinosphaeridium trifurcatum trifurcatum to comply with the Code, since it contains the nomenclatural type of the species. This in turn means that Peteinosphaeridium trifurcatum trifurcatum of Staplin et al. 1965 [ex forma typica of Eisenack 1959] will require a new name, since it is rejected. However Booth considers that this variety is in fact synonymous with Peteinosphaeridium bergstromii Staplin et al. 1965, and that the latter, being the first legitimately published name for the taxon assumes priority.

The present author does not accept this opinion and resultant conclusions, believing that the underlying premise, that of rejection of the neotype of Eisenack 1959, is unnecessary and in fact merely compounds the existing taxonomic confusion. Booth's contention that 'the neotype was incorrectly appointed and must be rejected ...... [I.C.B.N. Art.8]'. is not borne out by reference to Article 8 of the Code. This does not require rejection of a neotype under these circumstances, but states 'in the case of a neotype, it may be superseded if it can be shown that the choice was based upon a misinterpretation ...... or was made arbitrarily'. Thus, although Eisenack's choice of neotype could be considered arbitrary, adoption of this drastic taxonomic revision is not obligatory under the Code, and since the intention of the original author [Eisenack 1931, 1938, 1959] is perfectly clear, the status quo established in the literature is adopted in this study. The infra-specific taxa attributed to the species P.trifurcatum by Eisenack and accepted in this study are listed below.

1. P.trifurcatum subsp. breviradiata
2. P.trifurcatum subsp. intermedium Eisenack 1976
3. P.trifurcatum subsp. trifurcatum
4. P.trifurcatum subsp. hypertrophicum Eisenack 1976.

Peteinosphaeridium nanofurcatum Kjellstrom 1971.

Pl.15,figs.7,8.

1971b Peteinosphaeridium nanofurcatum Kjellstrom 1971a, p.55, Pl.4,fig.5.

1973 Peteinosphaeridium nanofurcatum Eisenack Cramer and Diez p.915.

Original Diagnosis

Peteinosphaeridium sp. with thin single-walled, spherical, psilate vesicle. No excystment structure recorded. Angular proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Numerous processes in length about one twelfth of vesicle diameter, psilate, lambda-shaped, homomorphic, bifurcate with bulbous furca-tips.

Description

The single specimen recorded is smaller than the range reported by Kjellstrom amongst specimens from the Baltic. However the species is based on so few individuals, (six), and the morphology is so distinctive that the present author feels justified in attributing this individual to Kjellstrom's taxon.

Dimensions

vesicle diameter	:	36
process length	:	3.5
furca length	:	3

Remarks

The morphology of the single specimen recovered is identical to the description of Baltic material given by Kjellstrom.

Occurrence

Longvillian (Caradoc), Shropshire.

Previous Records

Viruan (Llandeilo), Baltic (Kjellstrom).

Peteinosphaeridium nudum

(Eisenack 1959) Eisenack 1969.

Pl.13,figs.5,6,7,8; Pl.33,figs.4,7.

1959 *Baltisphaeridium trifurcatum nudum* Eisenack p.203,Pl.17, figs.4,5,6.

1962 *Baltisphaeridium trifurcatum nudum* Eisenack p.71.

1963 __Baltisphaeridium__ __trifurcatum__ forma __nuda__ Downie and Sarjeant p.90.

1964 __Baltisphaeridium__ __trifurcatum__ subsp. __nudum__ Downie and Sarjeant p.98.

1965 __Baltisphaeridium__ __trifurcatum__ subsp. __nuda__ Eisenack p.139.

1965 __Baltisphaeridium__ __nudum__ Staplin Jansonius and Pocock p.190,Pl.20,figs.2,6,7,8; fig.12.

1968 __Baltisphaeridium__ __trifurcatum__ subsp. __nuda__ Eisenack p.7,Pl.2,fig.1.

? 1968 __Baltisphaeridium__ __nudum__ Martin p.59,Pl.3,fig.152; Pl.4,fig.163.

1969 __Baltisphaeridium__ __nudum__ Gorka p.32,fig.8.

1969 __Peteinosphaeridium__ __nudum__ Eisenack p.255.

1970 __Baltisphaeridium__ __trifurcatum__ __nudum__ Lister p.31.

1971b __Peteinosphaeridium__ __nudum__ Kjellstrom p.56,Pl.4,fig.6.

? 1973 __Peteinosphaeridium__ __nudum__ Martin p.16,Pl.2,fig.43; Pl.4,figs.135,141.

1973 __Peteinosphaeridium__ __nudum__ Rauscher p.74,Pl.2,fig.21.

1978 __Ordovicidium__ __nudum__ Loeblich and Tappan p.1281.

__Original Diagnosis__

The size and shape, particularly of the processes, is like __Baltisphaeridium__ __trifurcatum__ forma __typica__, however the processes are without membranes. (Trans.).

__Description__

In size-range and overall morphology the specimens encountered are closely similar to the type material of Eisenack (1959). No excystment structure recorded.

Dimensions

vesicle diameter	:	32[46]58
process length	:	10[17]28
process width	:	2.5[4]6
specimens measured	:	14
specimens recorded	:	>50

Remarks

The transfer of this species to the genus Ordovicidium, Tappan and Loeblich 1971, proposed in Loeblich and Tappan 1978 is rejected by the present author; the holotype of Peteinosphaeridium nudum [Eisenack 1959, Pl.17,fig.4], has a pylome, whilst Ordovicidium is characterised by the development of a partial rupture or median split as an excystment structure.

Comparisons

Ordovicidium elegantulum Tappan and Loeblich 1971 is similar in gross morphology but bears a granular ornament on the processes and excysts by means of a median split.

Occurrence

Caradoc [Shropshire]. Caradoc [Girvan]. Llandeilo [South Wales].

Previous Records

Middle Ordovician, Baltic [Eisenack, 1959, 1962, 1965, 1968]. ? Wenlockian, Belgium [Martin, 1968]. Middle Ordovician, Poland [Gorka 1969]. Middle Ordovician, Baltic, [Kjellstrom 1971]. ? Ashgillian, Silurian, Belgium [Martin 1973].

Peteinosphaeridium _trifurcatum_ subsp. _breviradiata_ (Eisenack 1959) Eisenack 1965.

Pl.14,figs.1-3; Pl.16,fig.4; Pl.33,figs.?6,8.

1931 _Ovum hispidum trifurcatum_ Eisenack p.112,Pl.4,fig.21.

1938 _Hystrichosphaeridium trifurcatum_ Eisenack p.16,Pl.4, figs.1,2,4,12.

1959a _Baltisphaeridium trifurcatum_ forma _breviradiata_ Eisenack p.202,Pl.17,fig.7.

1963 _Baltisphaeridium trifurcatum_ forma _breviradiata_ Downie and Sarjeant p.90.

1964 _Baltisphaeridium trifurcatum_ forma _breviradiata_ Downie and Sarjeant p.97.

1965a _Baltisphaeridium trifurcatum_ subsp. _breviradiata_ Eisenack p.138,Pl.11,fig.8; Pl.12,fig.15.

1968 _Baltisphaeridium trifurcatum_ subsp. _breviradiata_ Eisenack p.7,Pl.1,fig.9;Pl.2,fig.3.

1969 _Baltisphaeridium trifurcatum_ subsp. _breviradiatum_ Gorka p.25,Pl.5,figs.13-15.

1970 _Baltisphaeridium trifurcatum breviradiatum_ Lister p.31.

1971a _Peteinosphaeridium breviradiatum_ Kjellstrom p.32,fig.22.

? 1972 _Peteinosphaeridium palmatum_ Combaz and Peniguel p.136, Pl.2,figs.4,9,10-12.

? 1973 _Peteinosphaeridium breviradiatum_ Martin p.16,Pl.1, figs.5,10;Pl.2,fig.53;Pl.4, figs.137,144,145.

1973 _Peteinosphaeridium breviradiatum_ Eisenack Cramer and Diez p.895.

1975 _Peteinosphaeridium breviradiatum_ Tynni p.32,Pl.4,fig.4.

1976 *Peteinosphaeridium breviradiatum* Eisenack p.196,Pl.4, figs.13-15.

1978 *Peteinosphaeridium breviradiatum* Martin p.77,Pl.12

Original Diagnosis

The processes are shorter than the [vesicle] radius and very numerous. Distal furcae and wings only moderately developed. [Trans.].

Description

Vesicle spherical to sub-spherical, wall smooth, moderately thick [1u], bearing numerous stiff, short, apparently solid, radial processes which arise at 90° to the vesicle wall; process length 10-20% of vesicle diameter; processes are multifurcate distally and the stems bear membranes identical to those found in *P.trifurcatum* subsp. *intermedium* Eisenack 1976, although they may be less strongly developed than is usual with this subspecies. Excystment is by the development of a pylome.

Dimensions

vesicle diameter	:	52[59]66
process length	:	6[7]8
process numbers	:	40-100 approx.
specimens measured	:	7
specimens recorded	:	19

Remarks

The size-range recorded here is similar to that reported from Baltic populations [Eisenack 1965, Kjellstrom 1971]. This form is re-instated here as a subspecies of _P.trifurcatum_ (Eisenack 1959) Staplin Jansonius and Pocock 1965, since it appears to form part of a gradational sequence of morphotypes within this species, which can be recognised by changes in process length and abundance. Thus _P.trifurcatum_ subsp. _hypertrophicum_ Eisenack 1976, _P.trifurcatum_ subsp. _trifurcatum_ (Eisenack 1959) Staplin et al. 1965, _P.trifurcatum_ subsp. _intermedium_ Eisenack 1976, and _P.trifurcatum_ subsp. _breviradiata_ (Eisenack 1959) Eisenack 1965, are all closely related variants based on the same morphological stock.

Comparisons

P.trifurcatum subsp. _hypertrophicum_ has many fewer much longer processes. _P.trifurcatum_ subsp. _trifurcatum_ has fewer and longer processes. _P.trifurcatum_ subsp. _intermedium_ has slightly fewer somewhat shorter processes.

Occurrence

Caradoc, (Shropshire). Llandeilo, (South Wales).

Selected Previous Records

Ordovician, Baltic (Eisenack 1931, 1938, 1959, 1965, 1968, 1969). Middle Ordovician, Poland (Gorka 1969). Middle Ordovician, Sweden (Kjellstrom 1971). Caradoc to Llandovery, Belgium (Martin 1973). Ordovician, Baltic (Tynni 1975). Late Arenig, Baltic (Eisenack 1976). Caradoc, Newfoundland (Martin 1978).

Peteinosphaeridium trifurcatum subsp. intermedium Eisenack 1976.

Pl.14,figs.1,3; Pl.16,figs.1-3,5-8; Pl.33,fig.?2.

? 1972 Peteinosphaeridium trifurcatum Combaz and Peniguel p.137, Pl.2,figs.17,18.

1976 Peteinosphaeridium trifurcatum subsp. intermedium Eisenack p.195,Pl.4,figs.8-11.

1976 Peteinosphaeridium trifurcatum Kjellstrom p.36,fig.29.

1978 Peteinosphaeridium intermedium Jacobson p.297,Pl.1,figs. 10,11,14.

Original Diagnosis

A subspecies of P.trifurcatum similar in form to hypertrophicum n.subsp., however with shorter less projecting processes. Also the fins are less pronounced. [Trans.].

Description

Vesicle spherical, fairly thick-walled (1-1.5u), smooth, rarely microgranular to granular, bearing numerous stiff, radial, apparently solid processes which are distally trifurcate or quadrifurcate; processes are relatively short - 20-25% of vesicle diameter, and bear strongly developed, smooth, delicate, partially transparent axial membranes. These membranes or fins arise from the vesicle wall, adjacent to and connected with, process bases; they ascend the process stem to terminate slightly beyond the point of branching, so that the base of each secondary branch supports the top of a membrane; the slender distal portion of the branch normally remains free, however membranes may sometimes be developed right out to the distal termination of each secondary branch. The number of axial membranes per process stem is always directly related to the number of secondary distal branches. Excystment is by development of a pylome, the dimensions and morphology of which seems to be highly variable. Pylomes recorded range from small simple circular apertures, through to larger openings surrounded by high collars, apparently of thickened wall material (see Pl.16,figs.1,3,5,7); these approach the pylomes characteristic of _Peteinosphaeridium trifurcatum cylindroferum_ Eisenack 1968.

Dimensions

vesicle diameter	:	38(52)68
process length	:	8(10)16
process numbers	:	30->50
pylome diameter	:	8-28
specimens measured	:	14
specimens recorded	:	>50

Remarks

It is clear that this form has very close affinities with the various infra-specific taxa attributed to _Peteinosphaeridium trifurcatum_ (Eisenack 1959) Staplin et al. 1965, and the proposal of Jacobson (1978) that the process length of this sub-species should be considered a character of specific rank is not adopted in this study.

Comparisons

P.trifurcatum subsp. _hypertrophicum_ Eisenack 1976, has very much longer and fewer processes; _P.trifurcatum trifurcatum_

(Eisenack 1959) Staplin et al. 1965, has fewer and somewhat longer processes; P.trifurcatum breviradiatum (Eisenack 1959) Staplin et al. 1965, has very much shorter and more numerous processes. The present author considers it likely that all four forms make up a completely intergrading infra-specific complex.

Occurrence

Caradoc (Shropshire), Llandeilo (South Wales).

Previous Records

Arenig, Baltic (Eisenack 1976). Caradoc, Kentucky U.S.A. (Jacobson 1978).

Peteinosphaeridium trifurcatum subsp. trifurcatum
(Eisenack 1959) Staplin Jansonius and Pocock 1965.
Pl.15,figs.1,2,3; Pl.33,fig.1.

1931 Ovum hispidum trifurcatum Eisenack p.112,Pl.4,figs.22,23.
1937 Ovum hispidum trifurcatum Eisenack p.231,Pl.16,fig.5.
1938 Hystrichosphaeridium trifurcatum Eisenack p.16,Pl.2,figs. 3,5,8,9-11,14;Pl.3,fig.1.
1939 Hystrichosphaeridium trifurcatum Eisenack p.147,fig.18.
1951 Hystrichosphaeridium trifurcatum Eisenack p.188,Pl.2, figs.1,2,7.
? 1958 Hystrichosphaeridium trifurcatum Downie p.339,fig.4d.
1959 Baltisphaeridium trifurcatum form typica Eisenack p.202, Pl.17,figs.1-3.
1962 Baltisphaeridium trifurcatum Eisenack pp.71,75-76, Pl.3,fig.9.
1963 Baltisphaeridium trifurcatum Downie and Sarjeant p.90.

1964 _Baltisphaeridium_ _trifurcatum_ Downie and Sarjeant p.97.

1965a _Baltisphaeridium_ _trifurcatum_ subsp. _typica_ Eisenack p.138.

1965 _Peteinosphaeridium_ _trifurcatum_ forma _trifurcatum_ Staplin Jansonius and Pocock p.194.

1965 _Peteinosphaeridium_ _bergstromii_ Staplin Jansonius and Pocock p.194,Pl.20,figs. 12-14,16-18.

1968 _Baltisphaeridium_ _trifurcatum_ subsp. _typica_ Eisenack p.7.

? 1968 _Baltisphaeridium_ _bergstromii_ Martin p.44,Pl.5,fig.215; Pl.6,fig.299.

1969 _Peteinosphaeridium_ _trifurcatum_ Eisenack p.254.

non 1969 _Baltisphaeridium_ _trifurcatum_ subsp. _typicum_ Gorka p.23,text-fig.4;Pl.1,figs.1,5.

1969 _Peteinosphaeridium_ _bergstromi_ Gorka p.53,Pl.14,figs.7,8.

? 1969 _Baltisphaeridium_ _trifurcatum_ Konzalova-Mazancova p.86.

1970 _Baltisphaeridium_ _trifurcatum_ _typicum_ Lister p.31.

? 1971 _Peteinosphaeridium_ _trifurcatum_ Rauscher p.292,Pl.1,fig.2.

1971b _Peteinosphaeridium_ _trifurcatum_ Kjellstrom p.57,Pl.4,fig.7.

? 1972 _Peteinosphaeridium_ _trifurcatum_ Kjellstrom p.718.

? 1972 _Peteinosphaeridium_ _trifurcatum_ Johansson Karis and Kjellstrom p.580.

? 1973 _Peteinosphaeridium_ _trifurcatum_ Martin p.16,Pl.1,figs.36,38.

1973 _Peteinosphaeridium_ _trifurcatum_ _typicum_ Eisenack Cramer and Diez p.929.

? 1973 _Peteinosphaeridium_ _trifurcatum_ Rauscher p.74,Pl.2,fig.18.

? 1974 _Peteinosphaeridium_ Rauscher Pl.1,fig.15.

? 1976 _Peteinosphaeridium_ _trifurcatum_ Gorbatschev Fromm and Kjellstrom p.107.

Original Diagnosis

The processes are numerous and in length from the radius to the diameter [of the vesicle]. Bifurcations and fins are well developed. The laterally spreading furcae, occasionally form the shape of a double spherical shell. [Trans.].

Description

Vesicle spherical to sub-spherical, thick-walled [1-2u], smooth to shagrinate bearing fairly numerous, stiff, radial processes arising at 90° to vesicle wall; processes are apparently solid, of moderate length, 25-50% of vesicle diameter, and are distally trifurcate or quadrifurcate. Process stems bear thin delicate membranes identical to those of Peteinosphaeridium trifurcatum subsp. intermedium Eisenack 1976. Excystment is by development of a pylome.

Dimensions

vesicle diameter	:	46[52]61
process length	:	10[17]20
process numbers	:	10-25
specimens measured	:	20
specimens recorded	:	>100

Remarks

The degree of development of the process membranes varies between individual specimens but they are always present. The emendation of Peteinosphaeridium trifurcatum forma typica Eisenack 1959 to P.trifurcatum trifurcatum, Staplin Jansonius and Pocock 1965, [p.194] is accepted. Repetition of the specific epithet is required by the Code since this infra-specific taxon contains the neotype of the species [I.C.B.N. Art.24]. Locally this form is abundant, particularly in the Llandeilo and may form 10-20% of some assemblages.

Comparisons

P.trifurcatum subsp. *hypertrophicum* Eisenack 1976 has fewer and longer processes. *P.trifurcatum* subsp. *intermedium* Eisenack 1976 has more numerous and shorter processes. *P.trifurcatum* subsp. *breviradiatum* [Eisenack 1959] Staplin Jansonius and Pocock 1965 has many more, much shorter processes. *P.nudum* [Eisenack 1959] Eisenack 1969 never has processes bearing axial membranes.

Occurrence

Caradoc [Shropshire]. Caradoc [Girvan]. Llandeilo [South Wales].

Selected Previous Records

Ordovician, Baltic [Eisenack 1931, 1937, 1938, 1939, 1951, 1959, 1969]. Middle Ordovician, Baltic [Staplin Jansonius and Pocock 1965]. Ashgillian, Bohemia [Konzalova-Mazancova 1969]. Middle Ordovician, Gotland [Kjellstrom 1971]. Upper Llanvirn, [Staplin, Jansonius and Pocock 1965 - as *P.bergstromii*].

Genus PHEOCLOSTERIUM Tappan and Loeblich 1971.

Type species: *Pheoclosterium fuscinulaegerum* Tappan and Loeblich 1971.

Original Description

Medium-sized cysts, fusiform to ovate in outline, with extremities variable, broadly rounded to acuminate, the acuminate forms commonly terminating in a single simple, bifurcate or multifurcate process; wall thin; surface smooth or microgranulate; scattered capitate, trifurcate, quadrifurcate or foliate (rarely simple) processes communicating with the central body; no definite excystment opening observed other than a rupture or splitting of the wall.

Remarks

This monospecific genus, previously only reported from the Upper Ordovician of Indiana is similar to the genus Dactylofusa (Brito and Santos 1965) Cramer 1971; it differs in having processes distributed irregularly over the vesicle rather than arranged in longitudinal rows.

Pheoclosterium fuscinulaegerum

Tappan and Loeblich 1971.

Pl.20.fig.5.

1971	Pheoclosterium fuscinulaegerum	Tappan and Loeblich p.400, Pl.8,figs.1-7.
1976	Pheoclosterium fuscinulaegerum	Eisenack Cramer and Diez p.541.

Original Description

Body of vesicle variable in outline, elongate fusiform to elongate naviform, with extremities acuminate to broadly rounded; acuminate extremities commonly terminating in a pointed projection from the central body or in an elongate process that may have smaller projections on the sides or that may have bifurcate and trifurcate terminations; wall thin, about 0.5u in thickness; surface microgranulate; processes numerous, slender, tapering gently to the tips, communicating freely with the central body, scattered rather than arranged in definite rows, terminally trifurcate, although, rarely, a simple process may occur or one that has an inflated termination with five or six spines arising around the edges of the bulbous end; process wall microgranulate, similar in thickness to that of central body; excystment by a simple rupture of the central body.

<u>Dimensions</u>

		spec.1.	spec.2.
vesicle length	:	80	87
vesicle width	:	28	27
process length	:	7	8

<u>Remarks</u>

This species is extremely rare in the sequences studied, only two individuals being recorded; these are both very similar to the type material of Tappan and Loeblich but are somewhat narrower than the North American specimens. Granulation of vesicle and process walls was not apparent in transmitted light. No excystment structure recorded.

<u>Occurrence</u>

Caradoc (Shropshire).

<u>Previous Record</u>

Caradoc, Eden Formation, U.S.A. (Tappan and Loeblich 1971).

Genus PIREA Vavrdova 1972.

Type species: _Pirea dubia_ Vavrdova 1972.

Original Diagnosis

Acritarchs with pear to bottle-shaped shell, wall single layered, psilate, granulate or with transversal ribs (microstriate). Apical horn clavate, capitate, antapical end broadly rounded.

Remarks

This distinctive genus seems to be characteristic of the Lower Ordovician.

Pirea nervata

(Burmann 1970) Eisenack Cramer and Diez 1976.

Pl.34,fig.6.

1970 _Deunffia nervata_ Burmann p.320,Pl.15,figs.14,15.

1976 _Pirea nervata_ Eisenack Cramer and Diez p.563.

Original Diagnosis

Central body round to oval, bearing at the apical pole a short, plump, hollow process which does not taper and which is distally rounded. The neck-like process bears at its base a system of fine parallel ribs oriented longitudinally. The ribs hardly overlap onto the central body (Trans.).

Description

Vesicle hollow, pear-like in outline with a single blunt apical process; the narrow neck below this process shows traces of faint longitudinal striations. The vesicle wall appears to be microgranular but this is probably a preservational effect due to corrosion of the wall surface. No excystment structure recorded.

Dimensions

vesicle length	:	43
vesicle width	:	26
process length	:	4

Remarks

Only a single individual in a poor state of preservation was recovered despite a careful search for additional examples. The specific allocation made is based on the striate process base which Burmann considered diagnostic of P.nervata.

Comparisons

P.dubia Vavrdova 1972 has a less inflated vesicle and a much longer and more slender apical process. Burmann 1970 describes a number of species essentially similar to P.nervata, all under the generic name Deunffia, but they differ in having a smooth process base.

Occurrence

Lower Llandeilo [South Wales].

Previous Record

Upper Llanvirn, G.D.R. [Burmann 1970].

Genus SOLISPHAERIDIUM

Staplin Jansonius and Pocock 1965.

Type species: <u>Solisphaeridium</u> <u>stimuliferum</u> Staplin et al.1965 as <u>Hystrichosphaeridium</u> <u>stimuliferum</u> Deflandre 1938

<u>Original Diagnosis</u>

Vesicles spherical, wall relatively firm and rigid; several to numerous firm spines, hollow or solid, relatively long and slender, tapering continously towards the closed tips. Spines have a tendency to reduce their cavity through secondary deposition of wall material but, if present, the cavity communicates freely with the vesicle.

<u>Remarks</u>

Sarjeant 1968 emended the diagnosis of <u>Solisphaeridium</u> to include reference to the mode of excystment; 'Pylome lacking; opening of shell by splitting or by loss of an irregularly shaped piece of the shell wall'. (p.222). In addition Sarjeant noted that the mean shell diameter is typically greater than 20u. <u>Solisphaeridium</u> is thus differentiated from <u>Micrhystridium</u> (Deflandre 1937) Downie and Sarjeant 1963 by being larger and having hollow or solid processes. <u>Baltisphaeridium</u> (Eisenack 1958) Eisenack 1969 differs in having hollow processes separated from the vesicle cavity by solid proximal plugs, and in the development of a pylome as an excystment structure. <u>Elektoriskos</u> Loeblich 1970 is easily distinguishable from <u>Solisphaeridium</u> since it has abundant cylindrical hair-like processes which are always solid.

In 1974, Wicander [p.22] erected a new genus Ephelopalla, stating in the generic diagnosis ...... 'vesicle spherical, wall laevigate; processes laevigate, initially opening into vesicle interior, but becoming secondarily filled near the base, or at points between the base and the tip; excystment by splitting of vesicle wall'. Wicander went on to say, 'Ephelopalla ...... differs from Baltisphaeridium Eisenack 1958 in that the processes and vesicle are laevigate and the secondary fillings do not form plugs at the base of the processes'. This statement is difficult to understand since examination of both the original [Eisenack 1958] diagnosis of Baltisphaeridium and the later emendation and restriction, [Eisenack 1969], show that no reference at all is made to either process or wall ornament; indeed, in his 1969 paper, Eisenack states explicitly concerning the type species of the genus ...... 'the type B.longispinosum has in all its many examples a smooth surface'. [p.248]. Thus Ephelopalla and Baltisphaeridium appear similar in that both genera embrace smooth-walled forms. The comment of Wicander that in his genus the secondary [process] fillings do not form plugs at the process bases becomes inexplicable when one reads the diagnosis of E.elongata, the type species; here Wicander states '.... some [processes] become plugged with secondary deposits either at the base or at intervals between the base and tip'. From this it is clear that some specimens attributed by Wicander to Ephelopalla do in fact develop proximal plugs and thus must be indistinguishable from Baltisphaeridium Eisenack 1958; since these individuals develop a median split as an excystment mechanism they are now referable to Baltisphaerosum gen.nov.. The remainder of the specimens placed in Ephelopalla by the original author are morphographically identical with Solisphaeridium. Thus Ephelopalla appears to be a partial junior synonym of Solisphaeridium and Baltisphaeridium (now in part Baltisphaerosum gen.nov.) and as such is illegitimate and must be rejected (I.C.B.N. Art.63.1).

It should be noted that the somewhat ambiguous reference to 'firm spines' in the original diagnosis of Staplin et al. has led to confusion in the interpretation of the genus Solisphaeridium; this situation was worsened by the diagrammatic illustration of the genus (Staplin et al., p.181, text-fig.3). This drawing shows a vesicle bearing only straight and very rigid processes although this is not a feature mentioned in the generic diagnosis. Examination of the type species chosen by Staplin et al., (Solisphaeridium stimuliferum (Deflandre 1938) Staplin et al. 1965), shows this diagram to be misleading in the extreme. In the diagnosis of his species, Deflandre clearly stated of the processes '...... that appear rather flexible and are generally curved ......' (Trans.); a feature amply demonstrated in the illustration of the holotype (Deflandre 1938, Pl.10,fig.10). Since the type species thus unquestionably has flexible curving processes, the genus must be interpreted as including either rigid or flexible processes provided that they have a relatively firm wall; (presumably a wall which is not flimsy and easily folded or mechanically damaged).

<u>Solisphaeridium</u> <u>lucidum</u> (Deunff 1959) comb.nov.

Pl.30,figs.5-8.

1959	<u>Hystrichosphaeridium</u> <u>lucidum</u>	Deunff p.25,Pl.9,figs. 80,82,83,85-89.
1964	<u>Baltisphaeridium</u> <u>lucidum</u>	Downie and Sarjeant p.92.
non 1969	<u>Baltisphaeridium</u> <u>lucidum</u>	Martin p.56.
1969	<u>Baltisphaeridium</u> <u>lucidum</u>	Henry p.89,Pl.2,fig.14?; Pl.10,fig.76.
? 1970	<u>Baltisphaeridium</u> sp.	Paris and Deunff p.30,Pl.2, fig.27.
1973	<u>Baltisphaeridium</u> <u>lucidum</u>	Rauscher pp.106,110,Pl.7, figs.4,5.
1974	<u>Baltisphaeridium</u> <u>lucidum</u>	Martin pp.27,43,Pl.2,fig.42; non Pl.4,fig.129;?Pl.5,fig. 182.

<u>Original Diagnosis</u>

Fossil microplankton, pale yellow to clear brown, vesicle spherical or slightly ovoidal, thin and fragile, 30 to 40u in diameter. The vesicle is ornamented with a number of long slender processes between 15 and 30u in length which possess a radiating form in optical section (Trans.).

<u>Description</u>

Vesicle hollow, spherical to sub-spherical, wall thin (about 0.5u), apparently single-layered, probably smooth but possibly sometimes microgranular. The vesicle bears a number of smooth, simple, slender, homomorphic, flexible processes which have narrow bases and taper distally to a fine hair-like acuminate termination. Processes may be hollow and if so, communicate freely with the vesicle cavity, most however are probably solid for much of their length; possession of infilled processes, although strongly suggested by their delicacy and flexibility, is a feature difficult to determine with confidence. There is no apparent differentiation between vesicle and process walls. A number of specimens were recorded having an irregular, flap-like opening developed, [see Pl.30,figs.5-8, particularly fig.6]. Given the poor state of preservation of the populations recovered, it is not possible to unequivocally identify this opening as an excystment structure; however it should be noted that Henry 1969 [Pl.2,fig.14] illustrates a somewhat similar feature.

Dimensions

vesicle diameter	:	28[36]44
process length	:	7.5[11]15
process width	:	less than 1
process numbers	:	about 20
specimens measured	:	18
specimens recorded	:	146

Remarks

This species is abundant in the Llandeilian sediments of South Wales where it appears to be a characteristic form. Preservation of this material is generally poor with considerable carbonization and corrosion of the wall making it impossible to recognise the surface ornament, if any; many specimens seem to have a textured wall surface but this may well be a preservational feature. More important, the majority of processes observed were broken, having lost their fine, hair-like distal terminations; consequently the process length measurements quoted above are likely to be less than in the original organisms.

Comparisons

Solisphaeridium nanum comb.nov. is similar but is generally smaller and has more robust, shorter spines. S.flexipilosum Slavikova 1968 differs in being smaller and having shorter processes.

Occurrence

Llandeilo (South Wales).

Selected Previous Records

Llandeilo-Caradoc, France (Deunff 1959). Lower Caradoc, France (Henry 1969). ?Llanvirn, France (Paris and Deunff 1970).

Solisphaeridium nanum (Deflandre 1945) comb.nov.
Pl.22,figs.6,7; Pl.30,figs.3,4.

1942 Hystrichosphaeridium brevispinosum var. nanum Deflandre p.476,figs.1,16.

1945 Hystrichosphaeridium brevispinosum var. nanum Deflandre p.62,Pl.1,figs.5,7,?18.

1954 Hystrichosphaeridium brevispinosum var. nanum Deunff p.55.

1959 Baltisphaeridium brevispinosum var. nanum Downie p.59, Pl.10,fig.9.

1959 Baltisphaeridium brevispinosum var. wenlockensis Downie p.59,Pl.10,fig.4.

1960 Baltisphaeridium brevispinosum var. nanum Stockmans and Williere p.5,Pl.1,figs.18,19.

	1962a	Baltisphaeridium nanum	Stockmans and Williere p.54, Pl.1, figs.21,22,25.
	1962b	Baltisphaeridium wenlockensis	Stockmans and Williere p.90, Pl.1, fig.16.
	1963	Baltisphaeridium wenlockense	Downie and Sarjeant p.98.
	1966a	Baltisphaeridium nanum	Martin p.3.
?	1967	Baltisphaeridium wenlockensis	Lister and Downie p.172, Pl.23, fig.3.
	1969	Baltisphaeridium nanum	Martin p.58, Pl.4, fig.?189; Pl.7, fig.337.
	1970	Baltisphaeridium nanum	Lister p.54, Pl.2, figs.6-12; text-fig.17k.
	1971a	Baltisphaeridium nanum	Kjellstrom p.35, Pl.2, fig.7.
	1972	Baltisphaeridium nanum	Kjellstrom p.718.
	1973	Baltisphaeridium nanum	Eisenack Cramer and Diez p.159.
	1973	Baltisphaeridium nanum	Rauscher p.72, Pl.2, fig.13.
	1974	Baltisphaeridium nanum	Martin pp.27,43.

Original Diagnosis

The vesicle is spherical and is provided with simple spines which in length are of the order of one third of the diameter, these correspond closely to those displayed by Hystrichosphaeridium brevispinosum Eisenack, to which the outline is very similar. However, in the species of Eisenack the vesicle measures 57 to 61u reaching about 109u with the processes. Here the size is about half this, the type measuring 27u in diameter and 45u with the processes. This justifies separation of this form into the variety nanum.[Trans.].

Description

Vesicle hollow, spherical to sub-spherical, wall smooth, thin (<0.5u), apparently single-layered. The vesicle bears a variable number of hollow, smooth, simple, homomorphic, somewhat flexible processes which have relatively wide bases and taper to a slender acuminate distal termination; process interiors communicate freely with the vesicle cavity. There is no differentiation between the vesicle and process walls which merge via a curving proximal process contact. No excystment structure recorded.

Dimensions

vesicle diameter	:	22(27)36
process length	:	10(12)15
process numbers	:	20-35
specimens measured	:	9
specimens recorded	:	>50

Remarks

This species was first described by Deflandre 1942 as a variety of Hystrichosphaeridium brevispinosum Eisenack but was a nomen nudum and as such was invalid; the first valid use of the name dates from 1945 when Deflandre published a full description and designated a holotype. In 1959, Downie transferred both species and variety to the genus Baltisphaeridium Eisenack 1958 and subsequently in 1962 Stockmans and Williere elevated the variety nanum to specific rank. In his 1959 paper, Downie also erected a new infraspecific taxon Baltisphaeridium brevispinosum var. wenlockensis, from the Wenlock Shales; this form was differentiated from B.brevispinosum var. nanum by possessing more numerous spines. Lister 1970 (p.55) analyzed these two varieties in detail and concluded that when large populations are examined, the two taxa are seen to be merely end-members of a single continously variable complex; thus B.brevispinosum var. wenlockensis is objectively indistinguishable from B.nanum and is therefore a junior synonym and must be rejected.

Here the species nanum is transferred to the genus Solisphaeridium since the form of the processes shows that these individuals cannot be closely related to Baltisphaeridium sensu Eisenack 1969. The majority of processes observed were hollow but some may become solid distally; generally they become so delicate towards the tip that the exact structure is difficult to determine.

In the present material there is a tendency for individuals of this species to become larger as one moves up the stratigraphical column; in populations from sediments of Llandeilian age the mean vesicle diameter is only 25u whilst amongst individuals of Caradocian age the mean diameter goes up to 32u.

Comparisons

The larger specimens of S.nanum comb.nov. encountered, approach the size range of S.lucidum comb.nov. but differ from this species in having more robust processes with wider bases and a broadly curving process-vesicle contact. Baltisphaeridium psilatum Kjellstrom 1971b appears very similar in gross morphology but has processes which develop faintly defined proximal plugs. Polygonium gracilis Vavrdova 1966 has fewer longer processes and a vesicle which is markedly polygonal.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan). Llandeilo (South Wales).

Selected Previous Records

Ashgill, Wenlock, France (Deflandre 1945). Middle Devonian, France (Deunff 1954). Wenlock Shales, U.K. (Downie 1959) Upper Devonian, Belgium (Stockmans and Williere). Arenig, Llandeilo, Belgium (Martin 1966a). Llandeilo, Sweden (Kjellstrom 1971a). Arenig, Caradoc, France (Rauscher 1973).

Genus STELLIFERIDIUM

Deunff Gorka and Rauscher 1974.

Type species: Stelliferidium striatulum (Vavrdova) Deunff et al. 1974, as Baltisphaeridium striatulum Vavrdova 1966.

Original Diagnosis

Vesicle sub-hemispherical, 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 may be closed by an operculum, sometimes hinged, whose surface is smooth, granular or reticulate and which has the same outline as the opening. The single or double wall of the shell is ornamented by variable processes from the base of which a star-like system of crests diverges. The outline of these stars produce a network of polygonal rings on the shell surface. A membrane may be present [Trans.].

Remarks

Spherical or sub-hemispherical acritarchs with large polar openings were first described by Deunff 1961 who divided them into two genera, Priscogalea and Cymatiogalea, the two being differentiated by the presence of membranes in the latter. Priscogalea was said to possess processes having simple or branching distal terminations while Cymatiogalea was characterised by a wall ornament of membranes or processes and membranes, often arranged in a polygonal pattern. Both genera were subsequently much criticised, notably by Eisenack 1962, who commented that a large pylome, a feature diagnostic of both Priscogalea and Cymatiogalea was not unique and in fact should not be considered a feature of either specific or generic importance. Deunff 1964 accepted that, as originally diagnosed, Priscogalea was indistinguishable from Baltisphaeridium Eisenack 1958. He abandoned his genus and four species were transferred to Baltisphaeridium while the remainder were transferred to Cymatiogalea; at the same time Deunff emended this latter genus, emphasising the division of the shell surface into polygonal fields. Deunff considered that the possession of polygonal fields delineated by the wall ornament clearly distinguished Cymatiogalea from Baltisphaeridium. Cymatiosphaera Wetzel 1933 has similar fields but never has a large pylome. Despite the proposal of Deunff 1964 to abandon his own genus Priscogalea, many authors considered it to be a useful taxon and the name was retained and continued in use [see Martin 1969,p.84]. In 1974 Deunff

Gorka and Rauscher re-examined this whole group making use of detailed morphological information derived from the use of a scanning electron microscope. These authors showed that the group falls into two broad categories.

1] Forms having the vesicle surface divided into more or less polygonal fields which are bounded by the sculptural elements; these may or may not include membranes.

Forms such as this are clearly attributable to Cymatiogalea [Deunff 1961] Deunff 1964 but the genus was further emended to emphasise that it is restricted solely to individuals whose vesicle wall is divided into polygonal fields.

2] Forms whose surface is not divided into fields but which bear processes, from the base of which a star-like system of raised ridges radiates out over the vesicle surface to merge with those from adjacent processes. These forms may or may not have membranes.

The system of star-like ridges exhibited by this second category were considered to be of generic significance by Deunff et al. and they proposed a new genus Stelliferidium to accomodate such forms. At the same time a re-diagnosis was given of the original type species of the genus Priscogalea; it was shown that in fact this species, P.barbara, has a wall surface divided into 'more or less well defined fields', [Deunff et al. 1974 p.10]; consequently it falls into Cymatiogalea [Deunff 1961] Deunff et al. 1974 and was transferred into this genus. This means that the former Priscogalea is now without a type species and must be abandoned. As noted by Booth 1979 [M.S.], Stelliferidium is validly published and appears systematically justifiable since at least eight species are unquestionably attributable to it. The genus is readily distinguished from all other acritarch genera.

Stelliferidium striatulum

(Vavrdova 1966) Deunff Gorka and Rauscher 1974.

Pl.34,figs.1-4.

1966	Baltisphaeridium striatulum	Vavrdova p.411,Pl.1,fig.2; Pl.2,fig.3.
1970	Priscogalea striatula	Paris and Deunff p.30, Pl.2,figs.5,9.
1973	Cymatiogalea striatula	Rauscher p.80,Pl.3,figs.29,30.
1974	Stelliferidium striatulum	Deunff Gorka and Rauscher p.16,Pl.6,figs.2,19,20.
1979	Stelliferidium striatulum	Booth p.175,Pl.7,fig.5; Pl.9,figs.1-4.

Original Diagnosis

Shell with circular, rarely oval or subpolugonal outline, with large circular or subpolygonal opening (pylome). Number of radial appendages relatively high (about thirty five). Appendages 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 base.

Description

Vesicle hollow, spherical or sub-spherical, fairly thin-walled (about 0.5u); one side of the vesicle is always sharply truncated, the planar surface so formed being occupied by a very large pylome. The vesicle wall bears numerous hollow smooth processes which taper distally and have a slight basal constriction, this denotes the site of an internal process plug apparently formed of solid wall material; process interior is not in contact with the vesicle cavity. The distal terminations of processes are variable but commonly have at least second or third order branching; processes are distributed at random over the vesicle surface and are also located around the rim of the pylome. From the base of each process an ornament of fine ridges radiates over the vesicle surface and merges with those from adjacent processes.

Dimensions

vesicle diameter	:	31[37]45
process length	:	5[7]8
process width	:	0.5-1.5
process number	:	30-40
pylome diameter	:	27[32.5]43
specimens measured	:	7
specimens recorded	:	14

Remarks

The general preservation of the individuals recovered is poor, the vesicle surface in particular is usually corroded so that surface ornament is partially or wholly removed; thus the ridges radiating from each process base, a diagnostic feature of Stelliferidium, are often barely visible; some specimens do not appear to bear such ridges at all, but since they are otherwise identical to ornamented forms, this is considered to be a preservational effect and not a primary feature. All specimens recovered had lost the operculum leaving an open pylome.

Comparisons

Stelliferidium stelligerum (Gorka 1967) Deunff et al. 1974 is similar in overall morphology but has less complex more numerous processes and a considerably smaller pylome.

Occurrence

Llandeilo (South Wales).

Previous Records

Arenig, Bohemia (Vavrdova 1966). Llanvirn, Brittany (Paris and Deunff 1970). Arenig, France (Rauscher 1973). Arenig, U.K. (Booth 1979 M.S.).

Genus VERYHACHIUM Deunff 1954 ex Downie 1959.

Type species: *Veryhachium trisulcum* (Deunff 1951) Deunff 1959 ex Downie 1959.

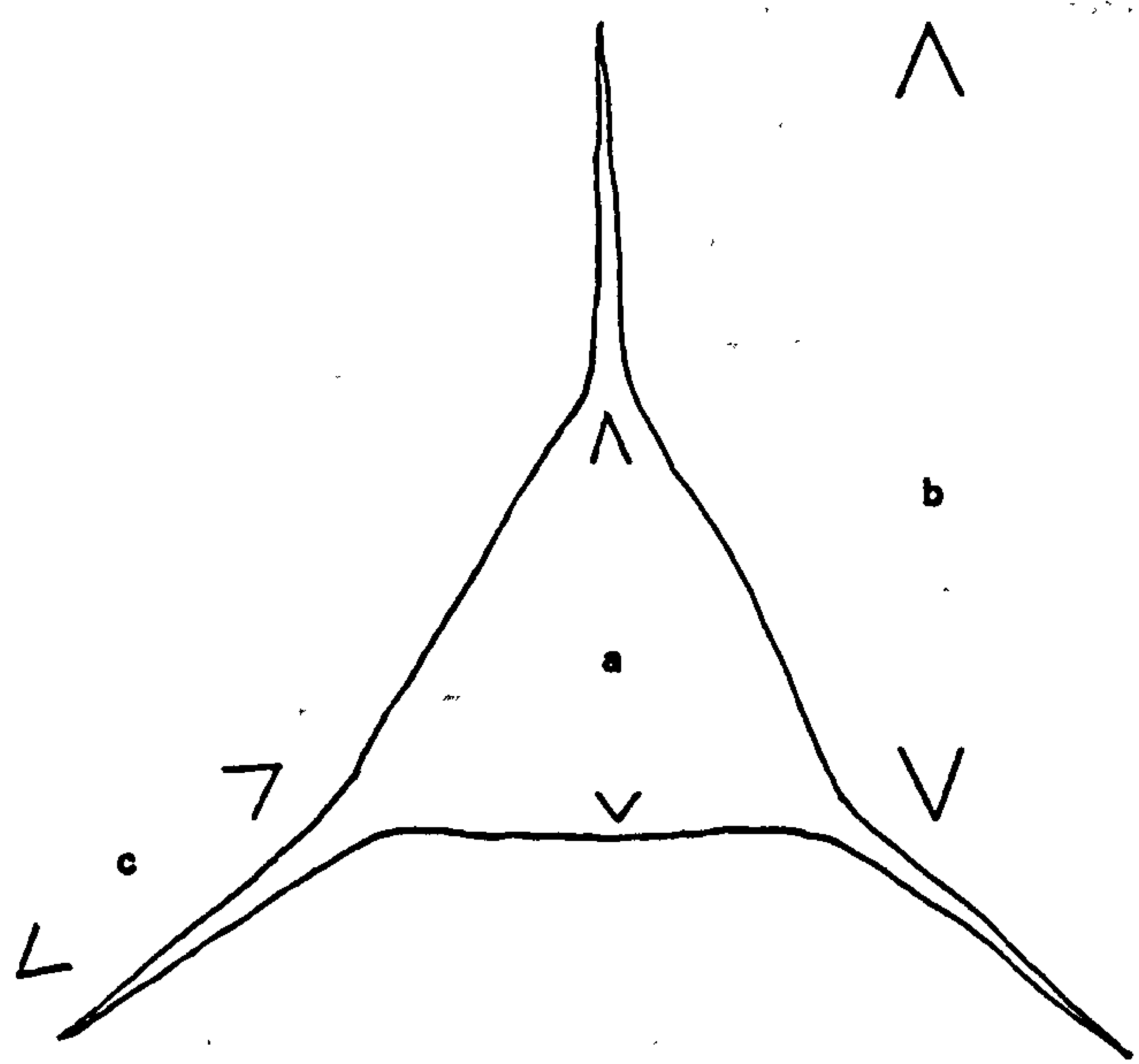
Emended Diagnosis

Vesicle thin-walled, polygonal, with processes from the angles forming an integral part of the vesicle, major processes in a single plane, commonly with accessory processess at various positions on the vesicle, processes distally closed and simple. Surface may be ornamented with grana or may be smooth. Excystment is by the formation of an epityche.

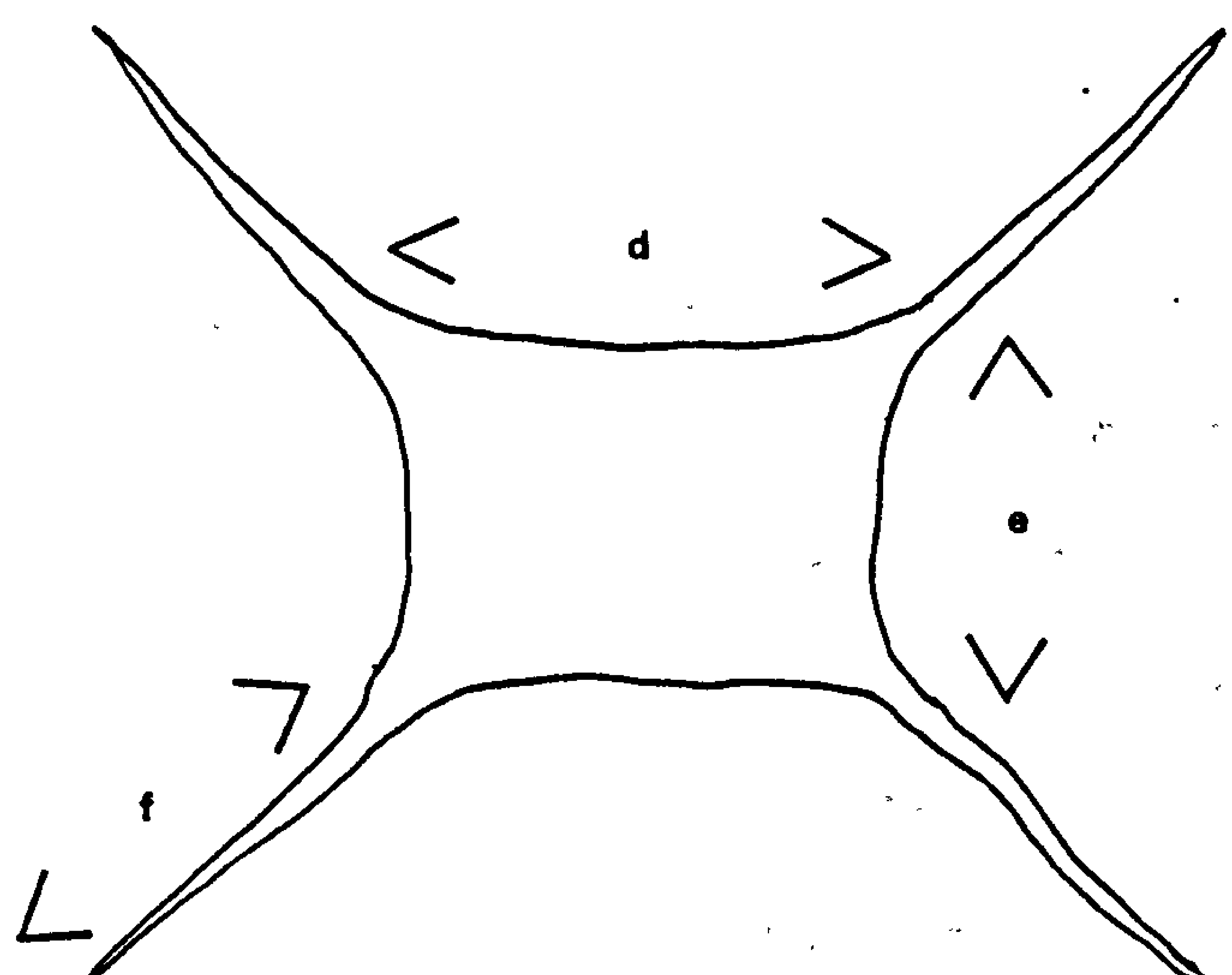
Remarks

The correct citation for the first valid authorship of the genus Veryhachium is a question that has led to considerable discussion in the literature. Although acritarchs are now generally accepted as belonging to the Plant Kingdom and consequently come under the provisions of the I.C.B.N., this state of agreement has not always existed. The name Veryhachium was first used by Deunff (1954, p.306; 1959,p.26) but in neither paper did the author make it clear if he considered these microfossils to be plants or animals. However, Loeblich and Tappan 1976 (p.306) point out that in his (Deunff 1959, p.23) systematic section, he includes his specimens in 'Odre des Hystrichosphaeridae, Famille des Hystrichosphaeridae', thus using zoological taxonomic terminations. The American authors cogently argue that Deunff, by implication, therefore considered his material to be zoological in affinity and that his taxa must consequently be treated under the rules of the I.C.Z.N.; if this view is accepted, then Veryhachium Deunff 1954 was invalid (type species not described, I.C.Z.N. Art.13 (a) (i)), as was Veryhachium Deunff 1959 (type species not designated, I.C.Z.N. Art.13b). Loeblich and Tappan further note that even if considered under the I.C.B.N., Veryhachium Deunff 1954 was still invalid (type species not described, I.C.B.N. Art.38) as also was Veryhachium Deunff 1959 (type species not designated, I.C.B.N. Art.10 and 37). Thus, under the provisions of both codes the name Veryhachium remained invalid until Deunff 1959 (p.27) had validly published the species trisulcum, and Downie 1959 (p.62) had subsequently designated it as type species for the genus Veryhachium. The generic

Text-fig. 19



a	vesicle height
b	vesicle + process height
c	process length



d	vesicle length
e	vesicle width
f	process length

Illustrating the terminology applied to the genus *Veryhachium* diagnosis was emended by Staplin 1961, Downie and Sarjeant 1963 and Loeblich and Tappan 1969. The emended diagnosis given here is essentially that of the latter authors (Leoblich and Tappan 1969, p.55) but with reference to a surface ornament of 'prickles or small spines'omitted, (see Villosacapsula, Leoblich and Tappan 1976).

Veryhachium downiei Stockmans and Williere 1962.
Pl.17,fig.3; Pl.35,figs.1-3.

1962a	Veryhachium downiei	Stockmans and Williere p.47, Pl.2,figs.20-22;text-fig.2.
1962b	Veryhachium downiei	Stockmans and Williere p.84, Pl.1,figs.2-4;text-fig.2.
1963	Veryhachium downiei	Stockmans and Williere p.451, Pl.1,figs.9,10;Pl.3,figs.1,2; text-figs.1-3.
1964	Veryhachium downiei	Cramer p.306.
1965	Veryhachium downiei	Raucher Doubinger and Manche-Bain p.310,Pl.3,fig.3.
1966	Veryhachium downiei	Martin p.374.
1967	Veryhachium downiei	Stockmans and Williere p.234, Pl.1,figs.1-7.
1969	Veryhachium downiei	Martin p.91,Pl.2,figs.85,102; Pl.6,fig.253;Pl.7,figs.345, 348,349;text-fig.40.
1969	Veryhachium downiei	Stockmans and Williere p.7, Pl.1,figs.18-21.
1970	Veryhachium downiei	Chauvel Deunff and Le Corre p.1221,Pl.1,fig.7.

1971	*Veryhachium downiei*	Cramer p.95.
1971	*Veryhachium downiei*	Deunff Lefort and Paris p.14,Pl.2,figs.7,8.
1971	*Veryhachium* cf. *downiei*	Henry and Thadeu p.1343, Pl.1,figs.4,12.
1971	*Veryhachium downiei*	Sheshegova p.44,Pl.12,fig.3.
1971	*Veryhachium downiei*	Deunff and Paris p.85,Pl.1, fig.19.
1974	*Veryhachium downiei*	Stockmans and Williere p.5, Pl.1,figs.12,14,16,17;Pl.2, figs.2,4,5,7,13,14;Pl.3, figs.5-7.
1974	*Veryhachium downiei*	Rauscher p.76,Pl.3,fig.7.
1974	*Veryhachium trispinosum*	Form-Group. Hill (M.S.)p.192.
1974	*Veryhachium downiei*	Martin pp.28,46,47.
1977	*Veryhachium downiei*	Downie p.34,Pl.3,figs.2,4.
1977	*Veryhachium downiei*	Playford p.38,Pl.20,figs. 4-13.

Original Diagnosis

Shape triangular with convex sides, the elongate processes are closed, straight or curved, simple. Vesicle size 15-18u, process length 10-15u.(Trans.).

Description

Central vesicle hollow, triangular in outline, small, fairly thin-walled (0.5-1.0u), smooth; each angle bears a hollow, simple, smooth process which arise in the same plane as the vesicle and taper distally to an acuminate termination; process interior communicates freely with the vesicle cavity; vesicle shape varies from inflated through straight-sided to slightly concave forms. Process length is generally equal to or somewhat less than vesicle height. Excystment is by the development of an epityche.

Dimensions

vesicle height	:	16[20]23
vesicle + process height	:	27[37]40
process length	:	10[15]24
specimens measured	:	23
specimens recorded	:	>200

Remarks

The dimensions recorded here show a greater size-range than the measurements for the type material quoted by Stockmans and Williere; this is in agreement with the findings of other workers (Rauscher 1973 : Playford 1977). As noted by several other authors (Cramer 1964 p.306 : Wicander 1974 p.36 : Playford 1977 p.38) this species apparently intergrades into other essentially similar species, notably V.trispinosum (Eisenack 1938) Deunff 1954 ex Downie 1959. Certainly a small percentage of specimens recorded here appear to approach the size-range of V.trispinosum and this suggests that there is some overlap between the two species. It is realized that a statistical study of sufficiently large populations might show that the two taxa form a continously variable, objectively indivisible complex; however such a study is beyond the scope of this work and this possibility remains unproven. It is undeniable that for the vast majority of specimens encountered, these two size-differentiated taxa represent viable species which have only minor overlap; this alone is a powerful argument for retaining the two as separate entities. V.downiei is common, sometimes abundant in the assemblages from Llandeilo but is rare in the Caradocian of Shropshire and Girvan. Epityches occur frequently in populations from Llandeilo.

Comparisons

V.trispinosum (Eisenack 1938) Deunff 1954 ex Downie 1959 is morphologically very similar but is considerably larger. V.trisulcum var. reductum Deunff 1959 ex Downie 1959 is distinguished by having very much shorter processes.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan). Llandeilo (South Wales).

Selected Previous Records

Upper Devonian, Belgium (Stockmans and Williere 1962). Silurian, Belgium (Martin 1966). Lower Ordovician, Belgium (Martin 1969) Lower Ordovician, France (Rauscher 1973). Frasnian-Famennian, U.K. (Downie 1977). Siegenian to Givetian, Ontario, Canada, (Playford 1977).

Veryhachium irroratum Loeblich and Tappan 1969.

Pl.18,figs.3,4,7.

1969	Veryhachium irroratum	Loeblich and Tappan p.56, Pl.3,figs.1-9;Pl.4,figs.1-4.
1978	Veryhachium irroratum	Kalvacheva p.308,Pl.1,figs. 11,12.

Original Diagnosis

Body compressed with inflated triangular outline, generally with three long hollow processes, tapering to a sharp point, and all lying in one plane. In rare specimens, a fourth process arises from the vesicle surface and is not in the plane of the three major processes. Wall about 0.5u in thickness, surface of body and processes strongly granulate, grana on the processes tending to develop into small prickles. Many specimens have a well developed epityche, the broadly ovate or tongue-shaped flap formed by a slit between two of the processes and resultant turned out portion of the wall. Rare specimens show a small nipple at or near the mid-point of this flap, corresponding to a notch in the remaining vesicle wall.

Description

Central vesicle hollow, triangular in outline, bearing a process at each angle in the same plane as the vesicle; the wall is moderately thick [0.5-1.0u] and is ornamented with strongly developed, irregularly sized and shaped grana which extend onto the processes; usually this granular ornament is developed right out to the process tip and becomes sharper and more thorn-like distally. The processes, always three in number, are hollow, simple, with acuminate distal terminations and have free communication with the vesicle cavity. No excystment structure recorded.

Dimensions

vesicle height	:	20[24.5]33
vesicle + process height	:	46[49]54
process length	:	12[22]33

specimens measured : 6

specimens recorded : 14

Remarks

The specimens recorded here differ from the type material of Loeblich and Tappan 1969 in having a less inflated vesicle outline and in commonly having somewhat shorter processes; despite these minor morphological variations, the nature of the wall ornament is so distinctive that clearly only a single species is involved.

Comparisons

V.irroratum is similar to *V.trispinosum* (Eisenack 1938) Deunff 1959 ex Downie 1959, but the latter species has vesicle and process walls which are always apparently smooth. *Villosacapsula setosapellicula* (Loeblich 1970) Loeblich and Tappan 1976, always has a surface ornament of dense hair-like spines, whilst species attributed to the genus *Arkonia* Burmann 1970 are distinguished by the development of a striate wall sculpture.

Occurrence

Early and Middle Caradoc (Shropshire). Caradoc (Girvan).

Previous Records

Llandeilo, Mountain Lake Member, Bromide Fm. Oklahoma (Loeblich and Tappan 1969). Late Ordovician, Diabase-Phyllite Group, Bulgaria (Kalvacheva 1978).

<u>Veryhachium lairdi</u>

(Deflandre 1946) Deunff 1959 ex Downie 1959,

Pl.19,fig.3; Pl.35,figs.9,10.

1946	<u>Hystrichosphaeridium lairdi</u>	Deflandre card 1112.(nom.nud.).
1954	<u>Hystrichosphaeridium lairdi</u>	Deunff p.306.
1959	<u>Veryhachium lairdi</u>	Deunff p.28,Pl.8,figs.75-79.
1963	<u>Veryhachium lairdi</u>	Stockmans and Williere p.454, Pl.3,fig.5;text-fig.7.
1964a	<u>Veryhachium valiente</u>	Cramer p.34,(nom.nud.).
1964b	<u>Veryhachium lairdi</u>	Cramer p.309,Pl.11,fig.16; Pl.12,figs.1,2;text-fig.27-10,11.
1964b	<u>Veryhachium valiente</u>	Cramer p.311,Pl.12,figs.3,4, 6;text-fig.28-7,9.
1965	<u>Veryhachium lairdi</u>	Rauscher Doubinger and Manche-Bain p.311,Pl.4. figs.1-3.
1966a	<u>Veryhachium lairdi</u>	Martin p.13,figs.14-15.
1966a	<u>Veryhachium valiente</u>	Martin p.14,fig.16.
1966b	<u>Veryhachium lairdi</u>	Martin p.376.
1966b	<u>Veryhachium valiente</u>	Martin p.376,text-fig.23.
non 1967	<u>Veryhachium lairdi</u>	Combaz Pl.3,figs.89-91.
1968	<u>Veryhachium valiente</u>	Cramer p.64.
1968	Acritarch 3364	Magloire p.491,Pl.9,fig.12.
1969	<u>Veryhachium valiente</u> complex	Cramer p.486.
1969	<u>Veryhachium lairdi</u>	Martin p.95,Pl.2,figs.75-81, 83,Pl.6,fig.258.
1969	<u>Veryhachium lairdi</u>	Kalvacheva p.88,Pl.1,fig.e.
1969	<u>Veryhachium valiente</u>	Konzalova-Mazancova p.90, Pl.16,fig.2.

1969	_Veryhachium lairdi_	Konzalova-Mazancova p.89, Pl.16.fig.1.
1969	_Veryhachium_ cf. _lairdi_	Konzalova-Mazancova p.89, Pl.16,fig.3.
1969	_Veryhachium lairdi_	Stockmans and Williere p.9, Pl.1,figs.15,16.
1969	_Veryhachium lairdi_	Henry p.76,Pl.1,fig.7.
1970	_Veryhachium lairdi_	Paris and Deunff p.27, Pl.1,figs.1,13.
1970	_Veryhachium lairdi_	Burmann p.304,Pl.11,figs.4,5.
1970	_Veryhachium valiente_	Cramer p.746.
1970	_Veryhachium valiente_	Cramer and Diez p.1079.
1970	_Veryhachium lairdii_	Loeblich p.741.
1970	_Veryhachium valiente_	Loeblich p.744.
? 1970	_Veryhachium bromidense_	Loeblich p.739,fig.34,A,B.
1971	_Veryhachium_ cf. _lairdi_	Downie Lister et al. Pl.2, fig.3.
1971a	_Veryhachium lairdi_	Sheshegova p.43,Pl.12,fig.20.
1971a	_Veryhachium valiente_	Sheshegova p.45,Pl.10, figs.8,14.
1971	_Veryhachium lairdi_	Cramer p.97.
1971	_Veryhachium valiente_	Cramer p.100.
1972	_Veryhachium_ cf. _lairdi_	Combaz and Peniguel p.130, Pl.1,figs.17,18.
1972	_Veryhachium lairdi_	Martin p.26.
1973	_Veryhachium lairdi_	Kalvacheva and Chobanova pp.5 to 19.
? 1973	_Veryhachium lairdi_	Thusu Pl.2,fig.5.
1973	_Veryhachium valiente_	Rauscher p.77,Pl.3,fig.9.
1974	_Veryhachium lairdi_	Martin pp.28,43.

1974	Veryhachium valiente	Stockmans and Williere p.9, Pl.2,fig.10.
non 1974	Veryhachium cf. valiente	Pothe de Baldis p.372, Pl.1,fig.12.
1974	Veryhachium valiente	Hill (M.S.) p.197.
1975	Veryhachium lairdi	Tynni p.38,fig.41b.
1977	Veryhachium lairdii	Playford p.39,Pl.20,figs.1-3.
1978	Veryhachium lairdi	Dean and Martin p.11.
1979	Veryhachium lairdi	Booth p.283,Pl.2,fig.5,(?); Pl.6,fig.17(?);Pl.7,fig.8(?); Pl.24,fig.4;Pl.25,fig.8; Pl.32,fig.12;Pl.34,fig.5.

Original Diagnosis

The shell, pale brown, clear brown to bright orange measures 10 to 30u in width. The maximum overall size of specimens observed in the formations of Veryhac'h ranges between 55 and 100u. The general form of the shell corresponds to that of a pillow, more or less inflated, with a spine at each angle. The shell may be in outline square, rectangular or lozenge-shaped. (Trans.).

Description

Central vesicle hollow, compressed, square to rectangular but outline varies from slightly convex through straight-sided to concave forms, wall moderately thin (0.5-1.0u), smooth. Each of the four angles bears a hollow, simple, smooth process in the same plane as the vesicle; processes taper distally to an acuminate termination and have free communication with the vesicle cavity; processes widen gradually towards the base and merge into the vesicle with a curving contact; process length is variable but commonly is approximately equal to the vesicle length. Excystment is by the development of an epityche.

Dimensions

vesicle length	:	21[30]45
vesicle width	:	16[26]36
process length	:	14[28]50
specimens measured	:	16
specimens recorded	:	>40

Remarks

V.lairdi was originally published by Deflandre 1946 as Hystrichosphaeridium lairdi but was a nomen nudum and as such was invalid under the provisions of both the I.C.Z.N. [Art.13 [a][i]] and the I.C.B.N.[Art.32.1]. The new combination V.lairdi was proposed by Deunff 1959 but the genus Veryhachium was itself technically invalid until a type species was subsequently designated [Downie 1959 p.62]. Although Deunff did not designate a type specimen in his 1959 paper, his species lairdi was nonetheless validly published since he used a zoological classification; under the Botanical Code, ommiting typification in this way would have invalidated the taxon. Loeblich 1970 p.742 designated a lectotype for V.lairdi and transferred these forms to the Plant Kingdom.

In 1964, Cramer [p.311] introduced V.valiente, a form very similar to V.lairdi but described by the author as differing by always having straight vesicle sides whereas V.lairdi has concave sides. Martin 1969 [p.95] subsequently commented that working with Ordovician and Silurian assemblages from Belgium she was unable to differentiate between V.lairdi Deunff ex Downie 1959 and V.valiente Cramer. Loeblich 1970 [p.745] agreed with the conclusions of Martin and noted that specimens referred to V.lairdi by Cramer 1964 are so similar to those attributed by the same author to V.valiente that; 'considering the limits in these variable species it is impossible to distinguish "V.lairdi" [sensu Cramer] from V.valiente'. Despite this, Loeblich had already commented on the previous page, 'this Silurian species [V.valiente] appears to differ from the Ordovician form' [presumably V.lairdi sensu Deunff]; this conclusion seems to have been based on the larger dimensions and more deeply excavated sides of the Ordovician material described by Deunff when compared with the Silurian examples recorded by Cramer and Loeblich himself. Examination of the literature referring to Ordovician acritarchs clearly shows this to be an unrealistic approach; many recorded Ordovician assemblages include four-spined forms attributable to Veryhachium, having both straight and concave sides and overall size-ranges similar to those given by Cramer for his Silurian and Devonian examples. [see Konzalova-Mazancova 1969 : Rauscher 1973 : this study].

In 1973 Kalvacheva and Chobanova carried out statistical tests on a population of these Ordovician forms from the Iskur Gorge, Bulgaria, one of their main aims being to evaluate vesicle shape as a specific indicator. The results show conclusively that V.lairdi and V.valiente are conspecific and they conclude [p.20] that the latter name is a junior synonym and should be supressed. The present author agrees with this proposal and the two morphotypes are here treated as a single species.

Rarely aberrant individuals are encountered that are trapezoidal in outline rather than quadrate (Pl.35,fig.10); Playford 1977 Pl.20,fig.1. figures a similar individual from the Devonian of Canada.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan). Llandeilo (South Wales).

Previous Records

V.lairdi has been recorded from the Ordovician, Silurian and Devonian on a world-wide bases.

Veryhachium longispinosum

Jardine Combaz et al. 1974.

Pl.19,figs.4,5.

1974	*Veryhachium longispinosum*	Jardine Combaz et al. p.116, Pl.1,fig.1.
1977	*Veryhachium longispinosum*	Vavrdova pp.111,112,text-fig.1.

Original Diagnosis

Shell rectangular with straight sides; wall thin, smooth; four long processes, slender, very elongate, hollow, clearly differentiated from the central vesicle.(Trans.).

Description

Central vesicle hollow, square to rectangular in outline, compressed, wall thin [0.5u or less], smooth; each of the four angles bears a process in the same plane as the vesicle; processes are very long, hollow, flexible, extremely slender, becoming almost hair-like distally where they taper to an acuminate termination; process interiors in free communication with the vesicle cavity.

Dimensions

		spec.1.	spec.2.
vesicle length	:	32	22
vesicle width	:	26	20
process length	:	50	80
specimens measured	:	2	
specimens recorded	:	2	

Remarks

The processes probably become solid distally but they are so slender that this is difficult to determine with confidence. No excystment structure recorded. This distinctive species is extremely rare.

Comparisons

V.lairdi (Deflandre 1946) Deunff ex Downie 1959 is similar but has more robust processes which are much shorter relative to the central vesical dimensions. V.oklahomense Loeblich 1970 has very much shorter processes.

Occurrence

Caradoc (Shropshire).

Previous Records

? Ashgill-Caradoc, Algeria (Jardine, Combaz et al. 1974).

Lower Llanvirn, Bohemia (Vavrdova 1977).

Veryhachium minutum Downie 1958 ex Downie 1959.

Pl.19,figs.1,2; Pl.35,figs.11,12.

	1958	Veryhachium minutum	Downie p.344,Pl.17,fig.4; text-fig.3C.
?	1967	Veryhachium lairdi	Combaz p.17,Pl.3,figs.89-91.
	1969	Veryhachium minutum	Martin p.97,Pl.1,figs.12,14, 18,31,35-39,55,60-63;text-figs.45,46.
?	1969	Veryhachium lairdi	Martin p.95,Pl.2,fig.79.
	1970	Veryhachium minutum	Martin Michot and Vanguestaine p.344.
	1971	Veryhachium minutum	Rasul p.170,Pl.21,figs. 9,10,11.(M.S.).
	1972	Veryhachium minutum	Martin p.27,Pl.5,fig.5.
	1973	Veryhachium minutum	Kalvacheva and Chobanova pp.5-20.
	1973	Veryhachium minutum	Rauscher p.63,Pl.1,figs.11,?16.
	1974	Veryhachium minutum	Potter p.156,Pl.15,figs.13,14; Pl.16,fig.12;Pl.22,fig.5.
	1974	Veryhachium minutum	Kalvacheva and Chobanova pp.177-186.
	1974	Veryhachium minutum	Hill p.187,Pl.27,figs.2-4.
	1974	Veryhachium minutum	Martin Pl.7,fig.215.
	1974	Veryhachium minutum	Stockmans and Williere p.7, Pl.2,figs.8,9.

1975	Veryhachium minutum	Martin Pl.3,fig.4;Pl.5,fig. 6;text-fig.13.
1978	Veryhachium minutum	Fournier-Vinas p.265,Pl.2, figs.2,3.
1978	Veryhachium minutum	Kalvacheva p.306,Pl.1,figs. 13,13a,19.
? 1978	?Impluviculus sp.	Vanguestaine p.255,Pl.4, figs.4,5.

Original Diagnosis

Test small, about 3-15u, formed by the united bases of the processes; test wall thin, colourless, transparent; processes conical; length 80-200% of test diameter, but difficult to distinguish test from process; number four or six.

Description

Central vesicle small, hollow, quadrate, compressed, thin-walled (about 0.5u), smooth; each angle bears a hollow simple, smooth process which arise in the same plane as the central body; rarely one or two accessory processes are developed on the faces of the vesicle and at right angles to it; processes taper distally to an acuminate termination, process interiors have free communication with the vesicle cavity. Proximally, process walls widen gradually to merge into the vesicle with a curving contact. No excystment structure recorded.

Dimensions

vesicle length	:	6(10)14
vesicle width	:	5(8.5)11
process length	:	7(8.5)10

specimens measured : 7

specimens recorded : 21

Remarks

Potter 1974 [M.S.] and Booth 1979 [M.S.] have discussed in detail the relationship between Veryhachium minutum, a form in which excystment is rarely if ever observed, and species belonging to the genus Impluviculus Loeblich and Tappan 1969. Forms attributed to this genus, notably I.miloni (Deunff 1968) Loeblich and Tappan 1969, are similar to V.minutum in both size and overall morphology. According to Loeblich and Tappan [p.48], a diagnostic feature of Impluviculus is the excystment structure which "when present is a quadrangular or rounded pylome in the center of the upper surface midway between the processes"; the inference that must be drawn from this statement is that specimens occur without this central opening; the authors do not comment on how these individuals may be differentiated from the extant species V.minutum. Potter 1974 [M.S.] [p.148] notes that additional sources of confusion may arise when dealing with these taxa; he points out that the opening in Impluviculus may be pseudomorphed by accidental rupture, internal growth of pyrite or even a flattened extra process or fold; to this the present author would add that in carbonised material the vesicle only has to be oriented so that the opening is on the under-surface for it to be obscured. It is apparent then that considerable practical difficulties attend the differentiation of these two forms. Potter [p.149], proposed that in any given assemblage of these small quadrate acritarchs, where some individuals have central openings then all specimens from that assemblage should be assigned to Impluviculus; conversely where no openings are observed then all should be attributed to V.minutum. This proposal is considered unwise since it could lead to substantial misunderstanding of the stratigraphical range of V.minutum by suppressing records of the species where it occurs together with Impluviculus spp. In fact, during this study this problem did not arise since no specimens with clear central openings were recorded and so all individuals were referable to V.minutum. This is quite in accordance with what is known of the distribution of these forms; examination of the literature shows that forms unequivocally attributable to Impluviculus are restricted to the Cambrian whilst V.minutum ranges from the Cambrian up into the Upper Devonian. Thus the two forms indisputably have very different stratigraphical ranges; this alone justifies maintaining them as separate taxa at least until more data are available.

Extremely rare individuals were recorded having an obscure central structure the exact form of which could not be determined (Pl.35,fig.12); this feature appear to be a fold or possibly a thickening of the vesicle wall but was clearly not an opening.

Comparisons

Impluviculus miloni (Deunff 1968) Loeblich and Tappan 1969 always has a central excystment opening. Veryhachium lairdi (Deflandre 1946) Deunff ex Downie 1959 is much larger.

Occurrence

Caradoc (Shropshire) Llandeilo (South Wales).

Selected Previous Records

Tremadocian, U.K. [Downie 1958]. Tremadocian - Llanvirn, Belgium [Martin 1969]. Caradocian, Belgium [Martin et al.1970]. Upper Cambrian, U.K. [Potter M.S.]. Upper Devonian, Belgium [Stockmans and Williere 1974]. Arenig, U.K. [Booth M.S.].

Veryhachium oklahomense Loeblich 1970.

Pl.19,figs. 7-10.

1971 *Veryhachium oklahomense* Loeblich p.742,fig.36,F,G.

Original Diagnosis

Central body rectangular to nearly square in outline, sides nearly straight, corners of central body drawn out in the plane of the central body into four relatively long thin, flexible processes that at the distal end become almost hair-like; processes hollow for a good portion of their length and communicate freely with the central body but become solid at their distal end, rarely a fifth process arises on the face of the central body and is directed at right angles to the body plane; wall thin, less than 1u in thickness, smooth; excystment by development of a small epityche.

Description

Central vesicle hollow, compressed. In most respects exactly like the diagnosis of the original author except that no accessory processes or excystment structure were recorded.

Dimensions

vesicle length : 9[14]20

vesicle width	:	9[12]16
process length	:	18[26]33
specimens measured	:	20
specimens recorded	:	>150

Remarks

The specimens encountered here show a somewhat greater size range than the type material of Loeblich 1970; in particular the smaller individuals approach the dimensions of V.minutum Downie 1958 ex Downie 1959; despite this V.oklahomense may usually be identified by the very long delicate processes which become hair-like distally; some overlap appears to exist in the morphography of these two species and it is possible that additional data derived from future research may show the two forms to be conspecific. V.oklahomense is rare in the early Caradocian of Shropshire but becomes abundant in the upper part of the sequence.

Comparisons

V.minutum is generally slightly smaller and has shorter more robust processes but clearly has close affinities with the present species. V.lairdi [Deflandre 1946] Deunff ex Downie 1959 is much larger.

Occurrence

Caradoc [Shropshire].

Previous Record

Ashgillian, Sylvan Shale, Oklahoma [Loeblich 1970].

Veryhachium rhomboidium (Downie 1959) emend.

Pl.19, figs.11-13.

1959	Veryhachium rhomboidium	Downie p.62, Pl.12, fig.10.
1960	Veryhachium rhomboidium	Stockmans and Williere p.2, Pl.1, fig.9; Pl.2, fig.23.
1963	Veryhachium rhomboidium	Wall and Downie p.781, Pl.113, figs.9-12; Pl.114, figs.1-3; text-figs.1, a-e.
1963	Veryhachium rhomboidium	Downie p.636.
1969	Veryhachium rhomboidium	Martin p.101, Pl.8, fig.373; text-fig.49.
1970	Veryhachium trapezionariou	Loeblich p.743, fig.38, A-C
1971	Veryhachium rhomboidium	Cramer p.99.
1974	Veryhachium rhomboidium	Hill p.189 (M.S.).

Emended Diagnosis

Test rhomboidal, surface smooth, walls thin to moderately thick, vesicle size 14 to 23u; processes five to nine in number, arising at corners of vesicle; process and vesicle wall smooth.

Description

Central vesicle hollow, rhomboidal, wall thin (about 0.5u), smooth; vesicle bears a low number of long, hollow, simple, slender, flexible processes which taper distally to an acuminate termination; process interior communicates freely with vesicle cavity; proximally the processes widen gradually to merge into the vesicle with a curving contact; process length variable but commonly up to twice the vesicle diameter.

No excystment structure recorded.

Dimensions

vesicle diameter	:	14[18]21
process length	:	23[31]45
process number	:	5[6]8
specimens measured	:	14
specimens recorded	:	46

Remarks

Frequently one or two processes which are smaller than the majority are seen on a single individual; this is a feature illustrated but not described, by Hill 1974 [M.S.] [Pl.27, figs.6,8] from Silurian assemblages. The present specimens tend to have more elongate and therefore distally more slender processes than previously described forms [see Downie 1959 : Martin 1969 : Hill 1974 [M.S.]; despite this, the overall morphology, size, and variable process dimensions all indicate that these late Ordovician specimens are attributable to V.rhomboidium.

The original description of Downie 1959 [p.62] gave the process number as four to six; Hill 1974 [M.S.] [p.190] noted that this led to morphographic overlap and confusion with the four spined form V.lairdi [Deflandre 1946] Deunff ex Downie 1959, [V.valiente sensu Hill]; to clarify this situation Hill proposed that V.lairdi [as V.valiente] be restricted to individuals with four processes whilst the diagnosis of V.rhomboidium was emended to include specimens with five to nine processes. This proposal is adopted here and additionally reference to process length is deleted from the diagnosis. Although the possibility of close affinity between *V.rhomboidium* and *V.lairdi* is accepted, the latter species has a much greater stratigraphical range and should be retained as a separate taxon. The base of the known stratigraphical range of this species is extended from the basal Llandovery down to the late Caradocian.

Comparisons

Goniosphaeridium splendens comb.nov. has shorter, more robust and more numerous processes. *V.lairdi* always has four processes in a single plane.

Occurrence

Upper Caradoc (Shropshire).

Selected Previous Records

Wenlock, U.K. (Downie 1959, 1963). Upper Devonian, Belgium (Stockmans and Williere 1960). Permian, U.K. (Wall and Downie 1963). Llandovery - Wenlock, Belgium (Martin 1969).

Veryhachium triangulatum Konzalova-Mazancova 1969.
Pl.18,figs.1,2.

1969	*Veryhachium triangulatum*	Konzalova-Mazancova p.89, Pl.16,figs.11,12.text-fig.5.
1975	*Veryhachium triangulatum*	Tynni p.38,fig.41e.

Original Diagnosis

Form with a triangular outline having sunken (concave) or at most, straight sides. With three unbranching wide projections which merge gradually into the central body.[Trans.].

Description

Central vesicle is hollow, triangular in outline, wall thin [about 0.5u] and appears smooth in transmitted light. Each angle bears a hollow, simple, smooth process which taper distally to an acuminate termination and lie in the same plane as the central body; process interiors communicate freely with the vesicle cavity. The process and vesicle junction is usually indistinguishable, the two merging imperceptibly to give a concave, or rarely a straight-sided appearance.

Dimensions

vesicle + process height	:	80[100]124
process length	:	44[59]72
specimens measured	:	8
specimens recorded	:	8

Remarks

The specimens recorded here appear to be larger than the dimensions quoted by Konzalova-Mazancova 1969[p.89],and in particular the processes seem longer; however all of the specimens illustrated by the original author are incomplete, having processes which are broken off towards the tips; thus these Bohemian specimens may have been originally larger than is suggested by the measurements given. No excystment structure recorded.

Comparisons

V.triangulatum is easily distinguished from all other forms by the concave triangular outline and very large size.

Occurrence

Caradoc (Shropshire).

Previous Record

Lower Ashgill, Bohemia (Konzalova-Mazancova 1969).

Veryhachium trispinosum

(Eisenack 1938) Deunff 1954 ex Downie 1959.

Pl.17,figs.1,2; Pl.35,fig.4.

	1938	Hystrichosphaeridium trispinosum	Eisenack p.14,figs.2,3.
	1959	Veryhachium cf. trispinosum	Deunff p.29,Pl.1,figs.5-7,9.
	1959	Veryhachium trispinosum	Downie p.68,Pl.12,fig.7.
	1971	Veryhachium trispinosum	Cramer p.99,fig.28.
	1972	Veryhachium cf. trispinosum	Combaz and Peniguel p.129, Pl.1,fig.16.
	1972	Veryhachium trispinosum	Martin p.28.
	1973	Veryhachium trispinosum	Thusu, p.138,Pl.2,fig.8.
	1974	Veryhachium trispinosum	Pothe de Baldis p.372,Pl.1, fig.11.
	1974	Veryhachium trispinosum	Stockmans and Williere p.8, Pl.1,fig.13;Pl.3,figs.1-4; Pl.4,fig.14.
	1974	Veryhachium trispinosum	Gorka p.231,Pl.10,figs.4-7.
?	1974	Veryhachium trispinosum	Rauscher p.99,Pl.5,fig.20.
	1974	Veryhachium trispinosum	Form-Group. Hill (M.S.).

1974	Veryhachium trispinosum	Martin pp.28,43,44,46,47.
1975	Veryhachium trispinosum	Tynni p.38,Pl.4,fig.11.
1978	Veryhachium trispinosum	Jacobson p.295,Pl.1,Fig.13.
1978	Veryhachium trispinosum	Form-Group Kalvacheva p.306, Pl.1,figs.14,16,30.
1979	Veryhachium trispinosum	Form-Group. Booth p.293, Pl.3,fig.15;Pl.8,fig.6;Pl.9, fig.5;Pl.13,fig.9;Pl.17,figs. 5,6;Pl.22,fig.8;Pl.26,fig.10; Pl.29,fig.2;Pl.31,fig.8;Pl.32, fig.2;Pl.35,fig.11.

Only the taxonomically most significant and the more recent literature citations are given; for a more comprehensive synonomy list up to 1970, see Cramer 1971 (p.99).

Original Diagnosis

Cysts are equilateral triangles with long twisted or curved spines. Spherical central bodies are seldom seen. The distance between two spines amounts to 80-100u.(Trans.).

Description

Central vesicle hollow, triangular in outline, wall thin (<0.5u) and smooth; each angle bears a hollow, simple, smooth process, the processes arise in the same plane as the central body and taper distally to an acuminate termination, the process interior communicates freely with the vesicle cavity; vesicle shape is variable from inflated through straight-sided to rare concave forms. Excystment is by the development of an epityche.

Dimensions

vesicle height	:	21(32)56
vesicle + process height	:	42(59)100
process length	:	16(29)40
specimens measured	:	19
specimens recorded	:	>200

Remarks

Trispinose acritarchs referable to the genus Veryhachium form a large and varied group and were both diverse and abundant throughout much of the Lower Palaeozoic. Since the morphology of this group is essentially very simple, in the past, speciation has proved a considerable problem. Only three basic morphographic variables are available to a palynologist attempting to classify these forms; two of these are vesicle shape and overall size whilst the third,the ratio of vesicle height to process length, is a function of the first two. Faced with this paucity of morphological data, past authors have approached the problem with two fundamentally different philosophies. The initial concept was to accept that size, shape, and the vesicle height to spine-length ratio are meaningful and recognisable characters which allow division of the group into identifiable and consistent taxa (Deunff 1959 : Jekhowsky 1961 : Stockmans and Williere 1962). Opposed to this point of view are those who consider these morphological characters to be non-objective, continously variable features of little taxonomic use (Cramer 1964, 1971). The latter author has argued strongly that since the morphology of this group as a whole is continously variable, then any 'species' based on differences in morphology must be totally subjective and therefore meaningless. In order to deal with the problem Cramer 1964 [p.304] proposed the use of Form-Groups which would be applied to all forms having a broadly similar morphology; inevitably such a Form-Group would include a number of existing species under one joint name. One of the Form-Groups suggested by Cramer 1964 was the V.trispinosum Form-Group [p.306] in which five extant species were placed. A serious disadvantage to this proposal of Cramer is that Form-Groups are not recognised under the provisions of either the I.C.B.N. or the I.C.Z.N. and so technically such a Group has no status. This scheme has not met with general acceptance although some authors [Hill 1974 [M.S.] : Booth 1979 [M.S.]] have adopted it.

During the present study, trispinose acritarchs were found to be abundant throughout much of the interval studied. It was decided to examine these forms in some detail in order to assess if the species in existence in the literature could be applied consistently to the assemblages recovered, or if this approach would be unrealistic. One hundred randomely selected individuals were measured and examined and based on these observations an attempt was made to assign each specimen to an existing Veryhachium species. It was found that only three individuals were difficult to speciate because their morphology fell between that of two species. Considering this evidence it was thought both feasible and desirable to proceed on this basis and to deal with these forms in the conventional manner. Consequently the Form-Group proposals of Cramer are here rejected. Subsequent experience during sample logging showed that the vast majority of individuals encountered fell readily into one of the extant species used. The decision to adopt the conventional binomial system for these acritarchs had two major advantages; firstly the taxa used are recognised under the I.C.B.N. and are therefore closely circumscribed and are immutable; secondly there is much less chance of potentially valuable palyno-stratigraphic data being lost; losses of this nature are inevitable if the 'lumping' advocated by Cramer is accepted. Despite the usage adopted here, it is fully realized that there is a small amount of overlap between some of the species used and that these may ultimately prove to be conspecific when more data are available; however it is clear that to determine the precise relationships between these various forms will require a major statistical exercise and is beyond the scope of this study. Thus the existing species of trispinose acritarchs are here accepted and adopted as meaningful and useable taxa.

Comparisons

Veryhachium downiei Stockmans and Williere 1962 has a similar overall morphology but is much smaller. *V.trisulcum* Deunff 1959 is distinguished by having very long, slender processes. *V.irroratum* Loeblich and Tappan 1969 has a surface ornament of grana whilst *Villosacapsula setosapellicula* (Loeblich 1970) Loeblich and Tappan 1976 bears a dense covering of hair-like spines.

Occurrence

Caradoc (Shropshire). Caradoc (Girvan). Llandeilo (South Wales).

Selected Previous Records

Ordovician, Baltic (Eisenack 1938). Ordovician, France (Deunff 1959). Wenlockian, U.K. (Downie 1959). Wenlockian, U.S.A. (Thusu 1973). Frasnian and Famennian, Belgium (Stockmans and Williere 1974).

Veryhachium trisulcum

(Deunff 1951) Deunff 1959 ex Downie 1959.

Pl.17,figs.5-7.

1959	Veryhachium trisulcum	Deunff p.27,Pl.1,figs.4,13.
1959	Veryhachium trisulcum var. venetum	Deunff p.27,Pl.1, figs.2,20.
1963	Veryhachium trisulcum var. venetum	Downie and Sarjeant p.94.
1964	Veryhachium trisulcum	Cramer p.306.
1965	Veryhachium trisulcum	Vavrdova p.351,Pl.2,fig.3.
1966	Veryhachium trisulcum	Timofeev Pl.14,fig.4; Pl.33,fig.7.
1969	Veryhachium trisulcum	Le Corre and Deunff p.46, figs.1,3,4.
1969	Veryhachium trisulcum var. venetum	Le Corre and Deunff p.46,figs.5-7.
1969	Veryhachium trisulcum	Henry p.76,Pl.1,figs.1,2,4,6; Pl.6,figs.39,43,45,46,48.
1969	Veryhachium trisulcum var. venetum	Henry Pl.6,fig.42.
1969	Veryhachium trisulcum var. venetum	Konzalova-Mazancova p.88,Pl.16,fig.5.
1970	Veryhachium cf. trisulcum	Paris and Deunff p.29, Pl.1,fig.2.

1971	_Veryhachium trisulcum_	Cramer p.100.
1971	_Veryhachium trisulcum_	Henry and Thadeu p.1343, Pl.1,figs.3,8,13.
1971	_Veryhachium trisulcum venetum_	Henry and Thadeu p.1343, Pl.1,fig.10.
1971	_Veryhachium trisulcum_	Sheshegova p.19,Pl.7,fig.5.
1973	_Veryhachium trisulcum_	Rauscher p.99,Pl.5,figs.19,21.
1975	_Veryhachium trisulcatum_	Tynni p.38,fig.41d.

Original Diagnosis

Shell yellow or brown, sometimes reddish, triangular, inflated, each angle bearing a long straight or flexible process; size of the central body : 35 to 40u, length of processes : 75-100u, overall size : 150-200u.[Trans.].

Description

Central vesicle hollow, triangular in outline, wall thin [about 0.5u], smooth; each angle bears a hollow, smooth, simple, slender process, each of which arise in the same plane as the vesicle and taper distally to an acuminate termination; process interior communicates freely with the vesicle cavity. Vesicle shape varies from inflated to straight-sided. Process length is at least twice the vesicle height, usually more. Excystment is by the development of an epityche.

Dimensions

vesicle height	:	22[28]44
vesicle + process height	:	62[93]120
process length	:	36[54]84

specimens measured : 22

specimens recorded : >200

Remarks

The diagnostic feature of V.trisulcum is the long slender processes which are at least twice the vesicle height. Deunff 1959 [p.27] proposed a new variety of this species, V.trisulcum var. venetum which was said to differ from V.trisulcum by, 'having a greater regularity of the central vesicle and a more balanced aspect .... the vesicle an equilateral triangle, distinctly swollen'. [Trans.]. Thus the distinction between these two taxa seems to be based on the interpretation that V.trisulcum var. venetum has a vesicle outline in the shape of an equilateral triangle whilst V.trisulcum, by implication, has a vesicle outline similar to an isosceles triangle; the latter feature is nowhere stated by the author as being characteristic of V.trisulcum. The present author found differentiation of these two forms impossible on an objective basis and examination of the literature shows clearly that previous workers have encountered the same difficulty. Tynni 1975 [fig.41d] illustrates an equilateral form but uses the name V.trisulcatum, a presumed typographic variant of V.trisulcum Deunff. Rauscher 1973 [Pl.5,figs.19,21], illustrates both an equilateral and an isosceles form but includes both under the name V.trisulcum. To clarify this situation and to formalise a state of affairs already existing in the literature, rejection of V.trisulcum var. venetum is proposed and the forms attributed to it are re-combined with V.trisulcum. This species appears to be restricted to the Ordovician.

Comparisons

V.trispinosum (Eisenack 1938) Deunff 1954 ex Downie 1959, is very similar but always has much shorter processes generally about equal to the vesicle height.

Occurrence

Caradoc (Shropshire)

Selected Previous Records

Ordovician, France (Deunff 1959). Middle Ordovician, France (Le Corre and Deunff 1969). Ordovician, France (Henry 1969). Ashgill, Bohemia (Konzalova-Mazancova 1969). Llandeilo-Caradoc, Portugal (Henry and Thadeu 1971).

Veryhachium sp. A.

Pl.35,figs.5-8.

? 1970 Acanthodiacrodium concaviusculum Burmann p.314,Pl.17, figs.8-10.

Description

Central vesicle hollow, compressed, rectangular with straight sides, wall thin (about 0.5u), apparently smooth. Each of the four angles bears a hollow simple smooth process in the same plane as the central vesicle; processes taper distally to an acuminate termination and have free communication with the vesicle cavity; processes widen gradually towards their base and merge into the vesicle with a curving contact. Each vesicle bears what seems to be a fold structure of the wall, varying in shape from single diagonal folds through rhombic folds to complex, double, cross-shaped features. No excystment structure recorded.

Dimensions

vesicle length	:	18[19.5]20
vesicle width	:	15[16]17
process length	:	13[15]18
specimens measured	:	5
specimens recorded	:	9

Remarks

Acanthodiacrodium concaviusculum Burmann 1970 is similar in overall morphology and in the presence of fold structures, but the dimensions quoted for these East German examples are 50% greater than in the present specimens; in addition the individuals illustrated by Burmann have rounded process tips, although she commented [p.314] that this might be a secondary feature. The material studied by Burmann was examined in thin-section and was also poorly preserved, both factors that make establishment of synonomy with specimens from acid-insoluable residues a difficult task; taking into account these factors and the striking fold-structures present, it is likely that the two forms are conspecific, however more data are required before this may be considered proven.

This form is rare and was only recorded in two samples from the lower part of the Llandeilo. It is difficult in all cases to determine the exact nature of the fold structure because of poor preservation.

Comparisons

Veryhachium sp.A is similar to V.lairdi (Deflandre 1946) Deunff ex Downie 1959 but is always smaller and has a fold structure occupying at least one vesicle face. V.minutum Downie 1958 ex Downie 1959 is very much smaller and has a smooth unfolded vesicle. Impluviculus miloni (Deunff 1968) Loeblich and Tappan 1969 is much smaller and always has an excystment opening on the upper face of the vesicle.

Occurrence

Middle and Lower Llandeilo (South Wales).

Previous Record

? Upper Llanvirn, G.D.R. (Burmann 1970).

? Veryhachium sp. B.

Pl.20,figs.4,7,8.

Description

Vesicle hollow, compressed, smooth, quadrate, thin-walled (<0.5u), each angle bears a hollow smooth simple process arising in the same plane as the vesicle and tapering distally to a fine hair-like acuminate termination. Proximally the processes widen gradually, merging into the vesicle with a curving contact. Internally a thick-walled (>1u), smooth, spherical or sub-spherical body is developed which is confined to the vesicle cavity and does not penetrate into the interior of the processes. No excystment structure recorded.

Dimensions

vesicle length : 7(9)12

vesicle width : 6[8]10

process length : 7[13]20

specimens measured : 7

specimens recorded : 21

Remarks

This acritarch is similar to Veryhachium oklahomense Loeblich 1970, a species occurring in abundance in the same assemblage; however, associated individuals of V.oklahomense are considerably larger and in particular have longer processes than the present form. In addition, the thick-walled internal body is always present here, a feature not recorded at all in larger specimens attributable to V.oklahomense. The nature and origins of this internal body are obscure; analagous structures have been described from other Lower Palaeozoic genera (see Cramer 1971, Pl.10,fig.157 : Pl.11,figs.160,166) and referred to as internal cysts; this choice of terminology is unfortunate since it is generally accepted that the majority of acritarchs represent, in their entirety, cysts of marine phytoplankton (Lister 1970 p.44 : Downie 1973 p.239). This being so, the term 'cyst' has certain genetic connotations which should not be ignored. In this particular context it is clear that Cramer used the term in a purely morphographic sense and not in the more specific way generally adopted by most authors including Cramer himself. The use of the term 'cyst' or 'internal cyst' for this type of feature is therefore rejected as misleading and the non-interpretive phrase ' 'internal body' is preferred.

Since the formation of this kind of internal body was probably facultative in the same way as excystment structures, their extreme rarity in the fossil record suggests that they were the result of unusual circumstances; the nature of such causal circumstances is wholly speculative, it is not even known if they were environmental or biological in origin; the normal composition of the bulk of associated assemblages tends to suggest the latter however, unless very few acritarch taxa had the capacity to form such structures. The function of such inner bodies is totally unknown. This form was only recorded from a single sample despite a careful search of other adjacent preparations, thus it appears to have been a phenomenon of short duration which may have been geographically localised; if so it is likely to be of little biostratigraphical use.

The affinities of this taxon are uncertain but because of the nature of the external body it is tentatively assigned to *Veryhachium*.

Comparisons

The only extant species comparable in morphology and size-range is *V.minutum* Downie 1958 ex Downie 1959, but this species has never been described with an internal body developed.

Occurrence

Marshbrookian, Caradoc (Shropshire).

Genus VILLOSACAPSULA Loeblich and Tappan 1976.

Type species: *Villosacapsula setosapellicula* Loeblich and Tappan 1976.

Original Diagnosis

Vesicle triangular in outline, with a hollow process at each angle in the plane of the vesicle, rarely with one or more supplementary processes arising from the face of the vesicle, processes communicate freely with the vesicle interior; wall thin, surface of vesicle and commonly that of processes with short scattered microspines, excystment by an epityche.

Remarks

The type species Villosacapsula setosapellicula was first described by Loeblich 1970 (p.743) but was attributed to the genus Veryhachium (Deunff 1954) Downie 1959. In 1976 Loeblich and Tappan (p.306) transferred the species to a new genus, Villosacapsula, which was distinguished from Veryhachium by having a spinose rather than a smooth or granular wall; at the same time the authors designated V.setosapellicula as the type species of their new genus.

Villosacapsula setosapellicula

(Loeblich 1970) Loeblich and Tappan 1976.

Pl.18,figs.5,6,8.

1970 Veryhachium setosapelliculum Loeblich p.743,figs.36A,B. 37A,B.

? 1970 Veryhachium calandrae (pars.) Cramer p.106,text-fig.29a.

1976 Villosacapsula setosapellicula Loeblich and Tappan p.306.

1978 Villosacapsula setosapellicula Loeblich and Tappan p.1235.

Original Diagnosis

Central body inflated triangular in outline, with sides slightly convex outward; three relatively short, flexible processes lie in the plane of the central body and terminate distally in sharp points; wall about 1u in thickness, covered with short scattered microspines, from 1u to 2u in length, showing no definite orientation, spines continue along processes out to the tips; excystment by a prominent epityche, with broadly arched margin that occupies over two-thirds the width of one side of the central body.

Description

Vesicle hollow, triangular in outline, wall thin (0.5-1u); each angle of the vesicle bears a moderately short, hollow, flexible process, in the same plane as the central vesicle, these processes have acuminate distal terminations and the process interior communicates freely with the vesicle cavity. The vesicle wall is ornamented with ubiquitous, short, apparently solid spines which are delicate and hair-like, the spines extend onto the process walls and commonly occur right out to the distal tips of processes. No excystment structure recorded.

Dimensions

vesicle height	:	20(23)40
vesicle + process height	:	40(50)52
process length	:	14(20)28
spine length	:	1-3
specimens measured	:	10
specimens recorded	:	12

Remarks

The specimens recorded here have a greater size-range and a less inflated vesicle shape than the North American material of Loeblich 1970; the latter feature may be the result of compression and distortion of the vesicle during preservation.

Comparisons

Veryhachium irroratum Loeblich and Tappan 1969 is very similar in gross morphology but bears an ornament of grana rather than spines. The *Veryhachium rosendae*, *V.leonense*, *V.helenae* group (Cramer 1970), differ in having an ornament of sparse, irregularly distributed spines and in commonly having processes in more than one plane.

Occurrence

Caradoc (Shropshire)

Previous Records

? Upper Caradoc, Maysville Fm. (Cramer 1970). Ashgill, Sylvan Shale, Oklahoma (Loeblich 1970).

Acritarch sp. A.

Pl.27,figs.7,8.

Description

Central vesicle hollow, wall relatively thin (1u or less) apparently single layered; vesicle bears a low number (eleven-fourteen), of stiff, radiating, solid, homomorphic processes which are ornamented with short thorn-like lateral branches; when fully developed these may become hair-like distally;

the spinose ornament is most strongly developed on the processes but may extend onto the vesicle wall where it is reduced in size and more widely dispersed. Process length is approximately half of vesicle diameter. No excystment structure recorded.

Dimensions

		specimen 1.	specimen 2.
vesicle diameter	:	32	30
process length	:	16	15
process numbers	:	11	14
specimens measured	:	2	
specimens recorded	:	2	

Remarks

The characteristic features of this form are the thin-walled polygonal vesicle and the solid spinose processes.

Comparisons

Solisphaeridium Staplin Jansonius and Pocock 1965, may have solid processes but always has a rigid spherical vesicle. Filisphaeridium Staplin et al. 1965 has a rigid spherical vesicle and processes which are distally differentiated. The closest affinities for this form are to be found with Astropheos Booth 1979 [M.S.] and Recavisentis Booth 1979 [M.S.]; however both these genera typically have hollow processes. The extreme rarity of the form suggests that these are possibly aberrant individuals which may be referrable to Recavisentis uncinatus [Downie 1958] Booth 1979 [M.S.].

Occurrence

Lower and Middle Llandeilo [South Wales].

Chapter Six

REWORKED ACRITARCHS

Introduction

It is now widely recognised that many palynological assemblages contain not only 'indigenous' palynomorphs but also forms which are known to belong to an earlier time period then the age of the strata being investigated (Funkhouser 1969; Richardson and Rasul 1978, 1979; Windle 1979). This phenomenon is caused by erosion and transport of pre-existing rocks which themselves contain palynomorphs, a process leading to the redeposition of the microfossils within a younger sediment body. This mechanism, known as recycling or reworking, has been discussed by Wilson (1964). Most palynomorphs are particularly prone to reworking because the resistant nature of the wall material makes them extremely durable. Acritarchs, in addition to their durability, are of relatively small size and often occur in great abundance; characteristics which combine to render the group extremely susceptible to reworking.

Samples from the Caradoc rocks of Shropshire were found to contain reworked acritarchs of different ages; these were present throughout the sequence in varying abundance (Text-fig.21). Samples from the early Caradoc of the Chatwall district contained a similar pattern of reworking to those from approximately age-equivalent strata in the Onny Valley; only the latter are discussed in detail here since the section is much more complete in this southern area. Most reworked acritarchs recovered are in a very good state of preservation; indeed in many samples they are better preserved than the associated acritarchs of Caradoc age. This peculiar feature of reworking has been observed in palynological assemblages from other parts of the geological column (Prof.C.Downie, pers.comm.).

Ages of the reworked acritarchs

The reworked forms recorded could be divided on an age basis into three broad categories.

a) Acritarchs of Tremadoc age : Many genera and species recovered, could be identified as Tremadoc taxa because their known stratigraphical ranges are restricted to strata of this age. The occurrences here cannot be interpreted as extensions of these ranges since the forms involved remain unknown in the Lower and Middle Ordovician despite extensive sampling at this level. Some of these undoubted Tremadoc acritarchs are illustrated in Text-fig.22. As can be seen the state of preservation is excellent.

b) Acritarchs of early Ordovician age : Many genera and species recovered could be identified as Lower Ordovician taxa because their known stratigraphical ranges are restricted to strata of this age. The occurrences here cannot be interpreted as extensions of these ranges since the forms involved are unknown in the Llandeilo. Some of these undoubted Lower Ordovician taxa are illustrated in Text-fig.23. The general state of preservation of these forms is also excellent.

Additional evidence exists for the reworked origins assigned to the two groups above. A number of acritarch assemblages from sequences of Caradoc age have been described from elsewhere in the world, notably from the U.S.A. and continental Europe; none of the forms interpreted here as reworked have been recorded in these Caradoc assemblages, a fact which substantiates their being considered as derived from pre-existing sediments.

c] Reworked acritarchs of probable Tremadoc age: The third group of reworked taxa identified here is composed of forms whose known stratigraphical ranges span the Tremadoc and early Ordovician but which have not been recorded from younger strata either in the British Isles or elsewhere. The reworked origin of these individuals seems certain, but it is impossible to assign a precise age to them. Nevertheless, although a possible early Ordovician age is accepted for some individuals of these taxa, it is probable that the majority were derived from rocks of Tremadoc age. This is because of the large numbers of individuals recovered, which suggests derivation from particularly rich pre-existing acritarch assemblages. Certain parts of the Tremadoc sequence in Great Britain are known to yield numerically abundant acritarch populations. A rough calculation suggested a figure of 100,000 individuals per gramme of rock for a sample from the Shumardia pusilla zone of the Shineton Shales of Shropshire (Downie 1958, p.332). These prolific numbers have led to the reworking of Tremadoc acritarchs into other parts of the geological column; for instance, reworked assemblages of Tremadoc age have been identified from Devonian rocks in Oxfordshire (Richardson and Rasul 1978) and from Tertiary rocks in south-east England (Prof.C. Downie, pers.comm.). Strata of Tremadoc age are unquestionably the commonest recognised source of reworked acritarchs in the British Isles. In contrast, the work of Booth (1979 M.S.) and the present author's own unpublished data indicate that the early Ordovician was a period of substantially lower phytoplankton productivity at least in this region. Thus, although individuals of many taxa could be from Lower Ordovician rocks, it is probable that the bulk of the numerically abundant forms are derived from Tremadoc strata. Examples of these reworked taxa of uncertain but probable Tremadoc age are illustrated in Text-figs.23 and 24.

In addition to the reworked forms described above, rare carbonised and often fragmented acritarchs were recovered. These individuals, whose poor state of preservation indicates a separate source from the main body of reworking, were usually unidentifiable and their age remains unknown.

Pattern of reworking in the type section of the Caradoc

The overall pattern of reworking within the Onny Valley section is shown in Text-fig.21. The figure for each group of reworked acritarchs identified in every sample is given as a percentage based on a count of two hundred specimens. No data are available from the basal lithological unit, the Coston Beds, since this horizon is almost devoid of palynomorphs. The onset of fine-grained sedimentation which resulted in the deposition of the Harnage Shales, coincided with the first reworking of acritarchs. The forms present include both Tremadoc and Lower Ordovician taxa indicating that at this early stage, strata of both ages were being actively eroded. Towards the top of the Harnage Shales and in the lower part of the Chatwall Sandstone, early Ordovician forms constitute the bulk of the reworking with only minor elements of probable Tremadoc age present. The most likely explanation of this is that erosion of Lower Ordovician sediments was occurring on a relatively widespread scale but as yet little Tremadoc material was exposed. An alternative explanation is a change of source area but this is considered unlikely. Up to Middle Chatwall Sandstone time the amount of reworking was more or less constant at between 10% and 20% . Above this level the number of reworked specimens being incorporated into the sediment increased dramatically, forming up to 70% of the total acritarch assemblage present. This tremendous upsurge in overall reworking was accompanied by a corresponding increase in the numbers of both undoubted and probable Tremadoc acritarchs being redeposited. The simultaneous increase in the abundance of these two categories obviously tends to justify the Tremadoc age proposed for the majority of the latter group. Extraordinarily high percentages of reworking continued throughout the Longvillian and Marshbrookian, with Tremadoc forms dominating the assemblages. The maximum level of reworking was reached in the Alternata Limestone where up to 94% of the acritarchs included in the sediment were derived, the 'indigenous' Caradoc taxa being effectively swamped out. The percentage of early Ordovician forms present fluctuated throughout this period but was always minor. This massive increase in reworking indicates that an acritarch-rich source rock area of Tremadoc age had been extensively breached and was eroded over a substantial period of time. By the early Actonian, reworking had been reduced to a mere 1% or 2% and was maintained at this low level for the remainder of Caradoc time. This diminution in acritarch reworking coincided with a switch to a low energy mudstone environment (the Acton Scott Beds) presumably indicating a change in the sediment source. It is not apparent if this was due to a final denudation of the source area leading to a reduced sediment supply or to a change in the current activity responsible for the Caradoc deposition.

If one accepts the interpretation of the majority of the non age-diagnostic acritarchs as having a Tremadoc origin, then an interesting distribution pattern of the reworked phytoplankton emerges; this pattern is essentially that of an inverted Tremadoc-Lower Ordovician stratigraphy reflected by the reworked acritarchs. Such an inversion, with younger microfossils being redeposited in the lower horizons and older forms in the overlying horizons, would naturally be expected where relatively undisturbed conformable strata were being eroded and laid down again in an adjacent depositional environment. It may be assumed that rocks of this age would have been almost unaltered during the Caradoc, since the Ordovician was a period of little tectonic activity in this region (Earp and Hains 1971, p.89).

Provenance of the reworked acritarchs

The Tremadoc and Lower Ordovician acritarchs encountered are in an excellent state of preservation; this suggests that they were not transported over any great distance and underwent rapid reburial. It is therefore necessary to look for possible source rocks which are reasonably close to the site of deposition; it is unlikely that the reworked material was derived from the west since this region was undergoing deposition during Caradoc time. To the east and south the Midland Shelf formed a stable block during the Palaeozoic; Tremadoc rocks are widespread over this platform although Lower Ordovician strata are practically unknown (Richardson and Rasul 1978b, p.37). To the south-east of Shropshire, probably close to the edge of the Midland Shelf, great thicknesses of Tremadoc sediments existed; although no traces have yet been found it is possible that Lower Ordovician rocks were also deposited in such marginal areas. Acritarch bearing Tremadoc and early Ordovician sediments are known from North Wales (Booth 1979, M.S.; author's unpublished data) but the distances involved here are considerable and a closer source is considered more likely. It therefore seems probable that the reworked acritarchs recorded were derived from the east or south-east from on or adjacent to the Midland Shelf.

Mechanism of reworking

The accepted explanation for reworking of palynomorphs is that they are eroded and transported while encapsulated within particles of pre-existing sediment and so are protected from damage. If such recycled rock particles are present in a sediment then they should be visible under microscopic examination [see Richardson and Rasul 1978b,p37]. In the present study, fine-grained sediments such as the Harnage Shales yielded numerous reworked acritarchs. Thin-sections of this horizon were prepared and examined to see if lithoclasts were present; no traces of recycling as clasts was observed, the sediment presenting a uniformly fine-grained appearance; the dimensions of particles were between 5 and 100u with a mean of approximately 30u. The particles present were thus at most only slightly larger than reworked acritarchs recovered from the same sample; perhaps more significantly all the grains examined appeared to be mineral rather than rock particles. Finally, although no acritarchs were positively identified in thin section, the sediment was clearly organic rich and without exception the particulate organic matter observed was trapped in the interstices of the sediment. These factors make it unlikely that acritarchs were reworked in an encapsulated state; on the contrary, the evidence suggests that they were eroded and redeposited as discrete sedimentary particles. This hypothesis is supported by the distribution pattern of the reworking which is apparently unaffected by changes in the type of sediment being deposited. For example, similar reworked acritarchs are found in comparable numbers in sandstones, limestones and micaceous flagstones. This fact alone strongly suggests that the acritarchs were being introduced into the sediment-water body system independently of the non-organic sediment particles. Given the small size, low density and large surface area of acritarchs they would certainly be carried over longer distances by current activity than would mineral particles of similar dimensions.

If an independent origin for the reworked acritarchs is correct then further conclusions can be drawn. Considering the excellent state of preservation of reworked individuals, it is probable that dissolution of the parent rock was both easy and relatively quickly accomplished. Since an indurated sediment would resist erosion, it follows that the Tremadoc and Lower Ordovician rocks being eroded were probably at most only partly consolidated.

The retention of the most delicate morphological features observed on many reworked acritarchs, suggests that erosion and transport was not only rapid but did not take place in a sub-aerial environment. Structures such as the fine distal terminations of <u>Vulcanisphaera cirrita</u> [Text-fig.22-7], or the flimsy outer membrane of <u>Marrocanium simplex</u> [Text-fig. 23-3] would be unlikely to survive such turbulent conditions without encapsulation and protection. Even if mechanical damage was avoided, such features would suffer rapid oxidation and disintegration. It is therefore postulated here that erosion and redeposition of these pre-existing rocks took place predominantly in a sub-aqueous environment; wave and current action are considered the most likely agents for lifting and dispersing the unconsolidated sediments involved. Under such circumstances the enclosed acritarchs would be released directly into the supporting medium of the water-body, affording the means both of protection and rapid transport and reburial.

In conclusion, the evidence available suggests that the majority of reworked acritarchs recovered were derived from unconsolidated sediments; these rocks were probably located in a coastal situation adjacent to the Midland Platform and were eroded and redeposited in a shallow shelf environment, the principle agent almost certainly being marine action. This is in accord with what is known of local palaeogeography during the Ordovician, which seems to have been dominated by the slowly emergent landmass of the Midland Shelf. It is interesting to note that reworking from Tremadoc rocks in the same region continued into the Lower Silurian, the most likely source still being the Midland Platform (Hill 1974, M.S. p,239).

Note: The uplift and emergence of the Midland Platform, an area of widespread deposition during the Tremadoc, seems to have begun in early Ordovician time since Lower Ordovician deposits are very restricted over the block. Middle and Upper Ordovician strata are so far unknown. The abundant reworking discussed above can be related to the emergence of this block which was probably a function of local tectonic activity; certainly at the end of the Caradoc uplift and folding occurred as can be seen by the unconformable relationship of the overlying Silurian. It is possible that changes in sea level during the Caradoc were accentuated by the onset of the well documented late Ordovician glaciation. This global event probably 'locked up' large volumes of oceanic waters (Berry and Boucot 1973, p.275), and the consequent lowering of sea level would almost certainly have had great impact on littoral and neritic zones.

List of reworked species identified.

1. Tremadoc Forms

'*Archaeohystrichosphaeridium*' *zalesskyi* Timofeev 1959.
Cymatiogalea cristata (Downie 1958) Rasul 1974.
Dasydiacrodium palmatilobum Timofeev 1959.
Impluviculus multiangularis (Umnova 1971) Vanguestaine 1973 (M.S.).
Micrhystridium shinetonensis Downie 1958.
Saharidia fragile (Downie 1958) Combaz 1967.
Timofeevia cf. *phosphoritica* Vanguestaine 1978.
Trichosphaeridium annolovaense Timofeev 1966.
Vulcanisphaera britannica Rasul 1977.

2. Probable Tremadoc Forms

Acanthodiacrodium / *Actinotodissus* spp.
Micrhystridium robustum Downie 1958.

'*Polygonium*' spp.	
Stelliferidium cortinulum	(Deunff 1961) Deunff Gorka and Rauscher 1974.
S.distinctum	(Rasul 1974) Booth 1979 (M.S.).
Vulcanisphaera africana	Deunff 1961.
V.cirrita	Rasul 1977.

3. Lower Ordovician Forms

Arkonia tenuata	Burmann 1970.
A.virgata	Burmann 1970.
Coryphidium australe	Cramer and Diez 1976.
C. cf. *baraka*	Cramer and Diez 1976.
C.bohemicum	Vavrdova 1972.
Culcitispina brevis	Booth 1979 (M.S.).
Dicrodiacrodium normale	Burmann 1968.
Frankea breviuscula	Burmann 1970.
F.hamata	Burmann 1970.
F.longiuscula	Burmann 1970.
F.sartbernardense	(Martin 1966a) Burmann 1970.
Marrocanium simplex	Cramer, Kanes et al. 1974.
Multiplicisphaeridium maroquense	Cramer, Allam et al. 1974.
M.multiradiale	(Burmann 1970) Eisenack, Cramer and Diez 1976.
M.rayii	Cramer, Allam et al.1974.
Pirea dubia	Vavrdova 1972.

<u>Striatotheca frequens</u>	Burmann 1970.
<u>S.principalis</u>	Burmann 1970.
<u>S.quieta</u>	(Martin 1969) Rauscher 1973.
? <u>Tunisphaeridium eligmosum</u>	Vavrdova 1973.
<u>Vavrdovella arenigum</u>	(Vavrdova 1973) Loeblich and Tappan 1976.

Addendum

The group of acritarchs included under the name '<u>Polygonium</u>' in this chapter, embraces a wider variety of forms than the diagnosis of this genus; the original author considered that processes having a consistent concentric arrangement were characteristic of <u>Polygonium</u> (Vavrdova 1966,p.413). Some individuals showing this feature were recorded here (Text-fig.24-3), but the majority of specimens, otherwise indistinguishable, exhibit a random process distribution (Text-fig.24-4). These non-concentric forms constitute a taxonomic problem since no valid generic name has yet been proposed for them. 'Polygonium' refers to specimens both with and without a concentric process structure. The examples recovered are similar in overall morphology to <u>Goniosphaeridium</u> Eisenack 1969 emend. but differ in having more numerous and much more slender processes. This style of process, slender for most of the length and flaring suddenly at the base seems to be characteristic of the Tremadoc and Lower Ordovician. <u>Goniosphaeridium</u> as used here, typically has fewer, more robust processes which are conical in form, tapering gradually throughout their length

(Text-fig.20a). No attempt was made to speciate those forms of '*Polygonium*' considered to be reworked, the derived origin of such forms being inferred from their absence in the Llandeilo and the pattern of their distribution within the Onny Valley section. It is considered probable that the '*Polygonium*' complex includes forms transitional to the *Acanthodiacrodium* / *Actinotodissus* group and also to *Tectitheca* Burmann 1968.

Text - fig. 20

a) Showing a typical specimen of the genus <u>Goniosphaeridium</u>.

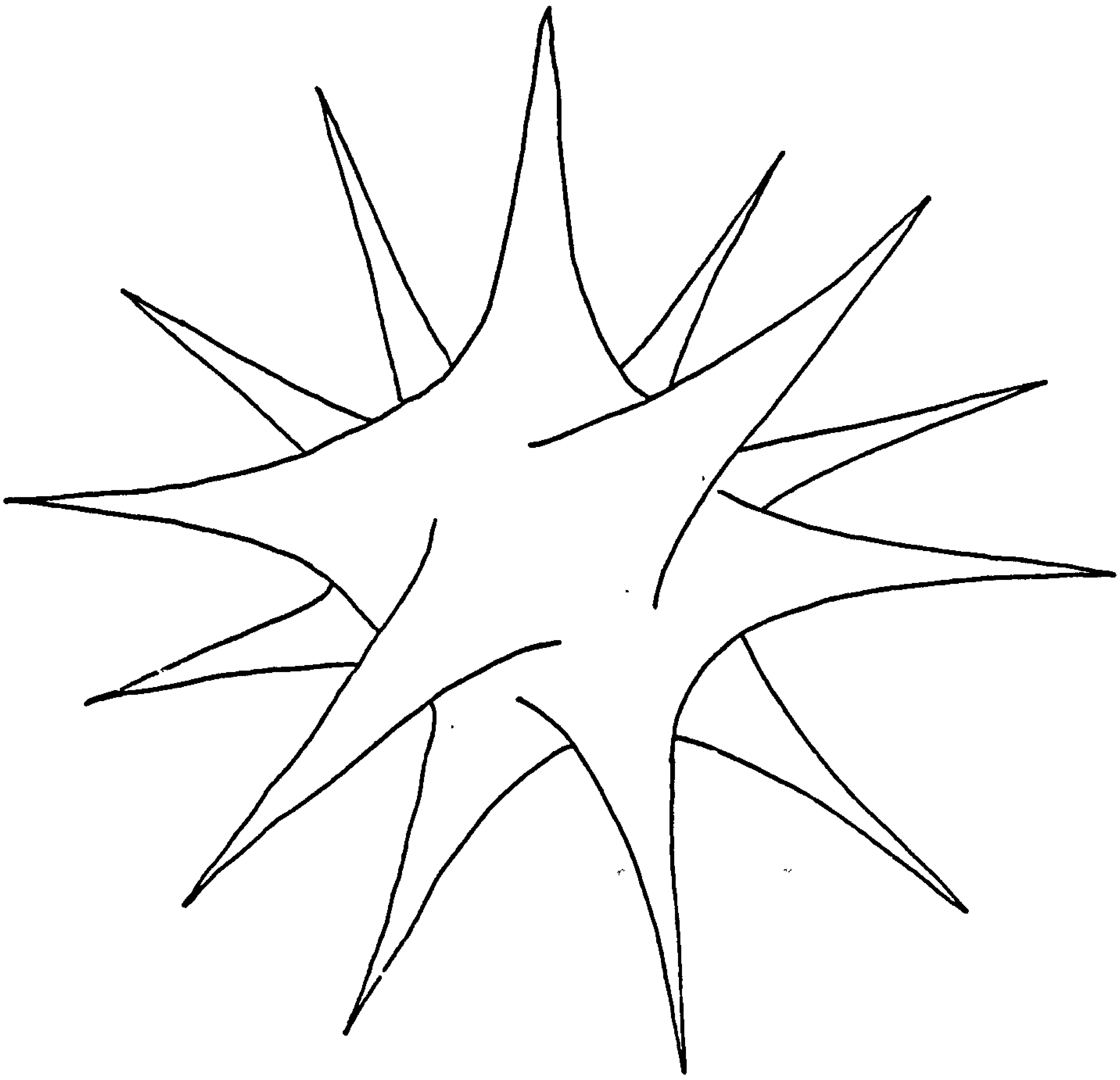
note the broad based, conical processes which taper gradually throughout their length. This style of process appears to be characteristic of Middle and Upper Ordovician populations.

b) Showing a typical specimen of the group referred to here as '<u>Polygonium</u>'.

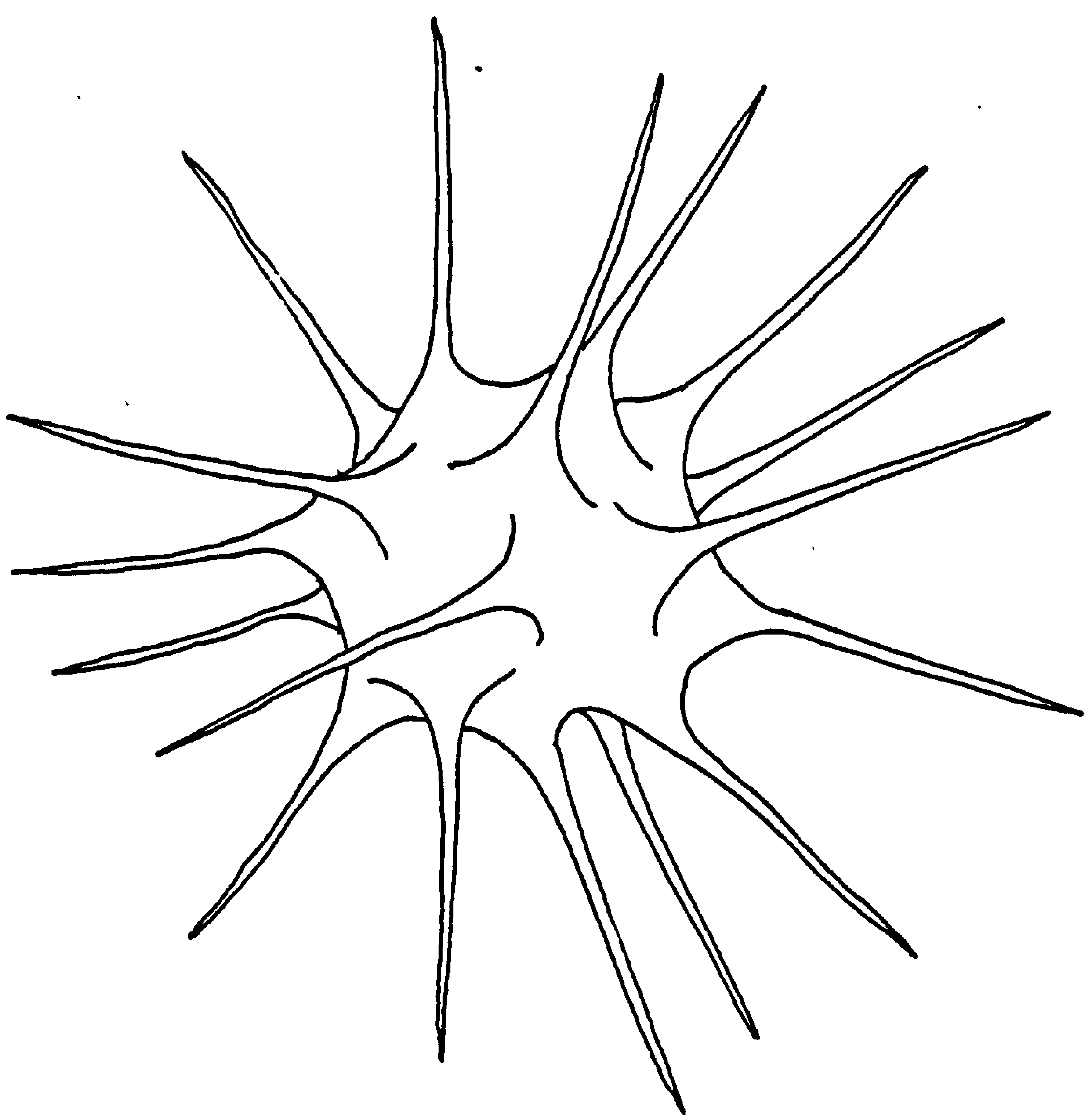
note the numerous slender processes which flare rapidly at the base. This style of process appears to be typical of Tremadoc and Lower Ordovician populations.

The two process styles illustrated should not be considered age-diagnostic nor are they mutually exclusive. However each style does seem to dominate and be characteristic of populations at the stratigraphical levels indicated.

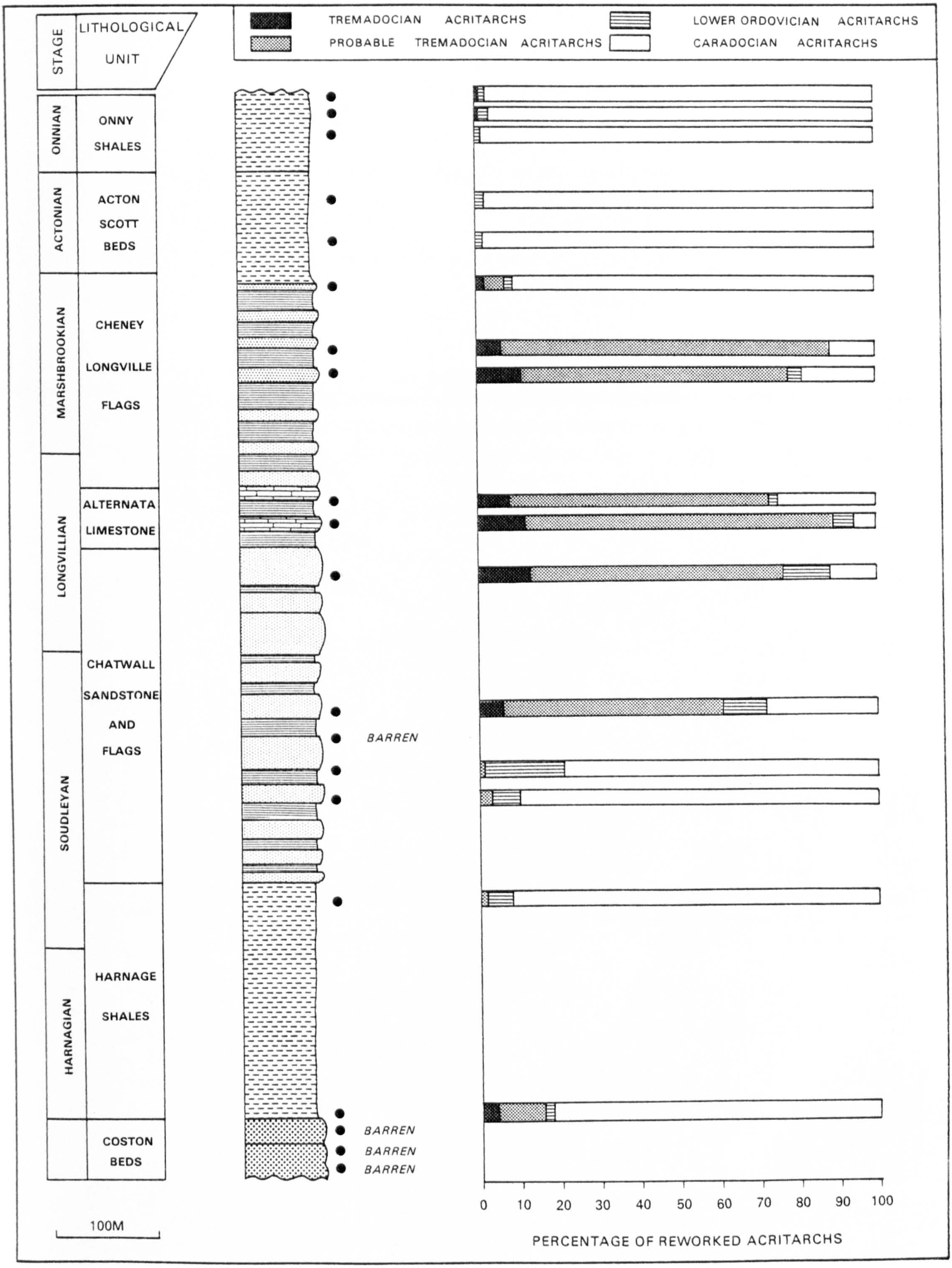
Text-fig. 20



a



b


STAGE
LITHOLOGICAL UNIT
TREMADOCIAN ACRITARCHS
PROBABLE TREMADOCIAN ACRITARCHS
LOWER ORDOVICIAN ACRITARCHS
CARADOCIAN ACRITARCHS
ONNIAN
ONNY SHALES
ACTONIAN
ACTON SCOTT BEDS
MARSHBROOKIAN
CHENEY LONGVILLE FLAGS
LONGVILLIAN
ALTERNATA LIMESTONE
CHATWALL SANDSTONE AND FLAGS
SOUDLEYAN
HARNAGIAN
HARNAGE SHALES
COSTON BEDS
BARREN
BARREN
BARREN
BARREN
100M
0
10
20
30
40
50
60
70
80
90
100
PERCENTAGE OF REWORKED ACRITARCHS

Text-fig. 21

Text - fig. 22

All magnifications X1200

ACRITARCHS REWORKED FROM ROCKS OF TREMADOC AGE

2. *Cymatiogalea cristata* (Downie 1958) Rasul 1974:
OV/A/2b-1; 9.8/106.0.

3. *Dasydiacrodium palmatilobum* Timofeev 1959:
OV/UHS/1-2; 8.8/123.1.

4. *Timofeevia* cf. *phosphoritica* Vanguestaine 1978:
OV/HS/2-1; 17.1/88.1.

5. *Saharidia fragile* (Downie 1958) Combaz 1967:
OV/HS/1-1; 21.9/113.0; phase-contrast.

6. *Trichosphaeridium annolovaense* Timofeev 1966:
OV/A/1a-1; 4.2/94.4.

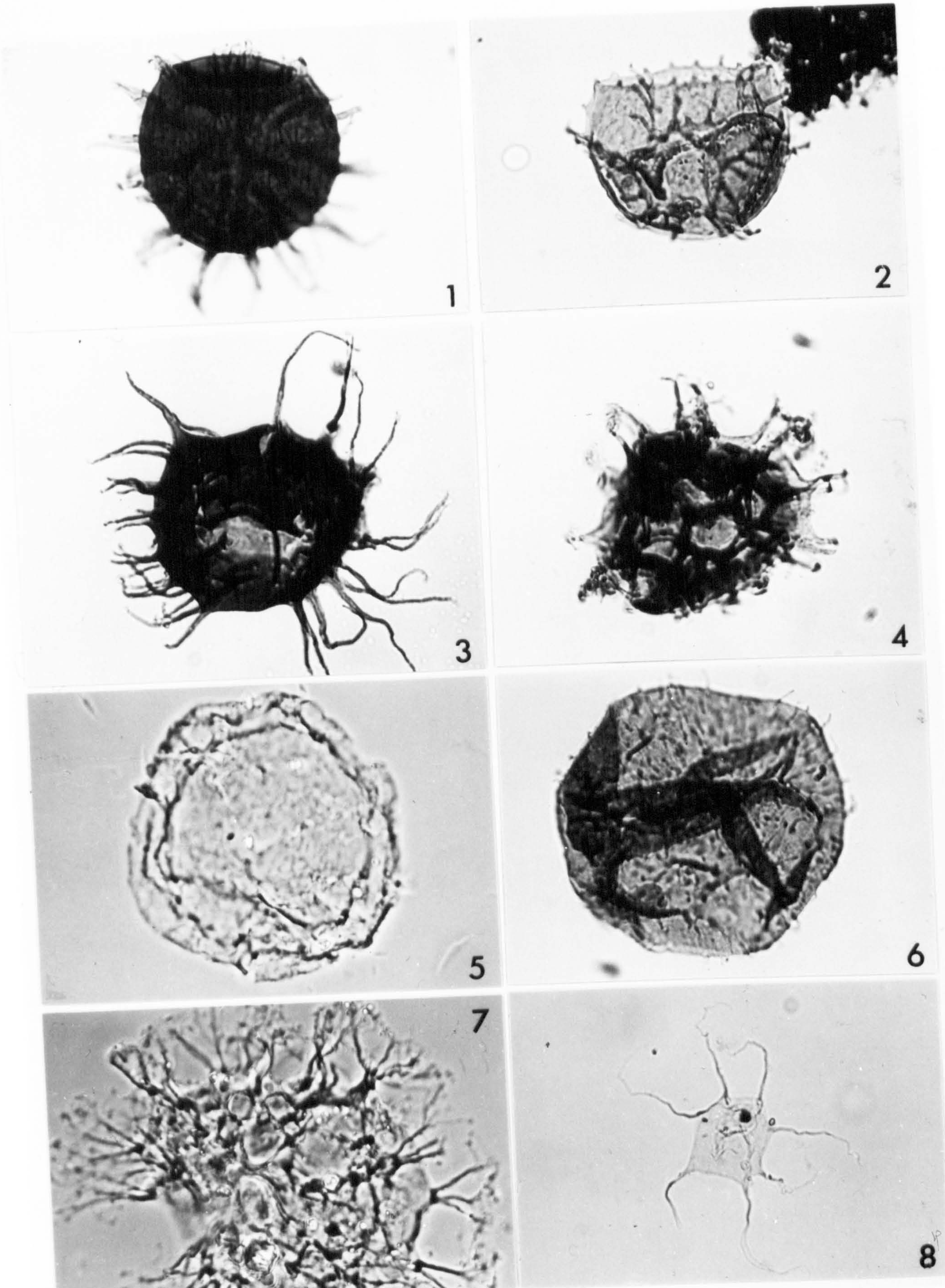
8. *Impluviculus multiangularis* (Umnova 1971) Vanguestaine 1973 (M.S.).

ACRITARCHS REWORKED FROM ROCKS OF PROBABLE TREMADOC AGE

1. *Stelliferidium distinctum* (Rasul 1974) Booth 1979(M.S.):
OV/A/1a-1; 6.1/130.4.

7. *Vulcanisphaera cirrita* Rasul 1977:
OV/HS/1-1; 19.6/102.1; phase-contrast.

Text-fig. 22



<u>Text - fig. 23</u>

All magnifications X1200

<u>ACRITARCHS REWORKED FROM ROCKS OF EARLY ORDOVICIAN AGE</u>

1. <u>Dicrodiacrodium</u> <u>normale</u> Burmann 1968:
NS/4-1; 6.4/89.2.

2. <u>Frankea</u> <u>hamata</u> Burmann 1970:
OV/LHS/2b-7; 15.4/121.8.

3. <u>Marrocanium</u> <u>simplex</u> Cramer, Kanes et al. 1974:
NS/4-4; 10.3/133.1.

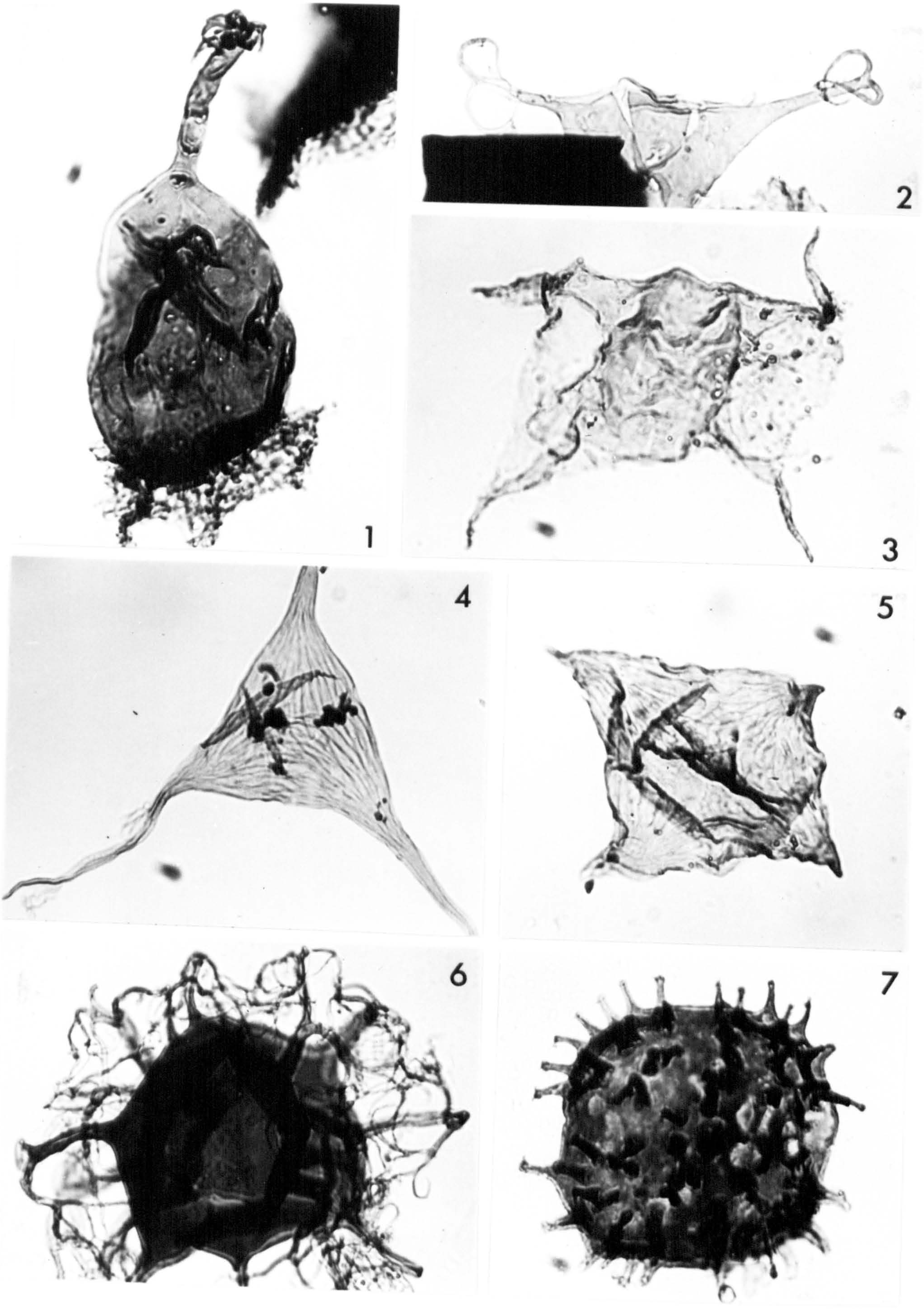
4. <u>Arkonia</u> <u>virgata</u> Burmann 1970:
OV/LCL/2-1; 15.1/105.2.

5. <u>Striatotheca</u> <u>quieta</u> [Martin 1969] Rauscher 1973:
NS/4-4; 20.2/96.8.

6. ? <u>Tunisphaeridium</u> <u>eligmosum</u> Vavrdova 1973:
OV/A/1b-1; 16.8/117.4.

7. <u>Coryphidium</u> <u>australe</u> Cramer and Diez 1976:
OV/MHS/1-3; 7.4/119.9.

Text-fig. 23



Text - Fig. 24

All magnifications X1200

ACRITARCHS REWORKED FROM ROCKS OF PROBABLE TREMADOC AGE

1,3,4 '*Polygonium*' spp.

1. OV/A/1a-1; 19.7/110.3.

3. OV/UHS/1-1; 22.3/129.2.

4. OV/A/1a-1; 20.0/108.0.

2. *Vulcanisphaera* sp.

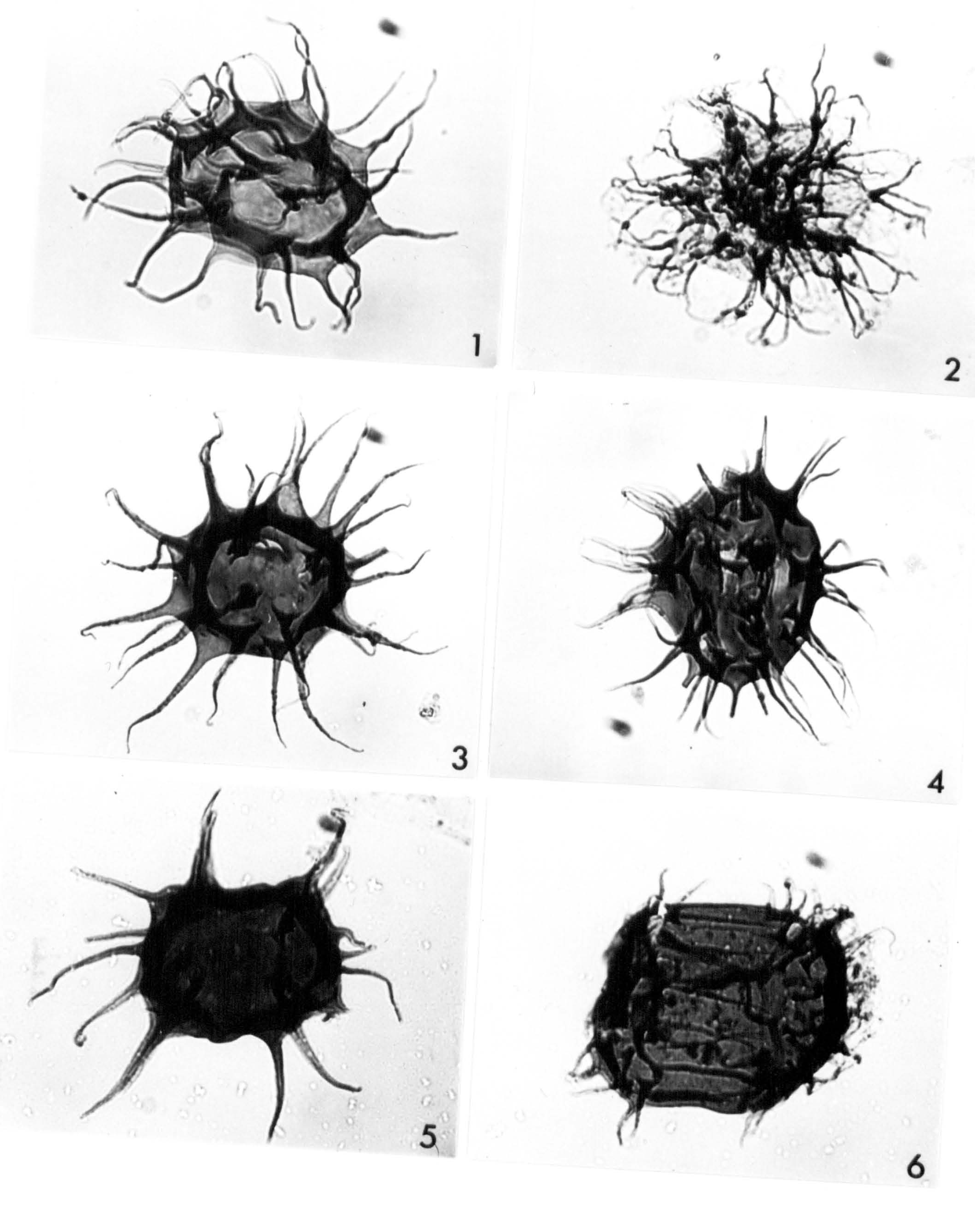
OV/A/1a-1; 21.2/127.4.

5,6 *Actinotodissus* / *Acanthodiacrodium* spp.

5. OV/UHS/1-1; 15.7/122.0.

6. OV/UHS/1-1; 12.6/107.9.

Text-fig. 24



Chapter Seven

STRATIGRAPHICAL PALYNOLOGY

In this chapter the assemblages of acritarchs recovered from the three study areas are discussed. Associations of species which are provisionally interpreted as having some stratigraphical significance are described from the Anglo-Welsh region. Assemblages from the Girvan district which are considered separately because of the special problems encountered with this material, give an indication of the palaeoenvironment during deposition.

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1. The Llandeilo Region

Samples from the type-area of the Llandeilo Series yielded acritarchs varying widely in abundance and diversity; most preparations contained only limited numbers of individuals representing comparatively few taxa whilst one or two assemblages were impoverished with acritarchs only rarely recorded; exceptionally acritarchs were abundant. The preservation of these microfossils was moderate to poor with compression of the vesicle and carbonisation of the wall being constant features. A number of long-ranging forms were present in most samples particularly representatives of the genera Peteinosphaeridium and Veryhachium. Some essentially Lower Ordovician taxa such as Barakella and Pirea apparently persisted in this area until earliest Llandeilo time while the distinctive species Astropheos _llandeilensis_ sp.nov., previously described from the British Llanvirn (Booth 1979 M.S.), remained common until early Middle Llandeilo time when it suffered an abrupt extinction. _Veryhachium_ sp.A has a limited local range, only being recorded from adjacent to the Lower-Middle Llandeilo boundary while the characteristic taxa _Solisphaeridium lucidum_ comb.nov., _Goniosphaeridium_ sp.B and _Nothooidium_ sp.A are present throughout the Lower and Middle Llandeilo. Common forms such as _Micrhystridium aremoricanum_, _M. henryi_ and _Multiplicisphaeridium raspa_, all well known from the Arenig and Llanvirn, probably became extinct in the late Middle Llandeilo although the possibility that they continued into the Upper Llandeilo cannot be excluded, (sporadic occurrences of these species in the Caradoc of Shropshire probably represent reworking).

The forms considered of potential stratigraphical significance are shown in text-fig.25 with an indication of their abundance. At present it is not considered practical to attempt any subdivision of the Llandeilo on the basis of acritarch floras.

2. Shropshire

Only assemblages from the type-section in the southern Caradoc area are considered in detail here since productive samples from the Chatwall district are stratigraphically restricted; the Harnage Shales alone contain abundant acritarchs at Chatwall, the higher horizons exposed either yielding impoverished assemblages or being altogether barren.

The type section in the valley of the River Onny contains prolific acritarchs at most horizons sampled, the microfossils generally being very well preserved. As shown in text-fig. 28 the Harnage Shales in this area are marked by the first appearance of a large number of taxa. This apparently significant phenomenon must however be regarded with circumspection since few data have been obtained from the Upper Llandeilo or the Costonian; consequently little is known of acritarch distribution across the Llandeilo-Caradoc boundary. Allowing for this gap in our knowledge a number of new or particularly important forms first appear in the Harnage Shales (see text-fig.26). Species such as <u>Epistomium trirhethium</u> gen.et sp.nov., <u>Diaphorochroa homoios</u> sp.nov., <u>Veryhachium irroratum</u> and <u>Villosacapsula setosapellicula</u> are all first recorded at the base of the Harnage Shales where they are associated with the distinctive sphaeromorph <u>Leiosphaeridia tenuissima</u>. This taxon, previously known only from Tremadoc to Llandeilo strata is here recorded up to the base of the Soudleyan. This association of species appears to be characteristic of the early Caradoc in the type area.

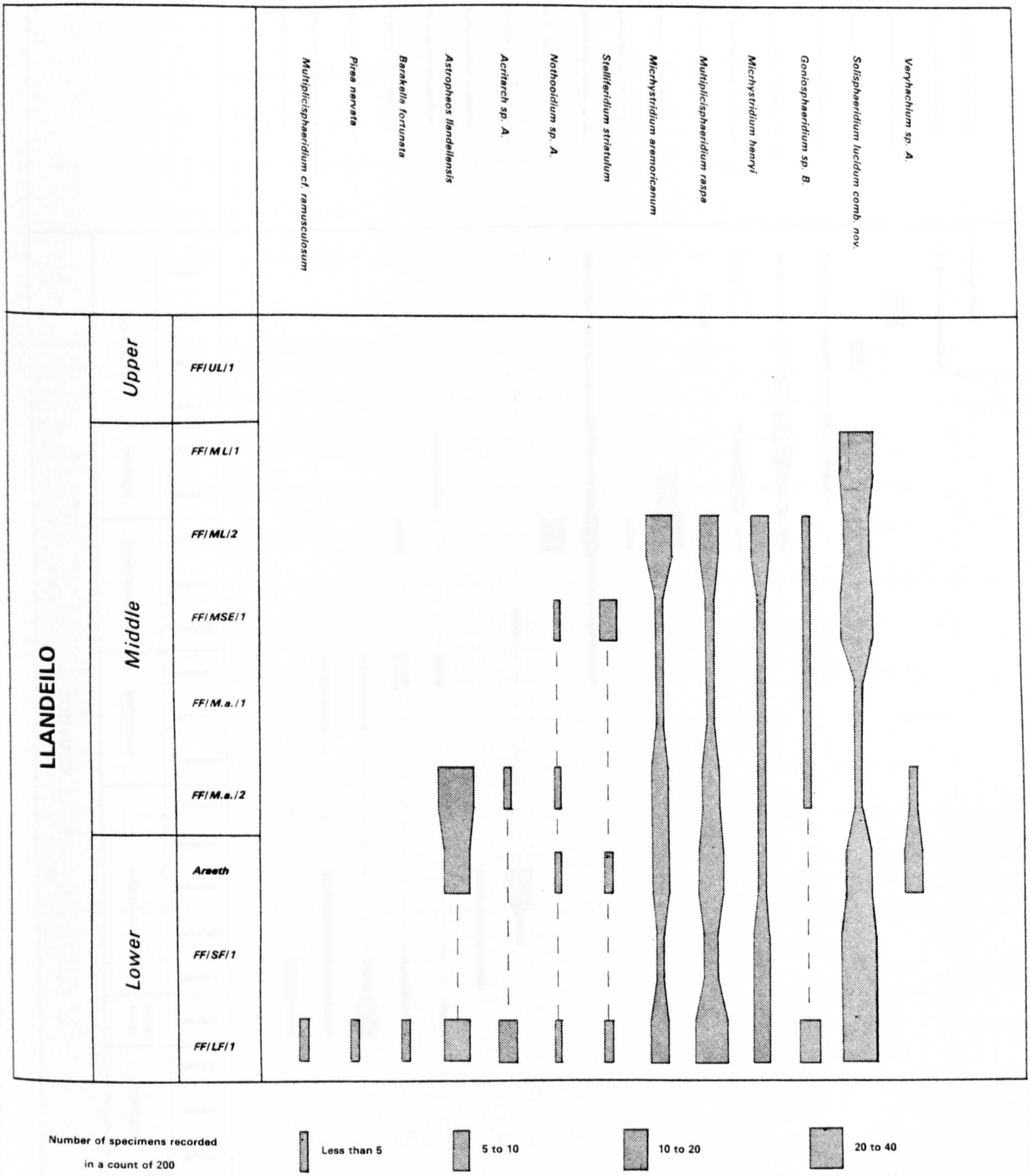
Data from the middle part of the type-section (Upper Soudleyan to Marshbrookian) are undoubtedly substantially modified by the high percentages of reworked acritarchs present in these assemblages. (see chapter 6, text-fig.21). The reworking tends to 'dilute' the indigenous species recovered so that rare forms are less likely to be recorded; this affects the apparent distribution of such forms so that many taxa appear to be missing from this part of the section.

Thus although the top of the Marshbrookian is apparently marked by an influx of new species, it is possible that some of the less common of these actually appear lower in the sequence but are not recorded here. Despite this, many of the new forms are sufficiently abundant that they may be considered as locally characteristic of the Upper Caradoc. This association of species such as Veryhachium rhomboidium, Baltisphaerosum christoferii comb.nov. Baltisphaeridium pauciverrucosum and Orthosphaeridium bispinosum sp.nov. is augmented at the base of the Actonian by the appearance of Diaphorochroa diaphorosos sp.nov.. This species is probably directly derived from the Lower and Middle Caradoc taxon Diaphorochroa homoios sp.nov.

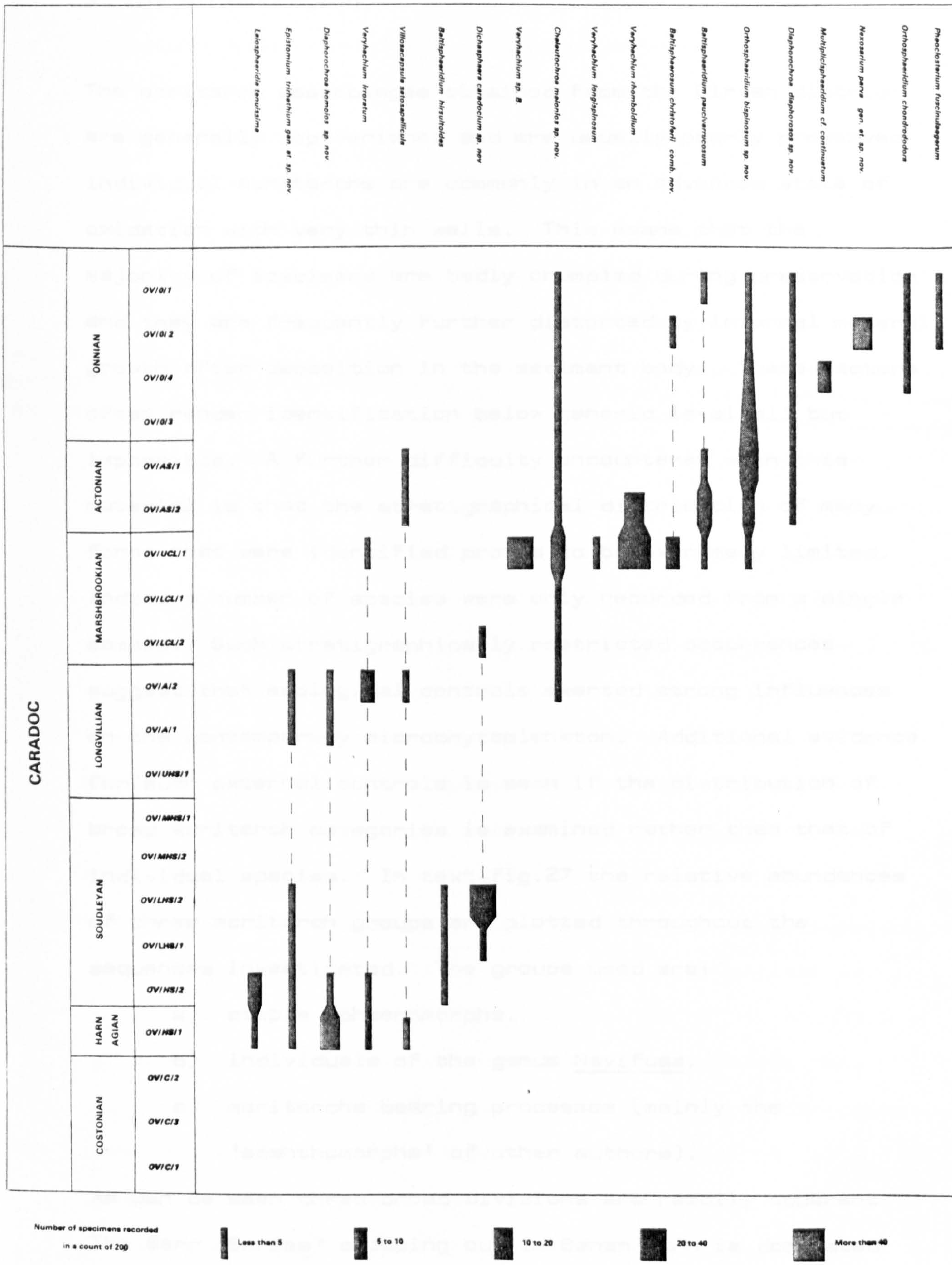
In the Onnian, rare but distinctive forms such as Nexosarium parva gen.et.sp.nov., Orthosphaeridium chondrododora and Pheoclosterium fuscinulaegerum first appear and are diagnostic of this topmost stage of the Caradoc.

The distribution and abundance of the most stratigraphically significant species are shown in text-fig.26. To summarise, four acritarch associations considered to be of stratigraphical significance are recognised from the Llandeilo-Caradoc of the Anglo-Welsh region. These appear to be characteristic of:

1. The Llandeilo.
2. The Lower Caradoc.
3. The Upper Caradoc.
4. The Onnian Stage.



Text-fig. 25 Distribution and abundance of selected acritarch species from the type section of the Llandeilo



Text-fig. 26 Distribution and abundance of selected acritarch species from the type section of the Caradoc.

3. The Girvan Region

The acritarch assemblages obtained from the Girvan district are generally impoverished and are usually poorly preserved; individual acritarchs are commonly in an advanced state of oxidation with very thin walls. This means that the majority of specimens are badly crumpled during preservation and they are frequently further distorted by internal mineral growth after deposition in the sediment body. These factors often render identification below generic level all but impossible. A further difficulty encountered with this material is that the stratigraphical distribution of many forms that were identified proves to be extremely limited. Indeed a number of species were only recorded from a single sample. Such stratigraphically restricted occurrences suggest that ecological controls exerted strong influences on the contemporary microphytoplankton. Additional evidence for such external controls is seen if the distribution of broad acritarch categories is examined rather than that of individual species. In text-fig.27 the relative abundances of three acritarch groups are plotted throughout the sequences investigated. The groups used are:

a] simple sphaeromorphs.

b] individuals of the genus <u>Navifusa</u>.

c] acritarchs bearing processes [mainly the 'acanthomorphs' of other authors].

As can be seen three broad divisions are readily apparent. The Barr 'Series' cropping out in Benan Burn is dominated by sphaeromorphs which never form less than 70% of the assemblages; navifusids and acanthomorphs combined form only a minor consituent. Higher in the stratigraphical sequence, within the Balclatchie and Ardwell Groups, sphaeromorphs still form an important part of the assemblages but Navifusids have become much more abundant and form between 25% and 70% of the total acritarch assemblages; acanthomorphs are rare or absent. It is significant that this situation exists both at Penwhapple Burn and in beds which are approximate lateral correlatives, on the shore north of Kennedy's Pass; from this it is clear that this is not a purely local phenomenon but a change in the composition of the microphytoplankton which occurred over much of the area. Finally in the Whitehouse Group and Shalloch Formation the abundance of sphaeromorphs is somewhat reduced while acanthomorphs become common; they do in fact become almost totally dominant locally. Navifusid numbers are much reduced at the base of this interval and the genus is altogether absent from higher horizons. This distribution pattern obviously does not reflect an evolutionary sequence and is best interpreted as the result of facies control of the contemporary acritarch populations.

A possible explanation of such a distribution pattern is suggested by the work of Staplin 1961. In an investigation of acritarchs from Devonian rocks in western Canada this author was able to demonstrate that sphaeromorphs dominated assemblages from shallow-water localities close to reefs; in addition this dominance was shown to be inversely proportional to increasing distance from the reefs and therefore increasing water-depth. This was not because of any decrease in sphaeromorphs [these actually increased in numbers away from the reef) but because of an increase in both abundance and diversity in acanthomorphs in the off-reef, deeper-water areas. From the results of this study it appears that the ratio of sphaeromorphs to acanthomorphs may be taken as a fairly sensitive palaeoenvironmental indicator. If this conclusion is applied to the Girvan data then it is probable that the calcareous sediments of the Barr 'Series' were shallow water deposits since the acritarchs that they contain are overwhelmingly dominated by sphaeromorphs.

Higher in the sequence the Ardwell Group, consisting of an essentially unfossiliferous shale-greywacke succession has been interpreted as a deep-water turbidite facies (Kuenen 1953, p.43). Williams (1962) accepted Kuenen's ideas and attempted to reconcile the close juxtaposition of shallow-water deposits with the 'deep-water' Ardwell Beds by postulating recurrently active faults bounding deep basins. Hubert (1965,pp.679-682) re-examined these sediments and suggested that they were not deep-water deposits but were in fact the product of shallow-water sedimentary processes. The evidence available from the acritarchs recovered would seem to support this contention since assemblages from this level continue to be dominated by sphaeromorphs while the rarity of acanthomorphs indicates shallow-water deposition. The abnormal abundance of Navifusids in these horizons remains enigmatic since nothing is known of the palaeoenvironmental distribution of these forms.

The Whitehouse and Shalloch Formation assemblages continue to be sphaeromorph dominated but show a notable increase in the numbers of acanthomorphs present. This may be taken to indicate an offshore and presumably deeper water locality but still within a shallow shelf environment. Once again this tends to confirm the conclusions of Hubert who suggested (p.297) that these horizons originated in the deeper part of the neritic zone.

In conclusion, the acritarch data available, while of limited stratigraphical interest, tend to confirm the view that Llandeilo-Caradoc deposition in the Girvan district took place during a gradual transgression across a pre-Llandeilo landmass.

Addendum

List of species identified from the Middle and Upper Ordovician of Girvan.

Baltisphaeridium longispinosum subsp. delicatum subsp.nov.

B. cf. multipilosum (Eisenack 1931) Eisenack 1959a.

Baltisphaerosum onniensis gen.et sp.nov.

Dichasphaira caradocium sp.nov.

Eupoikilofusa cabottii

Goniosphaeridium elongatum sp.nov.

G. cf. polygonale.

G. polygonale forma sphaeroidalis Eisenack 1965a.

G. splendens comb.nov.

Leiofusa sp.

Leiosphaeridia ketcheniata

L. cf. voigti.

Lophosphaeridium spp.

Micrhystridium spp.

Multiplicisphaeridium irregulare.

Navifusa ancepsipuncta.

N. similis.

Ordovicidium heteromorphicum.

Peteinosphaeridium nudum.

P. trifurcatum subsp. breviradiata.

P. trifurcatum subsp. intermedium.

Priscotheca sp.

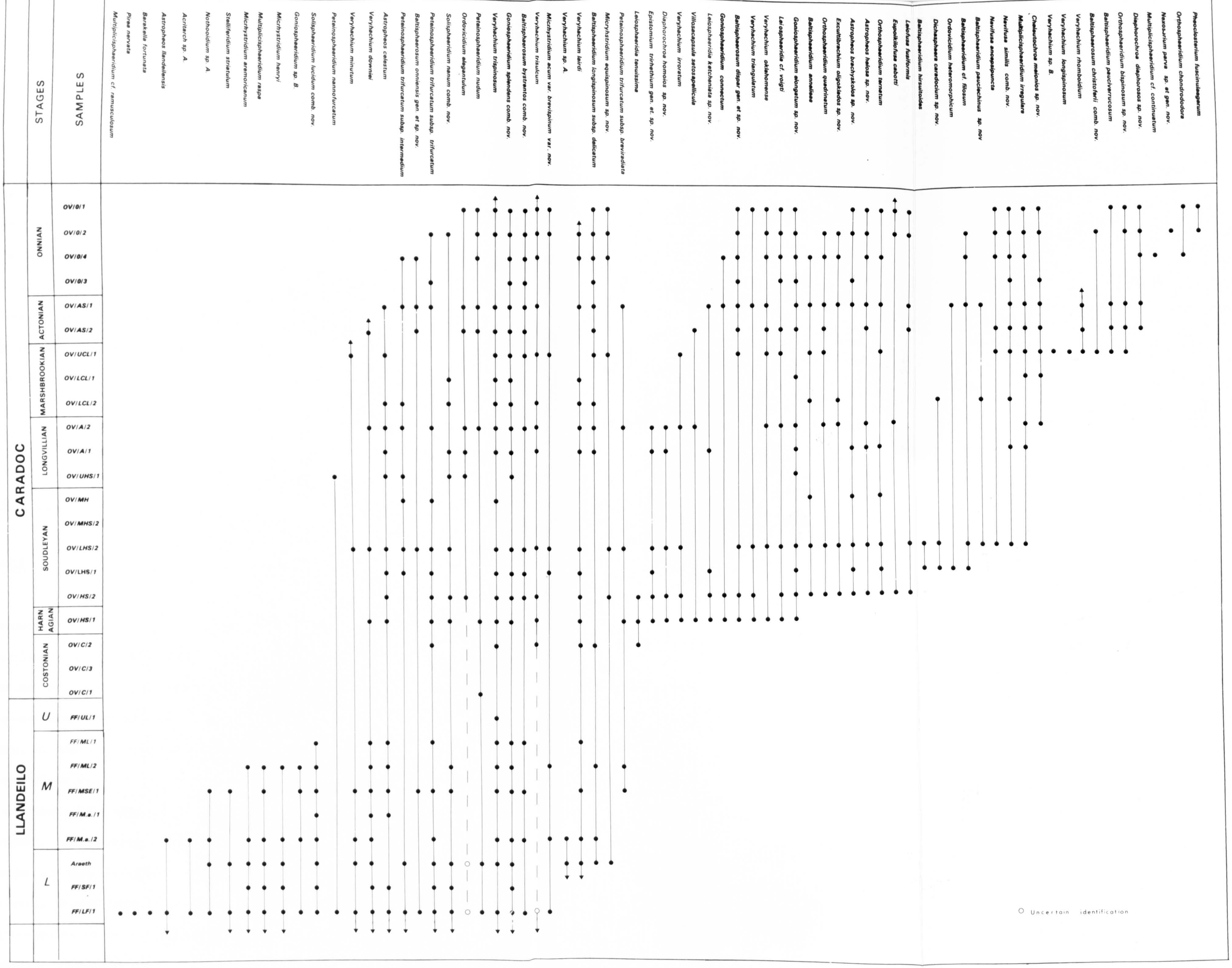
Veryhachium irroratum.

V. lairdi.

V. trispinosum.

V. trisulcum.

Text-fig. 27 Distribution and abundance of three acritarch groups throughout the Middle and Upper Ordovician of Girvan.



Text-fig. 28 Showing the stratigraphical distribution of acritarch species in the Llandeilo-Caradoc of the Anglo-Welsh region.

Chapter Eight

COMPARISONS WITH ASSEMBLAGES FROM OTHER AREAS

Comparisons are made with Llandeilo and Caradoc acritarch assemblages from other parts of the world. Section 1 consists of detailed comparisons with assemblages from specific localities. In Section 2 a general comparison is made between the Anglo-Welsh area and four other regions. Data from other areas are too scattered for this comparison to be extended.

Section 1

FRANCE

Llandeilo

Detailed comparison with acritarchs from France is not easy because of the relatively few and always poorly preserved, impoverished assemblages that have been described. In addition many of the published records either refer to material which is imprecisely located stratigraphically or which has been age-dated partly or wholly on the acritarch content. Rauscher (1973) describes a limited assemblage of Llandeilo age which is dominated by the genus Veryhachium. The only significant species recorded in common with the Anglo-Welsh area is Solisphaeridium lucidum comb.nov. which Rauscher records from the late Llandeilo to the early Caradoc.

Deunff and Le Corre [1969] list a very similar assemblage.

Caradoc

The most significant publications on acritarchs considered to be of Caradoc age are those of Deunff [1959] and Henry [1959]. The latter author in particular describes a diverse assemblage in which the genera Veryhachium Baltisphaeridium and Micrhystridium are prominent. Forms known from the British Caradoc such as Orthosphaeridium ternatum and possibly O.bispinosum sp.nov. are recorded here, as again is S.lucidum. However the French assemblages are characterised by abundant individuals of the genera Aremoricanum Deunff 1955 and particularly of Cymatiosphaera [Wetzel 1933] Deflandre 1954. These forms, belonging to several different species, are unknown in British Caradoc strata. On the other hand the genera Astropheos, Peteinosphaeridium and Goniosphaeridium all important constituents of the microphytoplankton in the type Caradoc in Shropshire are either rare or absent at this level in France.

BELGIUM

Llandeilo

Martin [1966a] refers to an impoverished assemblage from Sart-Bernard. Here as in the French assemblages the acritarchs are dominated by Veryhachium, Baltisphaeridium and Micrhystridium. Leiosphaeridia is also common while Cymatiosphaera is present. One of the few species occurring in common with the type Llandeilo in South Wales is

Multiplicisphaeridium raspa. Individuals of Frankea (as Veryhachium) sartbernardense are regarded by the present author as probably reworked.

Caradoc

Martin (1969a) and Martin Michot and Vanguestaine (1970) document a diverse, mainly Upper Caradoc assemblage from a number of localities in Belgium. Apart from almost ubiquitous forms such as Veryhachium trispinosum, V.trisulcum and V.lairdi, only Solisphaeridium lucidum, S.nanum and Peteinosphaeridium nudum occur in common with this study. Martin (1974) in describing an undifferentiated Caradoc-Ashgill sequence in a borehole at Lichtervelde records a number of species which are also known from Shropshire; these include Solisphaeridium nanum, Peteinosphaeridium trifurcatum trifurcatum, P.trifurcatum breviradiata, P.nudum, Goniosphaeridium splendens comb.nov. (as G.polygonale) and most significantly Eupoikilofusa cabottii (as Schizaeosporites sp.1). This latter species confirms the late Caradoc or Ashgill age suggested for this assemblage by Martin. It is interesting to note that as in the successions of Shropshire (this study) and D'Ombret (Martin et al. 1970) the sequence at Lichtervelde contains Tremadoc and early Ordovician acritarchs which Martin recognised as reworked.

PORTUGAL

Caradoc

A single acritarch assemblage has been described from Portugal which on the evidence of the microflora is interpreted as being of Caradoc age (Henry and Thadeau 1971). This assemblage is almost identical to those obtained from Brittany (Deunff 1959, Henry 1959) and is dominated by representatives of the genera Aremoricanum, Cymatiosphaera and to a lesser extent Priscotheca. Apart from species of Veryhachium, the only form possibly occurring in common with the Anglo-Welsh area is Orthosphaeridium bispinosum sp.nov. (as Veryhachium deunffi in part) although synonomy is not firmly established.

AUSTRALIA

Llandeilo

In the only publication to date on Ordovician acritarchs from Australia, Combaz and Peniguel (1972) discuss mainly Lower Ordovician assemblages dated on both macro and micropalaeontological grounds. However the upper part of the sequence investigated is interpreted by authors as being of Llandeilo age and a restricted acritarch assemblage of ten species is described. Of these only P.trifurcatum and V.lairdi are also known from Britain.

THE UNITED STATES OF AMERICA

Llandeilo and Caradoc

Both stratigraphical series are dealt with together here because of special problems attached to much of the literature dealing with this area. Diverse, abundant and extremely well preserved acritarchs have been described from the eastern central U.S.A. mainly by Loeblich and Tappan

(Loeblich 1970a, 1970b; Loeblich and Tappan 1969, 1970, 1971b, 1978; Tappan and Loeblich 1971). However, in the Llandeilo, out of twenty seven species recorded by these authors twenty six are new; in the Caradoc the figures are forty three new species out of forty three described. Work by Jacobson (1978) shows that forms proviously recorded from north-west Europe are present in American assemblages. From this it is clear that Loeblich and Tappan have concentrated on the description of new taxa and have excluded from their publications almost all references to previously described species. This factor means that detailed comparisons with the U.S.A. are of little value since the data currently available from this area is heavily biased. Despite this a general comparison is made in Section 2 since some of the species described from the U.S.A. by Loeblich and Tappan are also recorded in this study from the Anglo-Welsh area.

THE BALTIC

Many publications on Baltic mid and late Ordovician acritarchs have appeared, most notably those of Eisenack; unfortunately many of the assemblages recorded have no precise stratigraphical details given or have no independent controls for the assumed ages. For comparative purposes the work of Kjellstrom (1971a, 1971b, 1976) is mainly utilized here while Eisenack's data are incorporated where stratigraphical details are available.

Llandeilo

This is the interval dealt with most comprehensively by Kjellstrom, working with sub-surface material from the Grotlingbo and Ekon boreholes. The assemblages described by Kjellstrom are dominated by such genera as Baltisphaeridium, Baltisphaerosum gen.nov., Peteinosphaeridium and Goniosphaeridium. However, as in the case of the United States, the data presented here are biased. Kjellstrom only reports on those elements of the microphytoplankton which he groups under the heading 'Baltisphaerids'. From the work of Eisenack and the present authors own unpublished data it is clear that many other forms flourished in the Baltic region at this time. Genera such as Leiofusa, Leiosphaeridia, Navifusa and Veryhachium have all been recorded along with many others. Where possible these forms have been included in the general comparison in Section 2. At specific level a number of forms occur both in the Baltic area and in the Anglo-Welsh region, these include Peteinosphaeridium nannofurcatum, P.nudum, P.trifurcatum trifurcatum, P.trifurcatum intermedium, P.trifurcatum breviradiata and Veryhachium sp.A. In general the Baltic assemblages appear to be more diverse and more abundant than those recorded from the type-section at Llandeilo but this may be partially the consequence of poor preservation of the acritarchs from South Wales.

Caradoc

Kjellstrom (1971a, p.61) records seventeen 'Baltisphaerid' species from the Caradoc of the Grotlingbo borehole of which six, Baltisphaeridium hirsuitoides, Goniosphaeridium connectum, *Orthosphaeridium rectangulare*, *Peteinosphaeridium nudum*, *P.trifurcatum* and probably *Multiplicisphaeridium continuatum* also occur in the type section of the Caradoc in Shropshire. *B.hirsuitoides* appears to be restricted to Lower Caradoc strata in both areas. The percentage of common occurrences obtained from using Kjellstrom's work is greatly increased if the data of Eisenack and Tynni (1975) are incorporated where the stratigraphical details are thought to be reliable (Text-fig.29).

An additional problem that is encountered when trying to correlate Baltic acritarch assemblages with those of other areas is that during the Ordovician the Baltic appears to have been a site of optimum conditions for acritarch development. Published evidence and the present authors own unpublished data indicate that individuals of many species attain dimensions which are 30-40% greater in Baltic material than in, for example, populations of the same species in Britain. In addition Baltic forms are frequently thicker-walled and have more strongly developed secondary ornament. This sometimes leads to difficulties in identification of species where prominent wall or process sculpture included in a specific diagnosis, appears to be reduced or even absent away from this 'Baltic influence'.

RUSSIA

Drawing comparisons with Llandeilo and Caradoc acritarch assemblages from the U.S.S.R. is not considered advisable at the present time. Description and illustration in the

Russian literature is commonly totally inadequate for recognition of the numerous new forms described by Soviet authors; also many of these taxa are invalid under various provisions of the I.C.B.N. and cannot be used (see for example Loeblich and Tappan 1976). The inevitable outcome of this unfortunate situation has been that many western workers have in the past almost totally disregarded the Soviet literature so that a dual nomenclature is now well established. The increasing importance attached to fine details of secondary ornament by western workers will certainly tend to reinforce this dual nomenclature since detailed descriptions and high magnification, high quality illustrations are vital for the elucidation of such features. There seems to be little hope of reversing this deplorable trend without adequate re-description of much of the Russian material.

As yet, relatively few acritarch taxa are known which appear to have been both geographically widespread and stratigraphically restricted during Middle and Late Ordovician time. The present author considers that this is undoubtedly due to the inadequacy of the data currently available. The biased nature of data from the Baltic and North America, discussed above, is doubly unfortunate since the acritarchs from these areas are probably the most diverse, best preserved and thus potentially the stratigraphically most valuable assemblages so far recovered from strata of this age. The omission of many acritarch taxa from the literature dealing with these areas creates considerable difficulties in assessing the usefulness of these microfossils in international correlation, a problem which is exacerbated by the deficiencies of the Russian literature. Despite this a few taxa can now be recognised as having a wide areal distribution and which are restricted to the Middle and Upper Ordovician. Some of the more significant of these are listed below together with their known distribution.

Species	Geographical Occurrence	Stratigraphical Occurrence
Multiplicisphaeridium irregulare.	North America.	Llandeilo-Caradoc.
	Baltic.	Landeilo-Caradoc.
	Anglo-Welsh Area.	Caradoc.
Navifusa similis.	Baltic.	Upper Ordovician.
	Australia.	Llandeilo.
	Anglo-Welsh Area.	Caradoc.
	Girvan.	Caradoc.
Navifusa ancepsipuncta.	North America.	Llandeilo.
	Bulgaria.	Upper Ordovician.
	Anglo-Welsh Area.	Caradoc.
	Girvan.	Caradoc.
Veryhachium irroratum.	North America.	Llandeilo.
	Bulgaria.	Upper Ordovician.
	Anglo-Welsh Area.	Caradoc.
	Girvan.	Caradoc.

Species	Geographical Occurrence	Stratigraphical Occurrence
Eupoikilofusa	North America.	Ashgill-Llandovery.
cabottii.	Belgium.	Ashgill-Llandovery.
	Anglo-Welsh Area.	Caradoc-Llandovery.
	Girvan.	Caradoc.

The last species listed, *E.cabottii*, although not restricted to the Middle and Late Ordovician is worthy of mention since it appears to be one of the few distinctive and widespread species that are known to span the Ordovician - Silurian boundary. It is expected that this list of internationally useful stratigraphical markers will be substantially enlarged by future research.

Section 2.

In this section records of acritarch species from the Llandeilo and Caradoc of four widely separated areas are combined to give a general comparison between these regions and the Anglo-Welsh area investigated here. The percentage of common occurrences is taken to give an indication of the relationships between the palaeophytoplankton of these areas during mid and late Ordovician time. A number of factors combine to suggest that any conclusions which are drawn must be regarded as tentative. These factors are listed below.

1. Inequality in the number of publications dealing with each area.
2. Biased recording in the literature.

3. Inequality in the preservation of assemblages from different areas.
4. Poor acritarch recovery from the type Llandeilo.

Despite these factors it is clear from Text-fig.29 that in terms of species distribution the Baltic region is much more closely linked to the Anglo-Welsh area than are any of the other areas for which significant data are available. Over 50% of the species recorded from the Baltic are also known from the same stratigraphical horizons in the British Isles. Since acritarchs were predominantly planktonic in their mode of life this is a clear indication of a free interconnection between the shallow seas which covered the two areas in mid and late Ordovician time. This agrees closely with the findings of Williams [1969a, 1969b] who, on the basis of brachiopod distribution and provincialism postulated a south-westerly oceanic current from the Baltic into the Anglo-Welsh Trough during the Caradoc. The occurrence of a number of 'American' acritarch species within the Anglo-Welsh area suggests that a greater mixing of surface waters may have occurred across the Caledonian Trough than was suggested by Williams.

The comparison with France and Belgium shows far fewer species in common, approximately 30%, and of these many are forms such as Veryhachium lairdi and V.trispinosum which have a world-wide distribution. This disparity strongly suggests that these two areas were located in a different microfloral province to the Anglo-Welsh area during the Middle and Upper Ordovician.

This contention is supported by the most recent best estimates of the contemporary palaeogeography which are based mainly on palaeomagnetic data although palaeontological and sedimentary studies are also utilized. The latest base-maps for Llandeilo-Caradoc time indicate that France and southern Britain were separated by 50° of latitude and several thousands of kilometres during this period and that a substantial Scandinavian-eastern European landmass lay between them (Scotese, Bambach et al., 1979, fig.8). It is probable that Spain and Portugal occupied a high latitude position similar to that of France, a circumstance which may explain the close similarities between Portuguese acritarchs of Caradoc age and those of Brittany. It must be stated that other authors have suggested rather different configurations for middle and late Ordovician palaeogeography which often indicate a less dramatic spatial separation of these areas. For instance Whittington and Hughes (1972) show north-west Europe and southern England in much closer proximity but perhaps more significantly have the two areas located in different trilobite provinces. There seems little doubt that the two were separated by some feature which posed a formidable barrier not only to macrofaunal larvae exhibiting a planktonic or nektonic stage of strictly limited duration but also to the marine phytoplankton of the time.

The United States is the region which appears to have the lowest percentage of common occurrences with the Anglo-Welsh region at 16%. However as stated above, the data so far available from the United States is heavily biased and any comparison must necessarily be accepted as being of limited value. It is anticipated that future research will substantially modify our knowledge of acritarchs from the Ordovician of North America.

SPECIES RECORDED FROM THE ANGLO - WELSH AREA	FRANCE	BELGIUM	U.S.A.	BALTIC
Pheoclosterium fuscinulaegerum			•	
Orthosphaeridium chondrododora			•	
Nexosarium parva sp. et gen. nov.				
Multiplicisphaeridium cf. *continuatum*				•
Diaphorochroa diaphorosos sp. nov.				
Orthosphaeridium bispinosum sp. nov.	•			
Baltisphaeridium pauciverrucosum				•
Baltisphaerosum christoferii comb. nov.				•
Veryhachium rhomboidium				
Veryhachium longispinosum				
Cheleutochroa meionios sp. nov.				
Veryhachium sp. B				
Multiplicisphaeridium irregulare				
Navifusa similis comb. nov.			•	•
Navifusa ancepsipuncta			•	•
Baltisphaeridium pauciechinus sp. nov.				
Baltisphaeridium cf. *filosum*				
Ordovicidium heteromorphicum				•
Dichasphaera caradocium sp. nov.				
Baltisphaeridium hirsuitoides				•
Leiofusa fusiformis	•			•
Eupoikilofusa cabotti				
Orthosphaeridium ternatum	•			•
Astropheos helosa sp. nov.				
Astropheos brachyskolos sp. nov.				
Excultibrachium oligoklados sp. nov.				
Orthosphaeridium quadrinatum	•			
Baltisphaeridium annelieae				•
Goniosphaeridium elongatum sp. nov.				•
Leiosphaeridia cf. *voigti*				
Veryhachium oklahomense			•	
Veryhachium triangulatum				
Baltisphaerosum dispar gen. et sp. nov.				
Goniosphaeridium connectum				•
Leiosphaeridia ketcheniata sp. nov.				
Villosacapsula setospellicula			•	
Veryhachium irroratum			•	•
Diaphorochroa homoios sp. nov.				
Epistomium trirhethium gen. et sp. nov.				
Leiosphaeridia tenuissima				•
Peteinosphaeridium trifurcatum subsp. *breviradiata*		•		•
Micryhstridium equispinosum sp. nov.				
Baltisphaeridium longispinosum subsp. *delicatum*				
Veryhachium lairdi	•	•	•	•
Veryhachium sp. A				•
Micrhystridium acum var. *brevispinum* var. nov.				•
Veryhachium trisulcum	•			•
Baltisphaerosum bystrentos comb. nov.			•	
Goniosphaeridium splendens comb. nov.	•			•
Veryhachium trispinosum	•	•		•
Peteinosphaeridium nudum		•		•
Ordovicidium elegantulum			•	
Solisphaeridium nanum comb. nov.		•		•
Peteinosphaeridium trifurcatum subsp. *trifurcatum*		•		•
Baltisphaerosum onniensis gen. et sp. nov.				
Peteinosphaeridium trifurcatum subsp. *intermedium*			•	•
Astropheos celestum		•		
Veryhachium downiei		•		•
Veryhachium minutum	•	•		
Peteinosphaeridium nannofurcatum				•
Solisphaeridium lucidum comb. nov.	•	•		
Goniosphaeridium sp. B				
Micrhystridium henryi	•			
Multiplicisphaeridium raspa		•		
Micrhystridium aremoricanum	•			
Stelliferidium striatulum		•		
Nothooidium sp. A				
Acritarch sp. A				
Astropheos llandeilensis				
Barakella fortunata				
Pirea nervata				
Multiplicisphaeridium cf. *ramusculosum*				
TOTAL NUMBER OF SPECIES RECORDED	35	39	70	50
NUMBER OF SPECIES COMMON WITH ANGLO - WELSH AREA	12	12	11	27
PERCENTAGE OF SPECIES COMMON WITH ANGLO - WELSH AREA	34	31	16	54

Text-fig. 29 Showing how acritarch species recorded from four different areas compare with Anglo-Welsh assemblages.

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PLATE 1

All magnifications X500

1,2,4 _Baltisphaeridium_ _longispinosum_ subsp. _delicatum_ subsp.nov.

1. OV/HS/1-1; 19.9/113.9.
2. NS/4-1; 16.1/100.9. Holotype.
4. OV/A/26-1; 6.4/118.1; with rare accessory process.

3,5,6 _Baltisphaerosum_ _christoferii_ comb.nov.

3. OV/UCL/1-1; 15.4/100.8.
5. OV/AS/1-1; 15.0/125.2.
6. OV/UCL/1-1; 11.6/105.9; specimen with a median excystment split.

PLATE 1

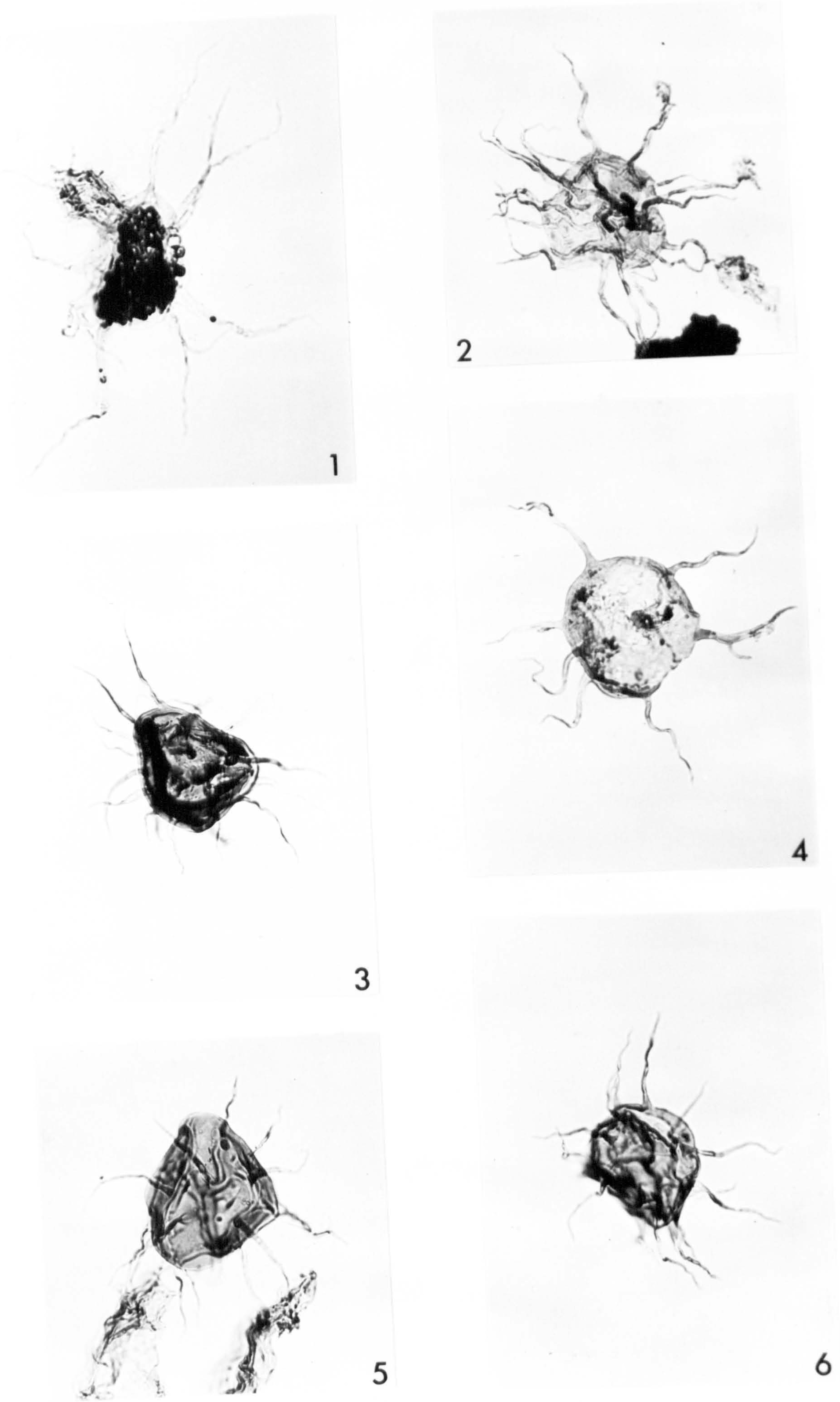


PLATE 2

All magnifications X500

1 - 3 Baltisphaerosum dispar gen. et sp. nov.

1. OV/LHS/2b-6; 6.2/102.5.
2. same specimen under Nomarski interference.
3. OV/AS/1-1; 18.3/103.1; Holotype.

4 - 6 Baltisphaerosum bystrentos comb. nov.

4. OV/A/2b-1; 5.9/105.2. specimen with a median excystment split.
5. OV/A/2b-1; 17.0/112.3.
6. OV/UCL/1-1; 13.6/118.8.

PLATE 2

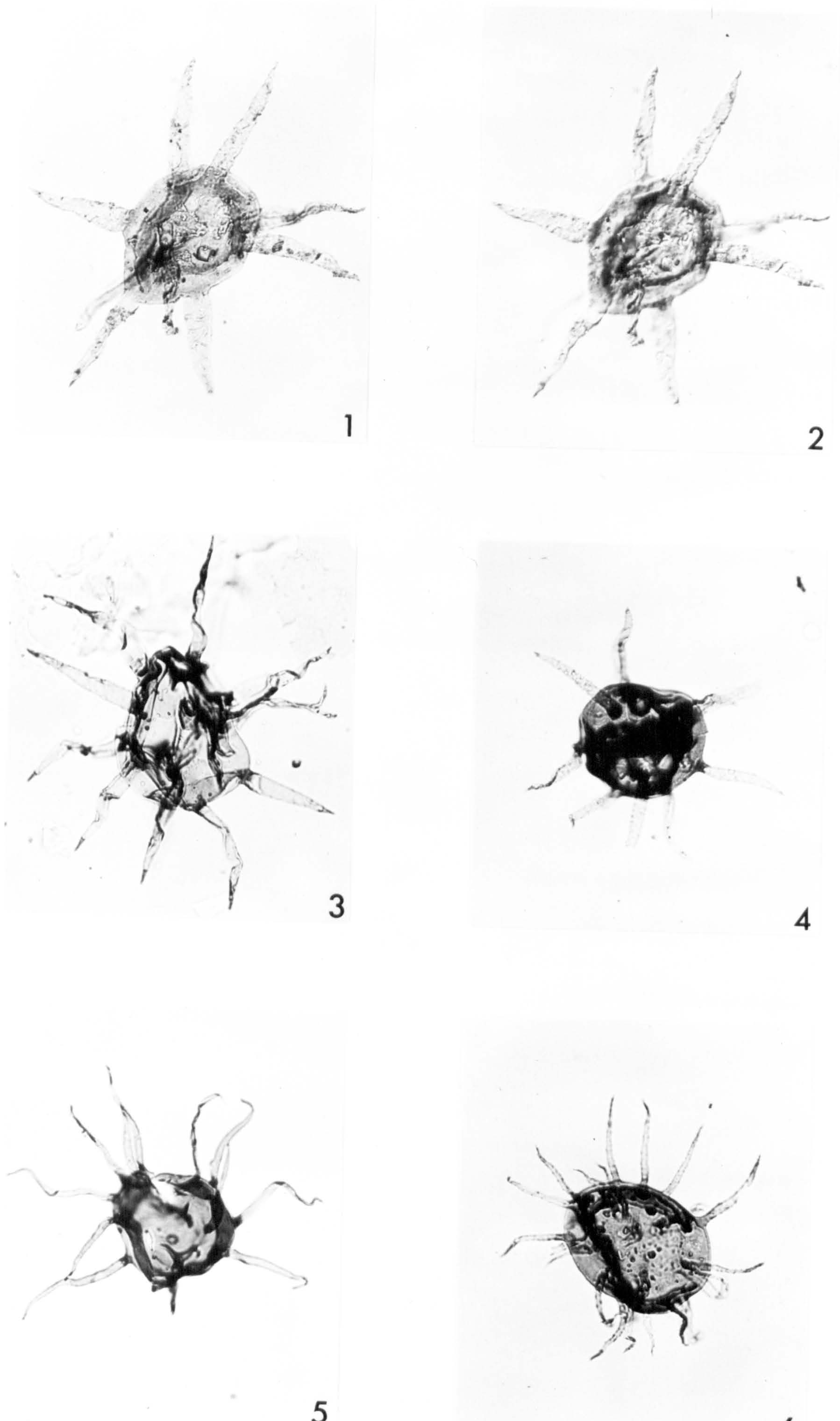


PLATE 3

1,2,4 Baltisphaerosum dispar gen. et sp. nov.

1. OV/AS/1-5; 2.6/101.6; X500.
2. OV/UCL/1-1; 2.7/97.1; X1200; phase-contrast.
4. OV/LHS/2b-6; 5.9/102.4; X1200; phase-contrast.

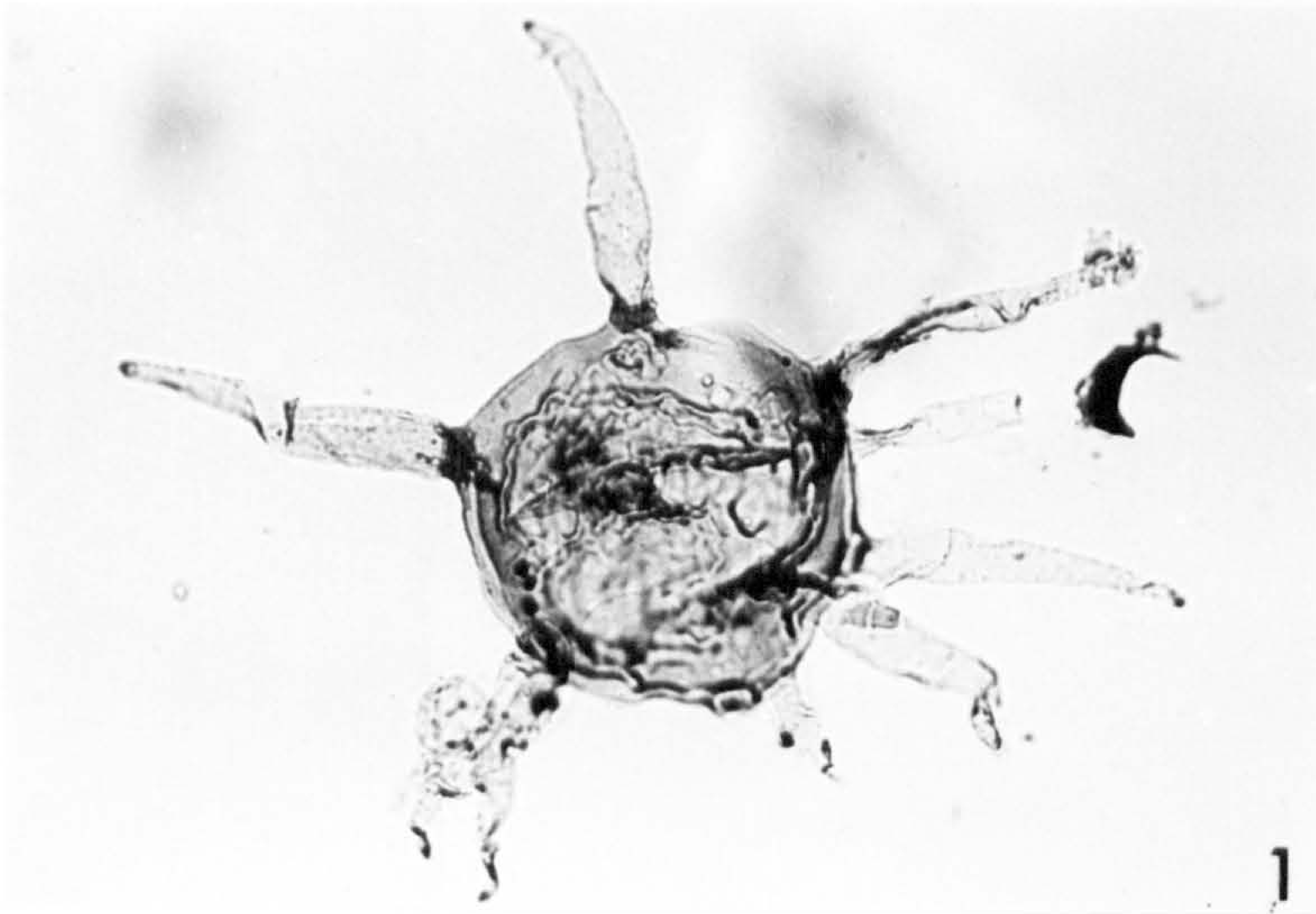
3 Baltisphaeridium pauciverrucosum

OV/O/1-6; 10.8/125.2; X500.

5 Baltisphaerosum bystrentos comb. nov.

OV/UCL/1-2; 13.6/118.8; X1200; phase-contrast.

PLATE 3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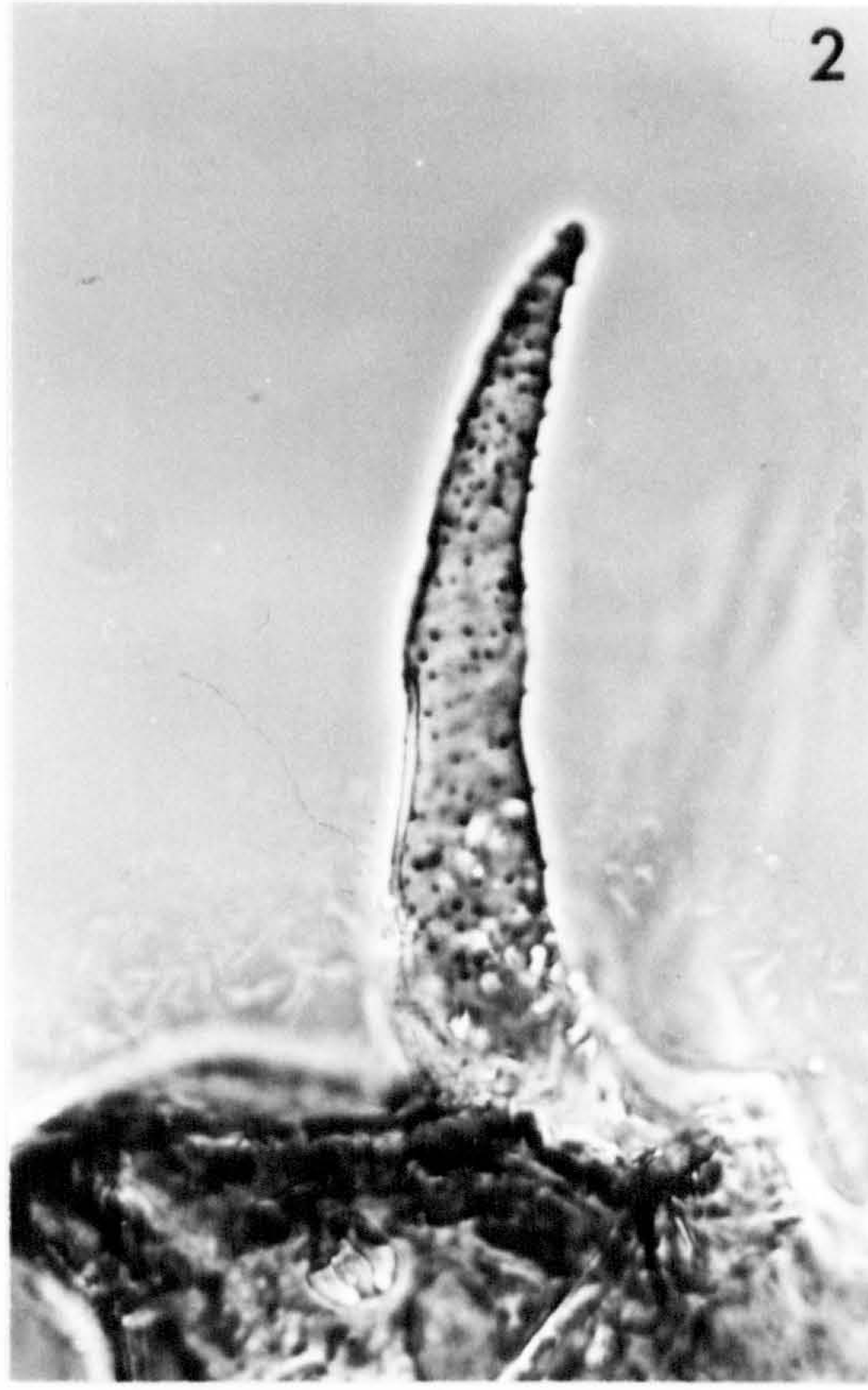
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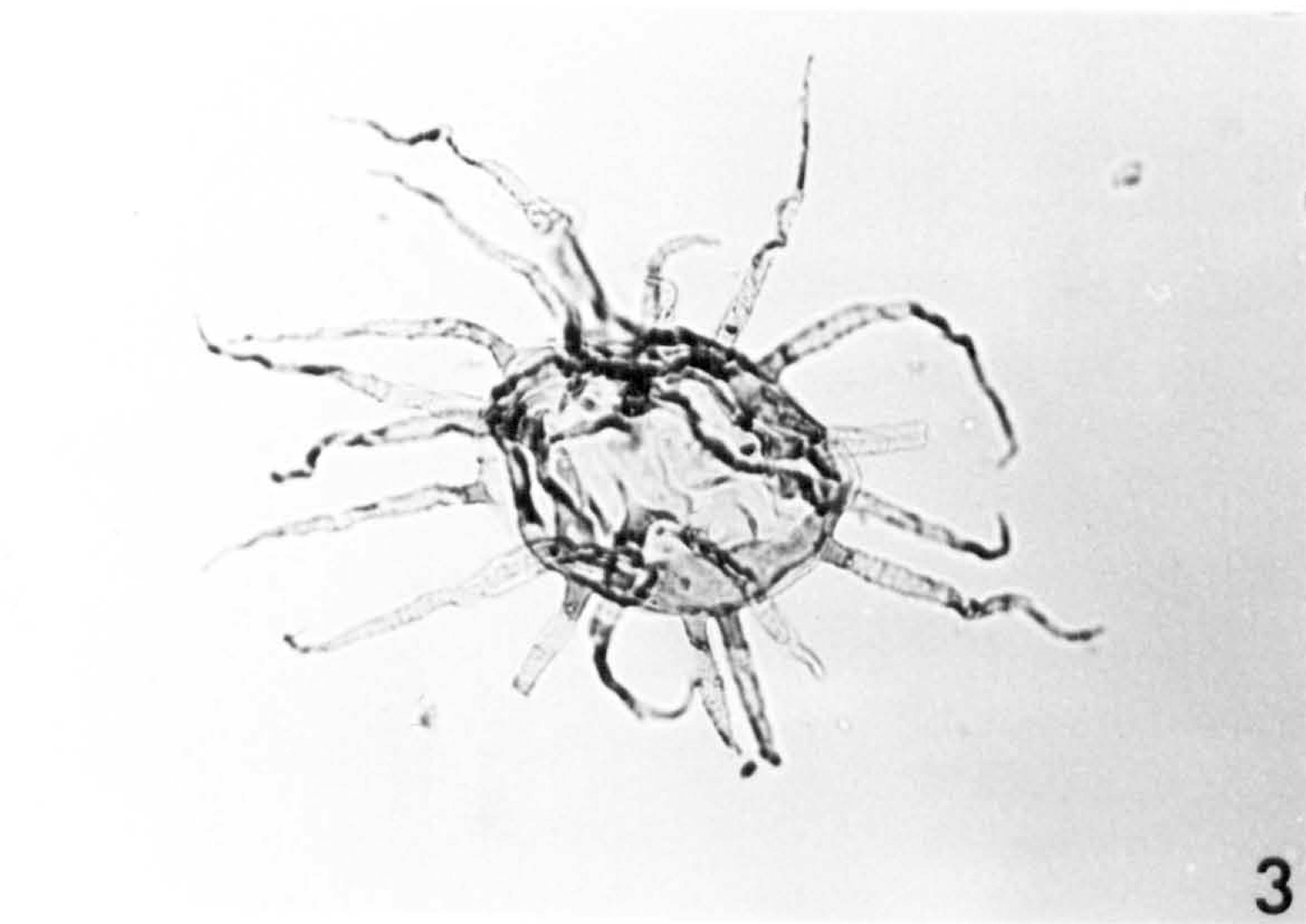
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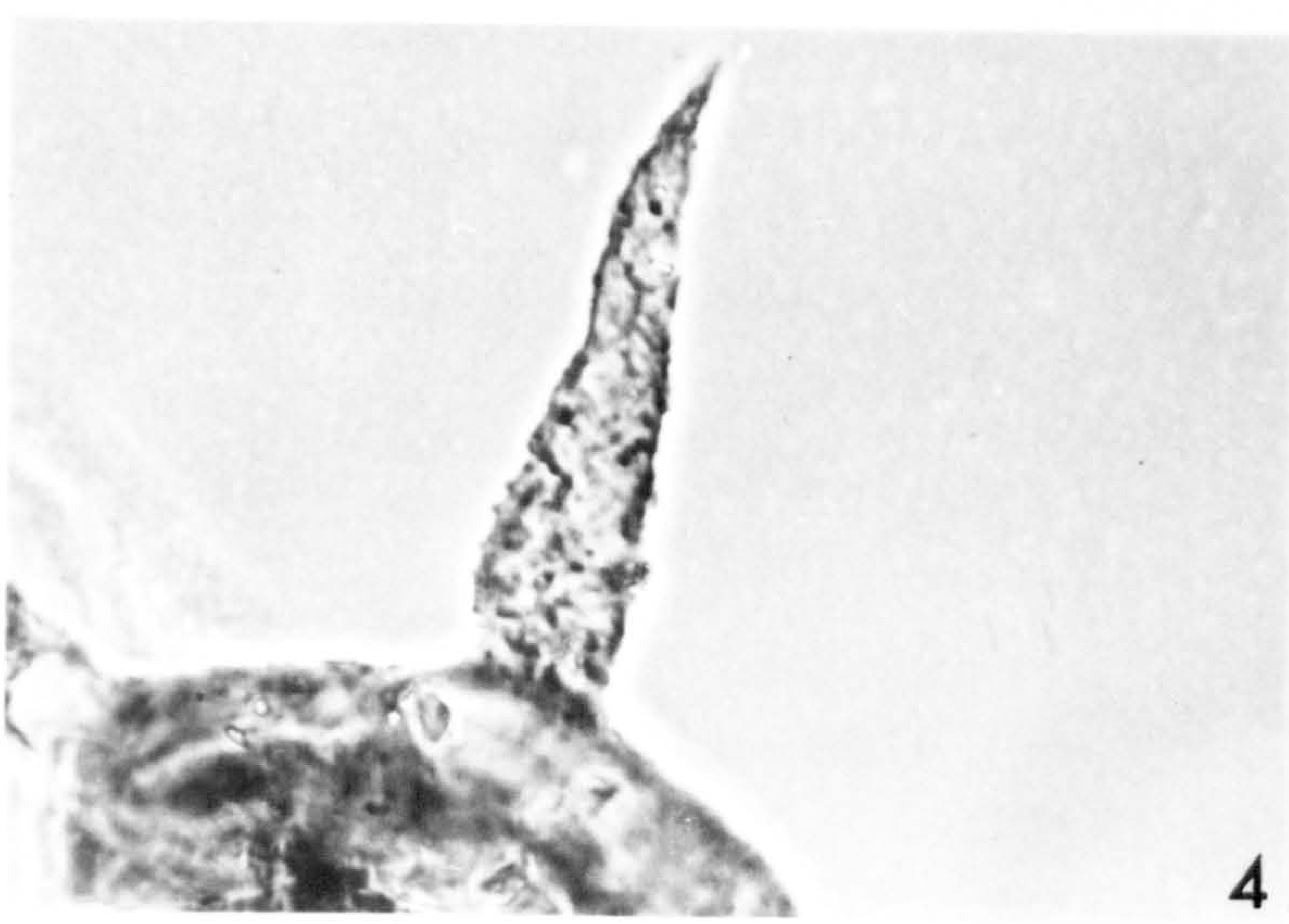
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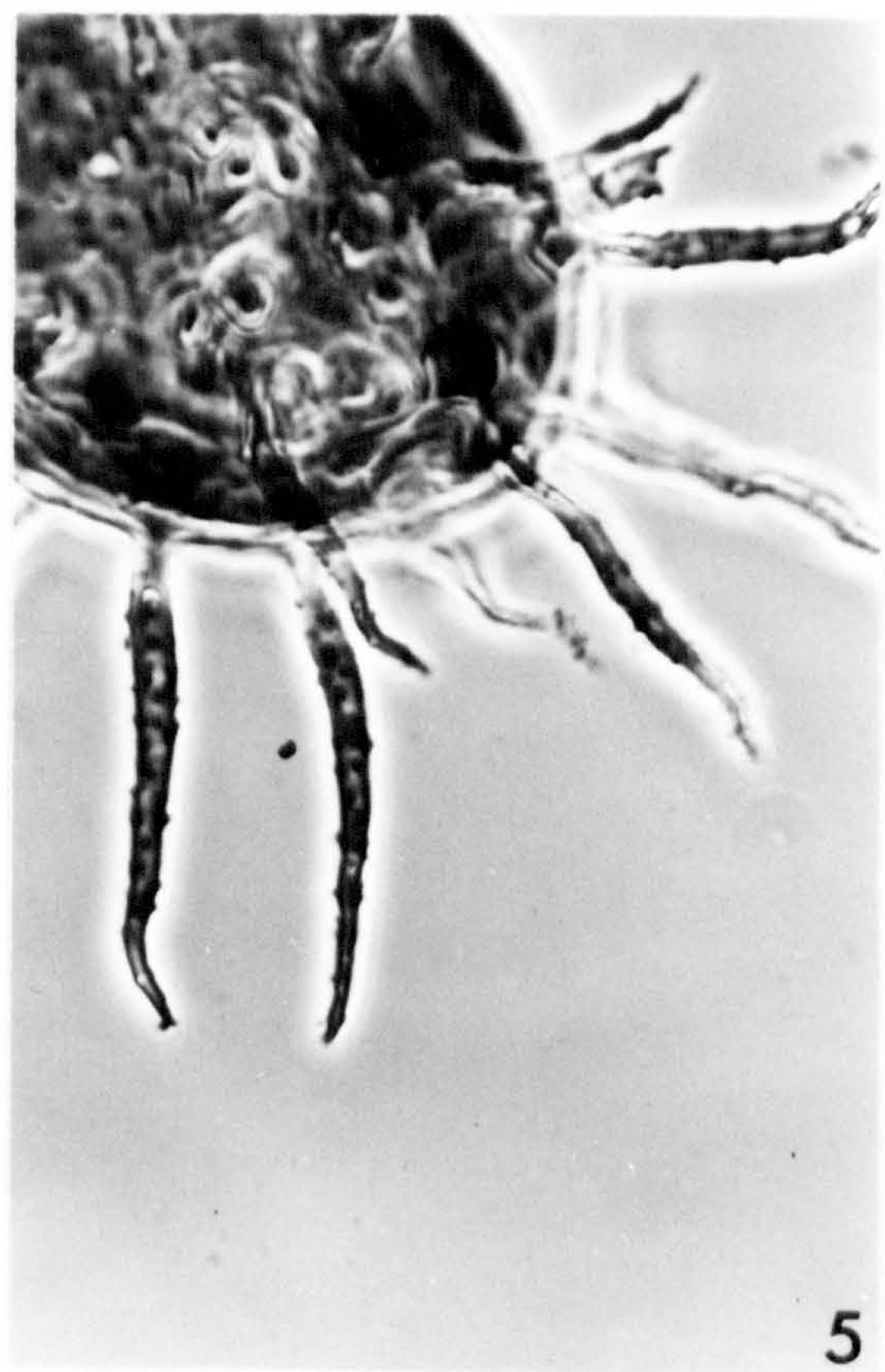
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PLATE 4

1 <u>Baltisphaeridium</u> <u>pauciverrucosum</u>

OV/AS/2-1; 6.4/125.6; X500.

2 <u>Baltisphaerosum</u> <u>christopherii</u> comb. nov.

OV/O/2-1; 21.0/101.4; X500; specimen with a median excystment split.

3,6,7 <u>Baltisphaeridium</u> <u>annelieae</u>

3. OV/LHS/2b-7; 20.5/97.4; X1200; phase-contrast.
6. OV/HS/2-1; 17.7/130.1; X1200; phase-contrast; specimen with aberrant short processes.
7. OV/LHS/2b-7; 20.9/97.5; X500.

4,5 <u>Baltisphaerosum</u> <u>onniensis</u> gen. et sp. nov.

4. OV/LHS/2b-2; 17.8/88.4; X500; holotype.
5. OV/LHS/2b-1; 19.9/116.6; X500; specimen with a median excystment split.

PLATE 4

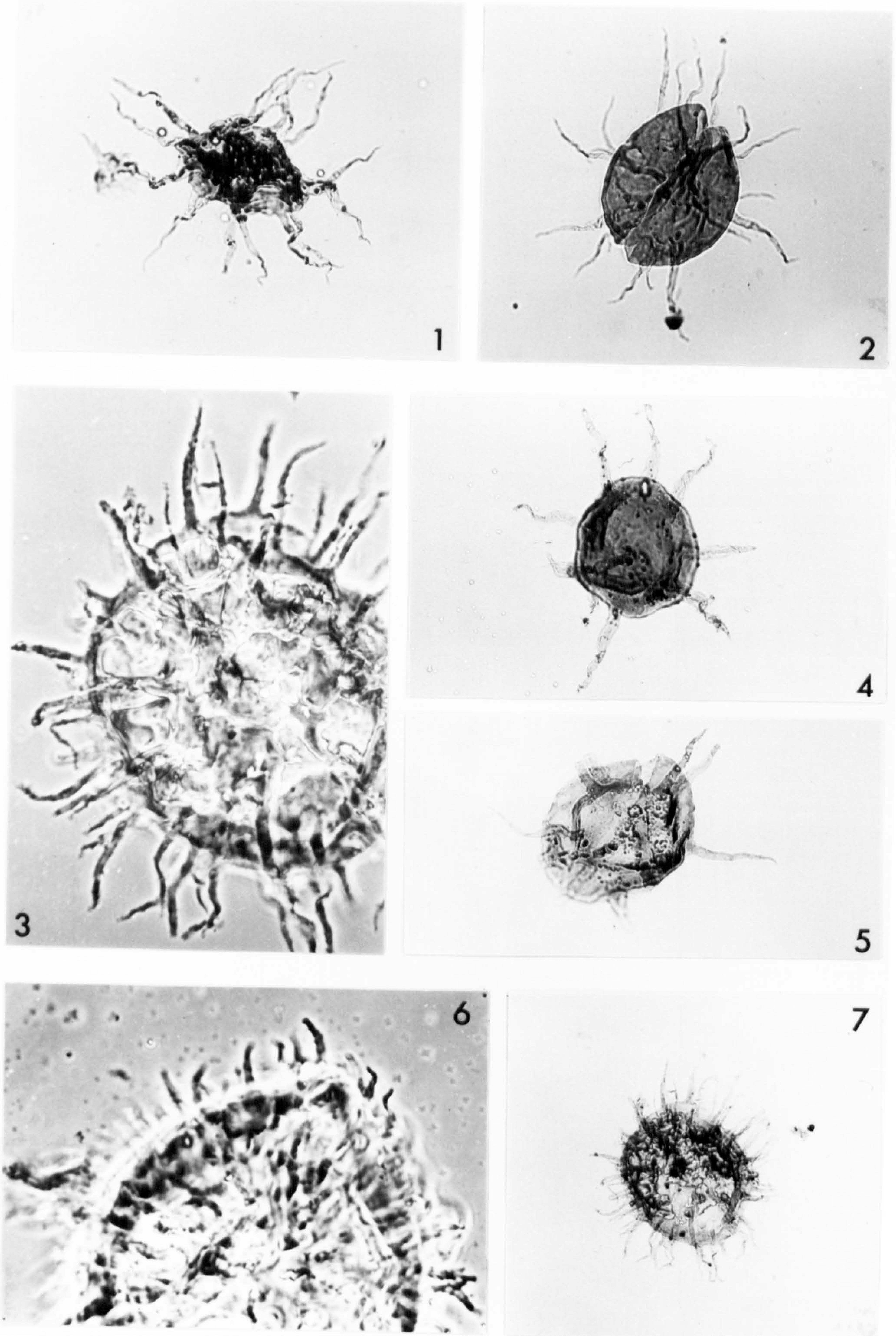


PLATE 5

1,2 <u>Baltisphaeridium</u> <u>hirsuitoides</u>

1. NS/4-4; 15.0/117.0; X500.
2. NS/4-6; 8.6/97.8; X500.

4 <u>Baltisphaeridium</u> cf. <u>latiradiatum</u>

OV/AS/2-1; 17.7/126.8; X500.

3,5,6 <u>Baltisphaeridium</u> cf. <u>filosum</u>

3. OV/AS/1-7; 21.5/96.5; X500.
5. OV/AS/1-9; 13.0/93.4; X500.
6. NS/4-1; 11.6/115.5; X500.

7,8 <u>Baltisphaeridium</u> <u>pauciechinus</u> sp. nov.

7. OV/LHS/2a-1; 10.4/118.8; X1200; phase-contrast; Holotype.
8. Same specimen at X500; apparent median split is a random rupture with irregular margins, probably caused by compression.

PLATE 5

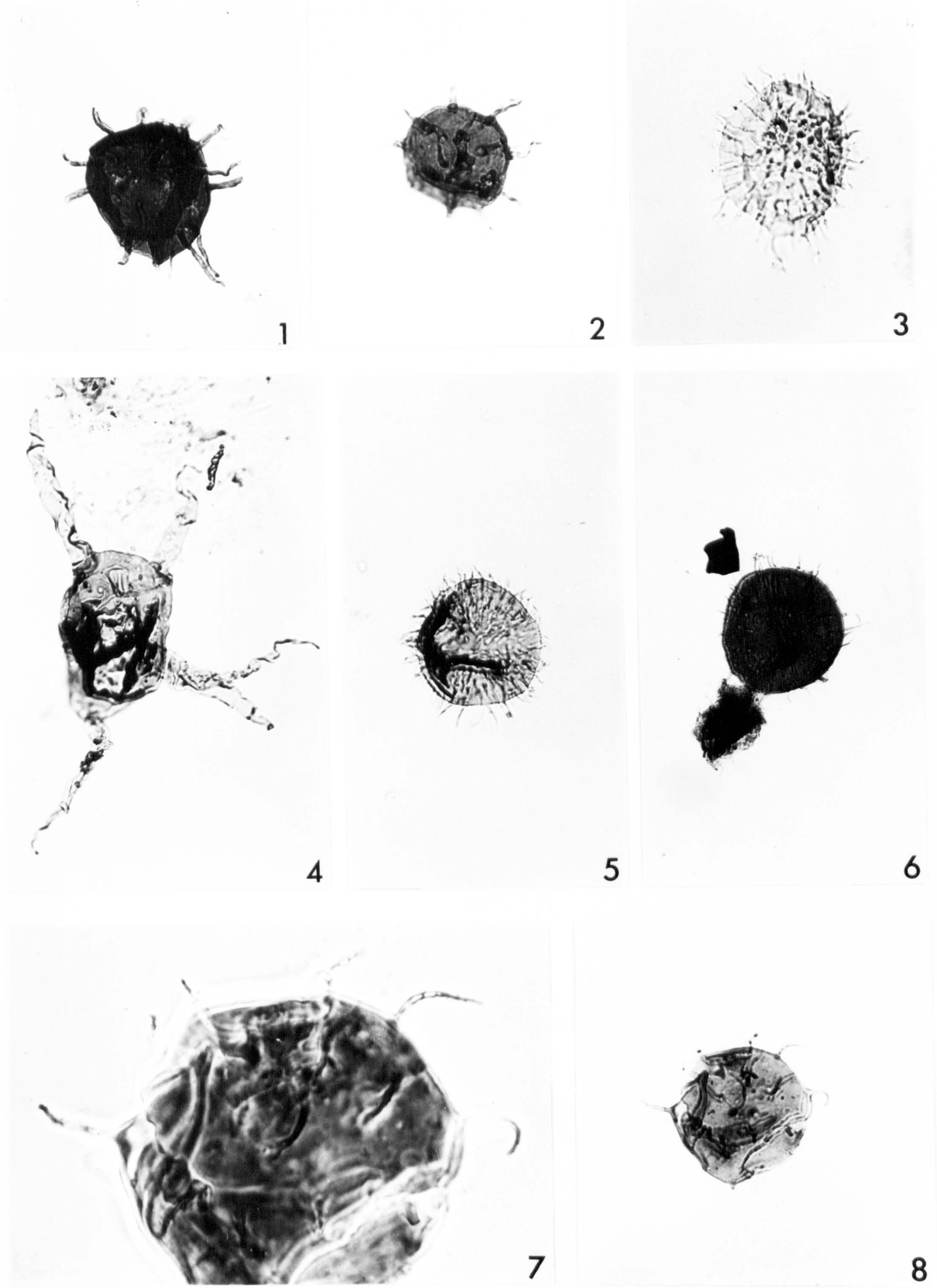


PLATE 6

1-5,7 Multiplicisphaeridium irregulare

1. OV/A/1a-1; 19.6/93.1; X1200; phase-contrast.

2. same specimen at X500.

5. same specimen, high focus; X500.

7. same specimen; X1200.

3. OV/O/2-1; 21.1/90.9; X500.

4. OV/UCL/1-13; 19.7/96.4; X1200; phase-contrast.

6 Multiplicisphaeridium cf. continuatum

OV/A/1a-1; 4.2/94.4; X1200.

PLATE 6

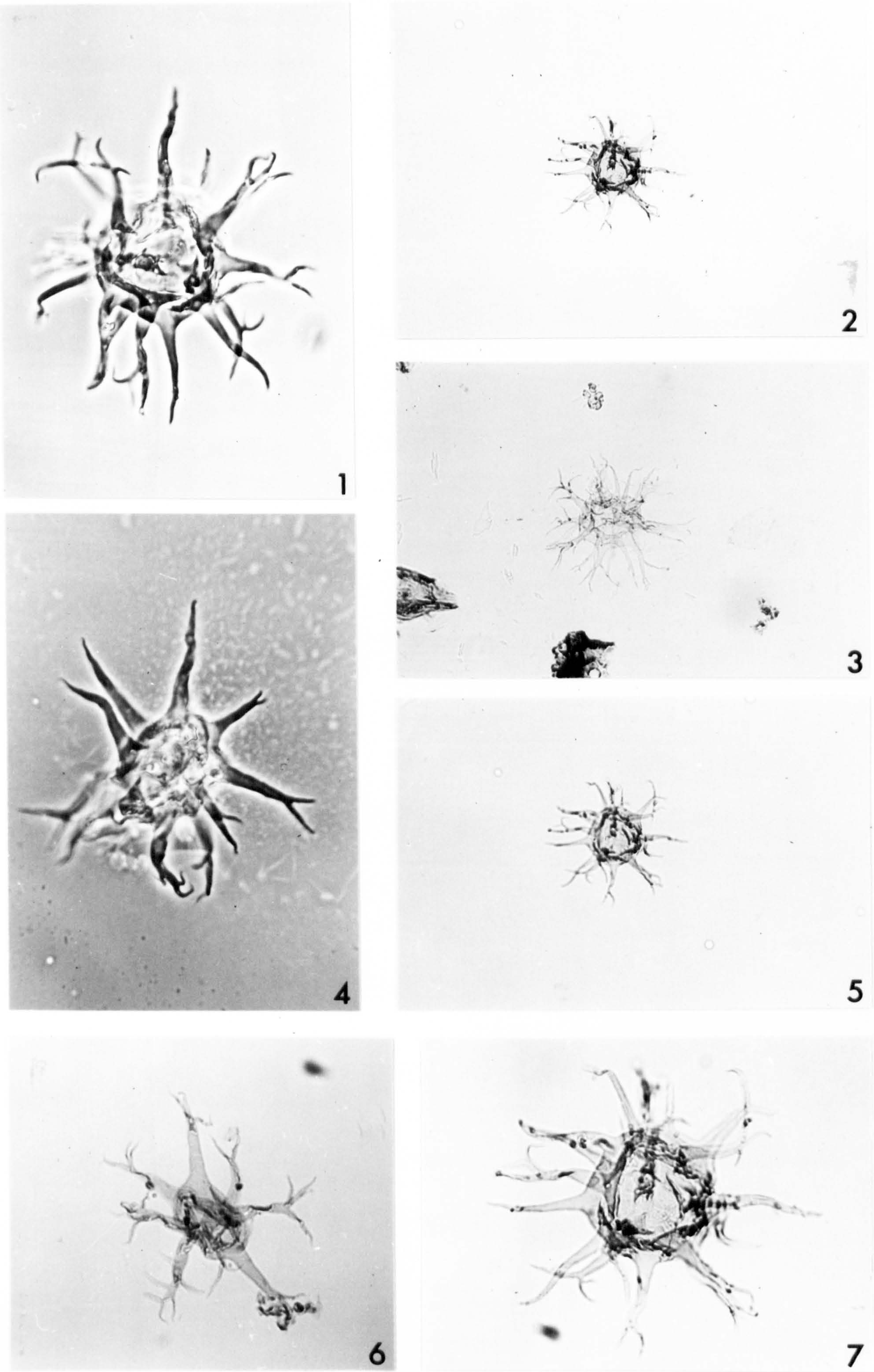


PLATE 7

1 - 3 Cheleutochroa meionios sp. nov.

1. OV/A/2b-1; 17.2/96.6; X1200; phase-contrast; holotype.
2. same specimen at X1200 in bright-field illumination.
3. same specimen at X500.

4 - 6 Diaphorochroa diaphorosos sp. nov.

4. OV/O/2-1; 20.0/96.8; X500.
5. OV/O/2-1; 18.6/102.6; X1200.
6. OV/O/4-1; 20.3/93.4; X1200; holotype.

7-10 Diaphorochroa homoios sp. nov.

7. OV/HS/1-1; 21.0/117.9; X1200; phase-contrast; holotype; showing granular ornament of vesicle wall.
8. same specimen in bright-field illumination; X1200.
9. OV/LHS/2a-6; 8.5/103.7; X1200; showing vesicle grana arranged in a reticulate pattern changing to converging ridges around the process bases.
10. NS/12-1; 3.8/113.6; X1200; specimen with a pronounced reticulate ornament.

PLATE 7

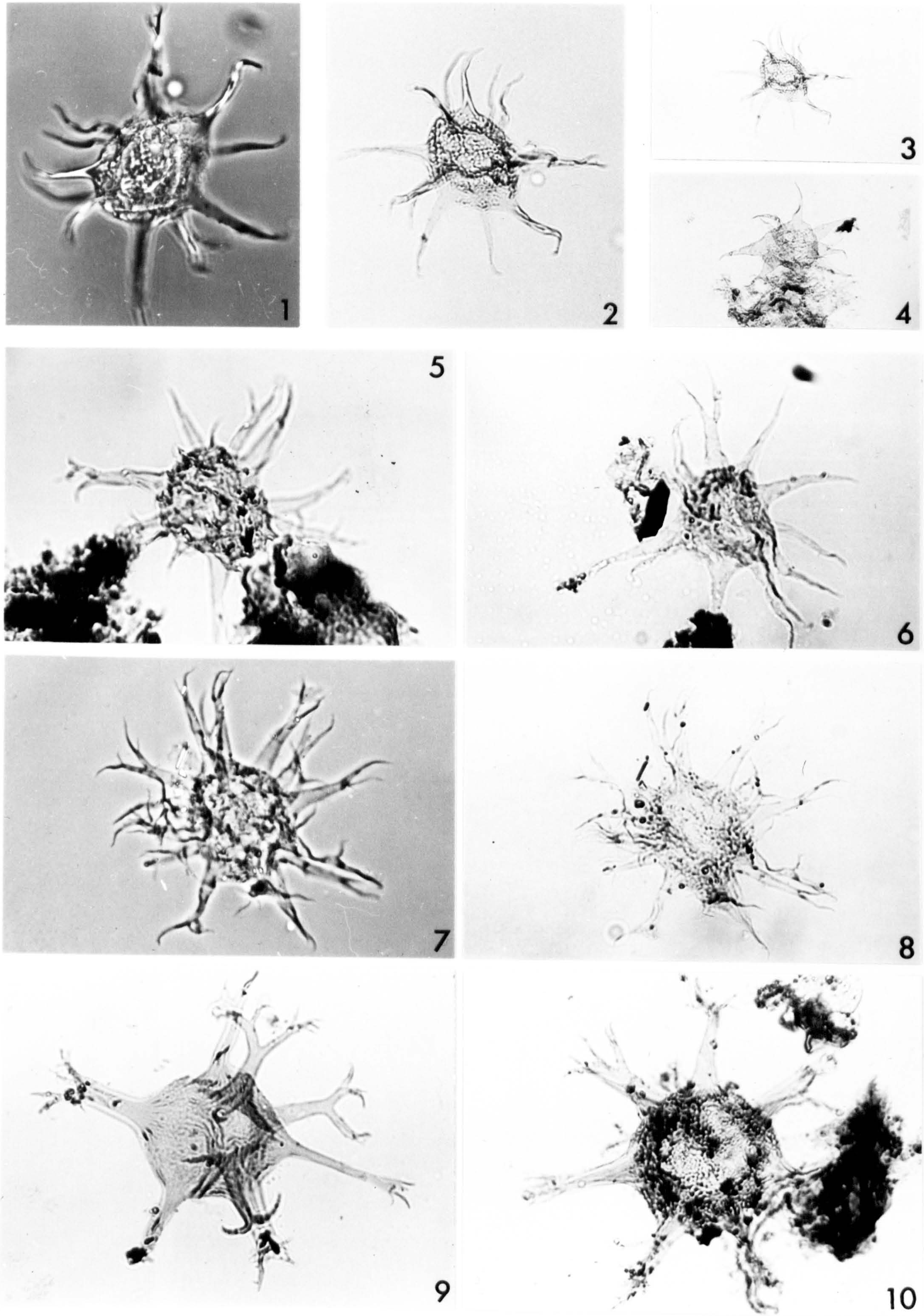


PLATE 8

1 - 7 Nexosarium parva gen. et sp. nov.

1. OV/O/2-1; 12.3/119.8; X500.
2. OV/O/2-1; 20.5/115.0; X500; specimen with a median excystment split.

3. OV/O/2-1; 14.9/86.7; X1200; holotype; note the characteristic plugs at the process bases.

6. same specimen under phase-contrast illumination.
4. OV/O/2-1; 21.4/110.5; X500.
5. same specimen at X1200.
7. OV/O/2-1; 16.2/125.1; X1200.

PLATE 8

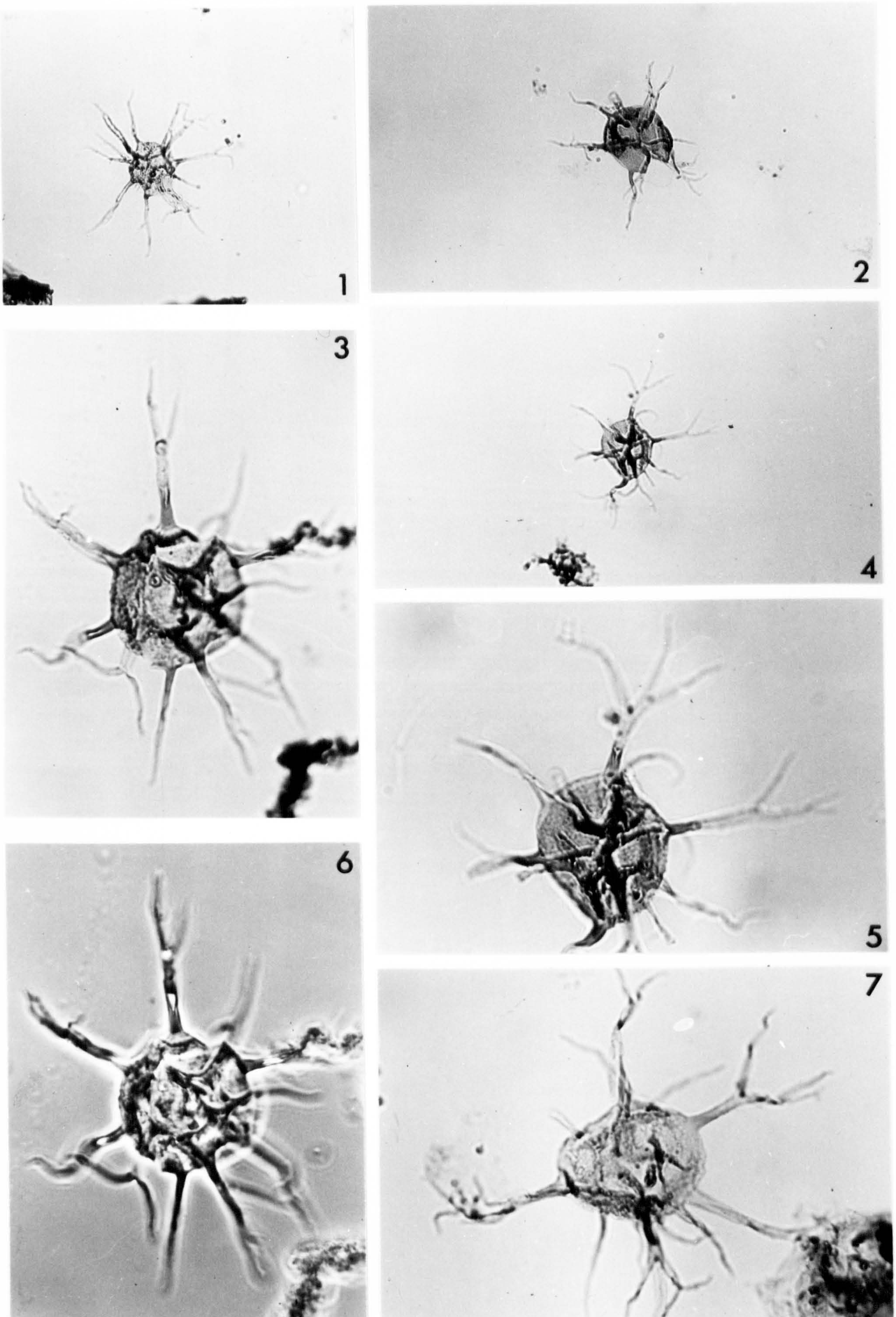


PLATE 9

1 - 8 *Navifusa ancepsipuncta*

1. OV/AS/2-9; 15.4/108.7; X1200; phase-contrast; high-focus; showing the fine pores of the central part of the vesicle.

2. same specimen; X1200; phase-contrast; low focus.
3. same specimen; X500; phase-contrast.
5. G/PB/2-1; 15.0/108.8; X500; Nomarski-interference; showing the large polar pores and the finer pores of the central part of the vesicle.

6. same specimen in bright-field illumination.
4. OV/O/4; S.E.M. photomicrograph; X500.
7. S.E.M. photomicrograph; X10,000; detail of fig.4 showing the pits which are the surface expression of the fine pores; note the otherwise smooth vesicle wall.

8. OV/O/2-1; 15.3/103.1; X1200; phase-contrast; showing the large polar pores.

PLATE 9

PLATE 10

All magnifications X500

1,2,4 *Navifusa similis*

1. G/PB/1-1; 20.8/99.5.
2. OV/LHS/2b-1; 18.8/108.5; Nomarski interference.
4. G/PB/1-1; 9.1/103.3; Nomarski interference.

3,5,6 *Orthosphaeridium chondrododora*

3. OV/O/4-1; 12.3/117.6.
5. OV/O/1-6; 19.4/92.6; specimen with reduced vesicle ornament and a median excystment split.
6. OV/O/1-2; 12.2/90.1; specimen with strongly developed vesicle and process ornament.

PLATE 10

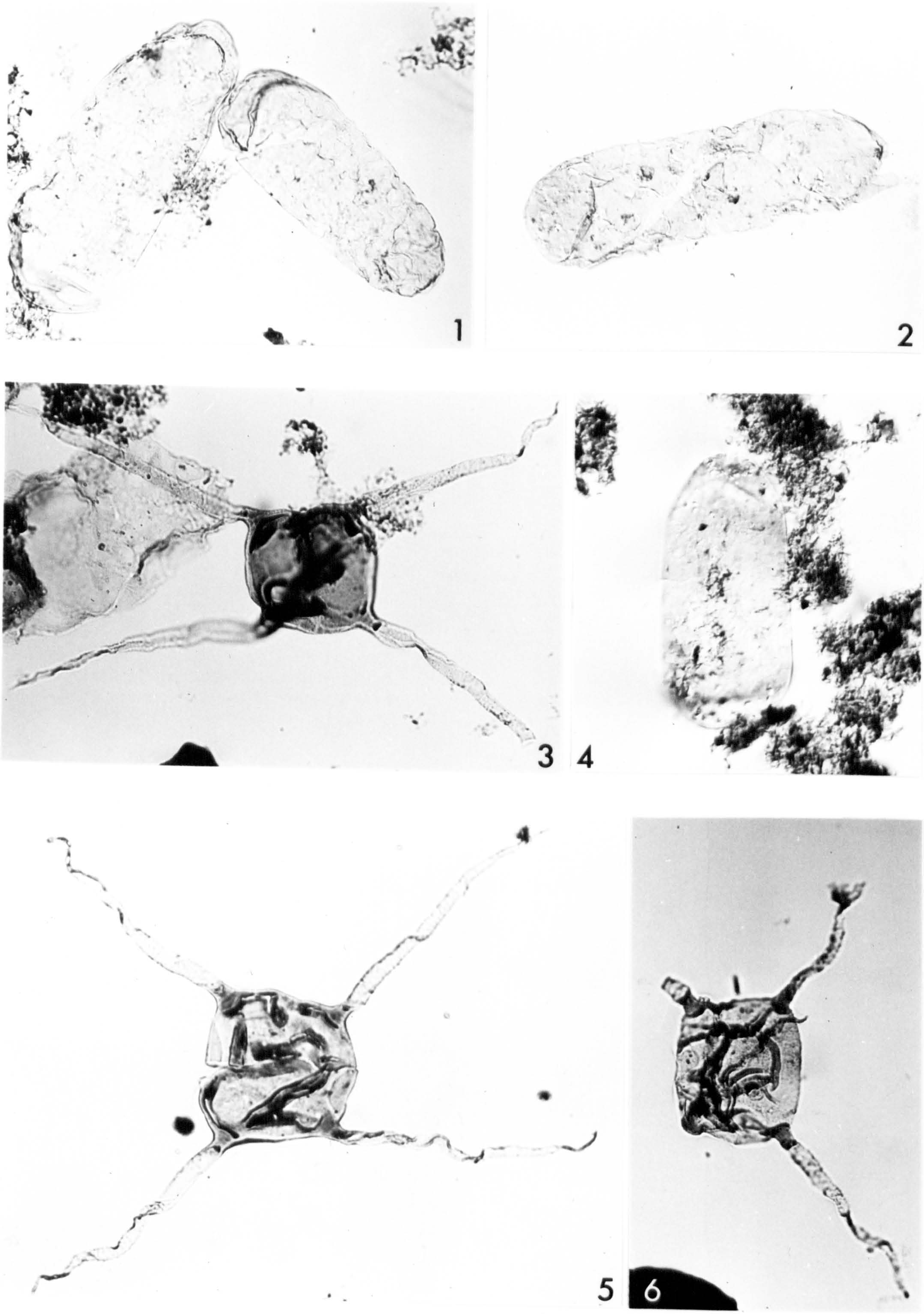


PLATE 11

All magnifications X400

1,2 Orthosphaeridium quadrinatum

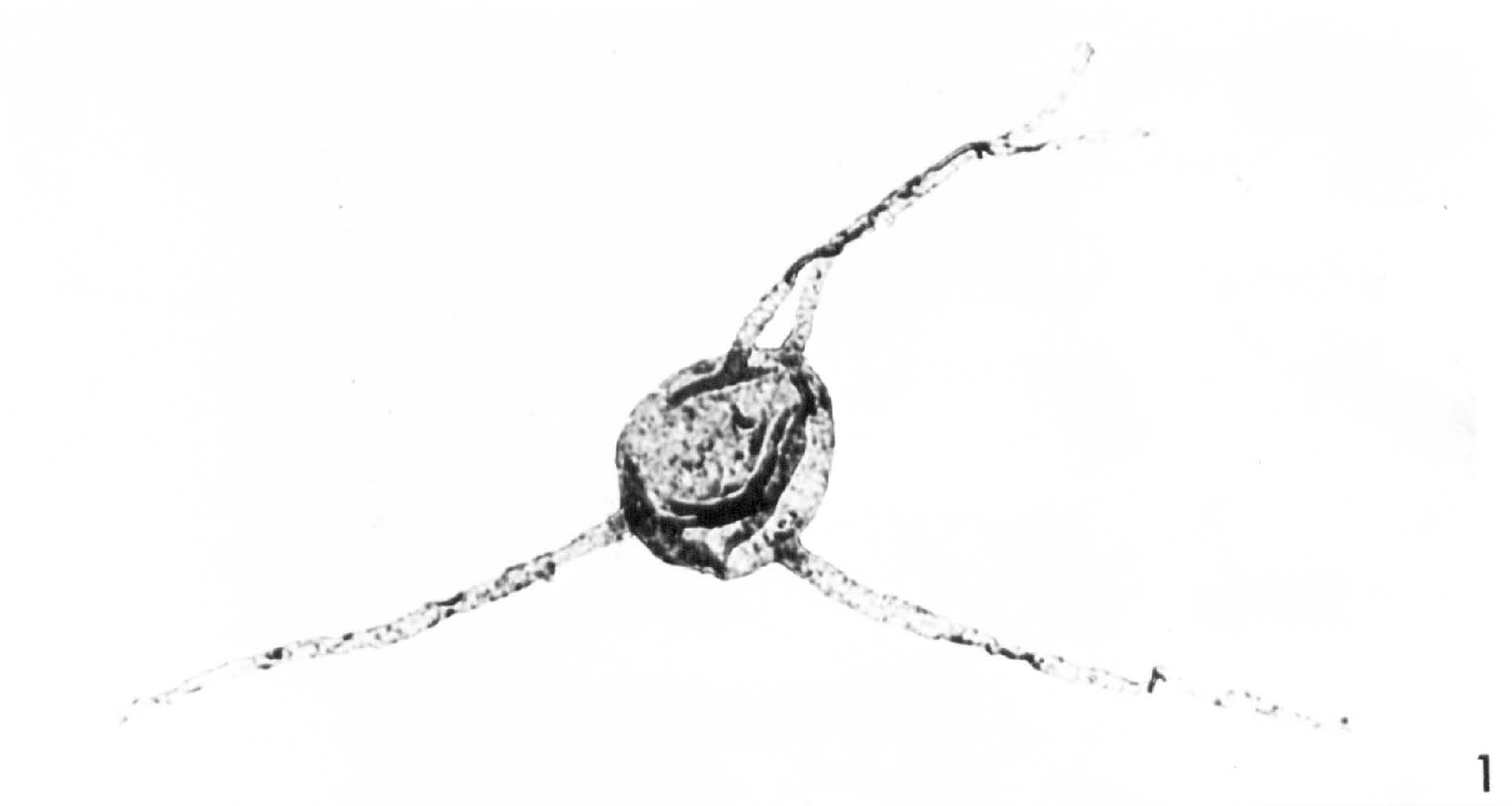
1. OV/LHS/2b-2; 10.9/107.3.

2. OVLHS/2b-2; 3.1/117.9.

3 Orthosphaeridium ternatum

OV/LHS/2b-1; 18.3/93.4.

PLATE 11



1

2

3

PLATE 12

1 Orthosphaeridium bispinosum sp. nov.

OV/AS/1-5; 8.3/129.6; X500; holotype; showing strongly developed vesicle and process ornament and an incipient median excystment split.

2 Orthosphaeridium quadrinatum

NS/4-5; 15.0/102.7; X500.

3 - 7 Orthosphaeridium bispinosum sp. nov.

3. OV/AS/1-1; 19.0/102.3; X500; specimen showing a widely gaping median excystment split.

5. OV/AS/1-5; 9.6/115,9; X500; half of a specimen which has ruptured completely across the median excystment split.

4. OV/AS/1; S.E.M. photomicrograph; X5000; detail of fig. 6 showing the vesicle wall ornament.

6. OV/AS/1; S.E.M. photomicrograph; X2000.

7. OV/AS/1; S.E.M. photomicrograph; X5000; detail of fig. 6 showing the process wall ornament.

PLATE 12

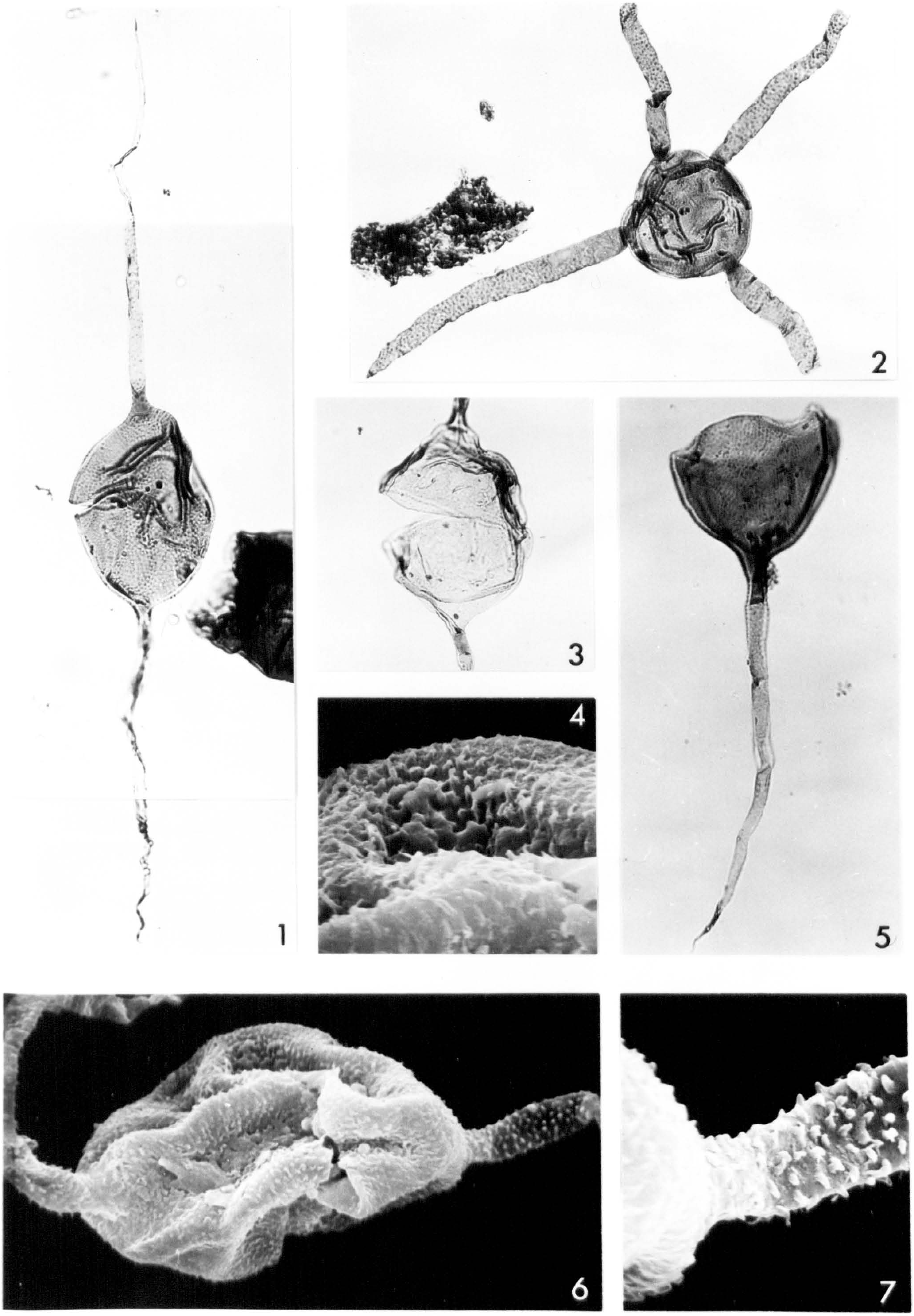


PLATE 13

1 - 4 *Ordovicidium elegantulum*

1. OV/HS/2-1; 18.3/119.6; X1200; phase-contrast.
2. OV/AS/1-1; 21.3/96.4; X500.
3. OV/AS/1-1; 18.4/110.6; X1200; phase-contrast; showing the granular ornament of the processes.
4. Same specimen at X500 in bright-field illumination.

5 - 8 *Peteinosphaeridium nudum*

5. OV/HS/1-1; 16.1/129.1; X1200.
6. OV/O/2-1; 18.9/112.8; X500.
7. OV/O/2-1; 18.6/124.0; X1200. showing smooth vesicle and process walls.
8. Same specimen at X500 in bright-field illumination.

PLATE 13

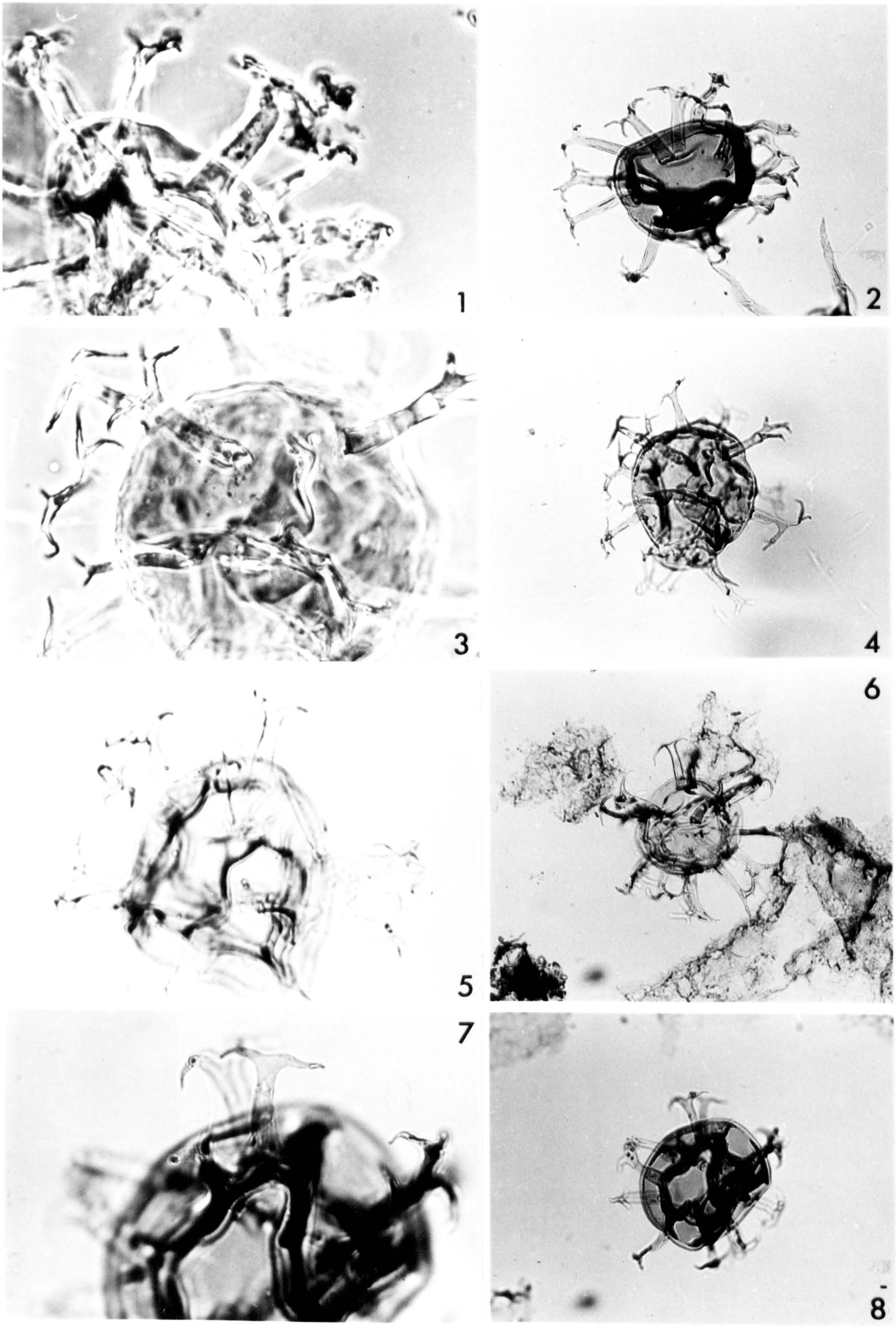


PLATE 14

1 - 3 *Peteinosphaeridium trifurcatum* subsp. *breviradiata*

1. OV/AS/1; S.E.M. photomicrograph; X4000; detail of fig.3.

2. OV/AS/1; S.E.M. photomicrograph; X5000; showing details of the process structure.

3. OV/AS/1; S.E.M. photomicrograph; X1000.

4 - 7 *Ordovicidium elegantulum*

4. OV/AS/1; S.E.M. photomicrograph; X2000; showing the microgranular vesicle wall and the coarsely granular processes; note the uneven distribution of grana.

5. OV/AS/1; S.E.M. photomicrograph; X5000; showing the uneven development of distal process branches.

6. OV/AS/1; S.E.M. photomicrograph; X10,000; showing details of the process ornament.

7. OV/AS/1; S.E.M. photomicrograph; X4000; showing a developing median excystment split; note the short, simple accessory process in the lower right-hand portion of the vesicle.

PLATE 14

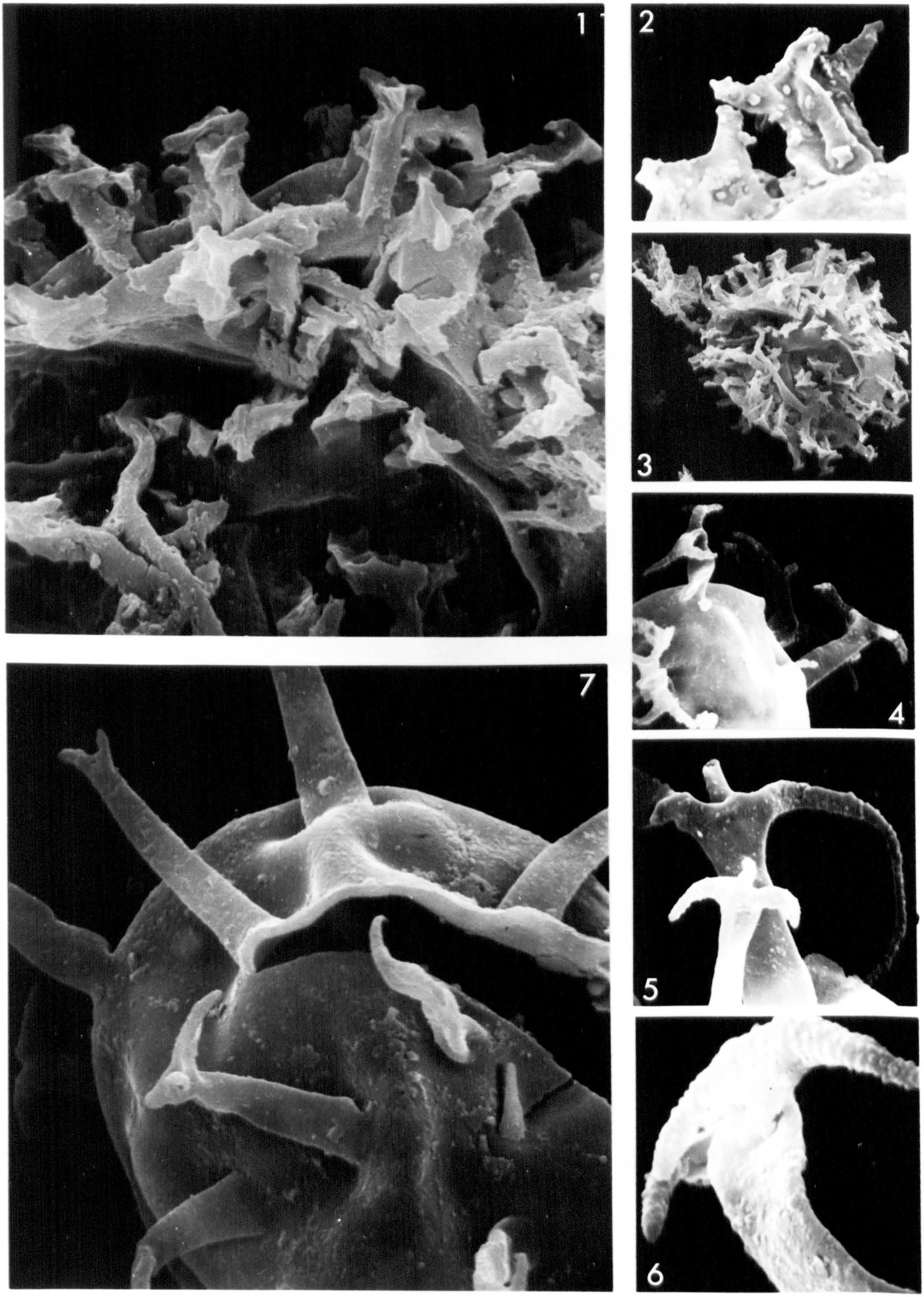


PLATE 15

1 - 3 *Peteinosphaeridium trifurcatum* subsp. *trifurcatum*

1. NS/4-1; 14.3/92.9; X500.
2. OV/A/2a-1; 15.5/115.8; X500; specimen with a pylome.
3. NS/4-6; 4.2/90.1; X500.

4 - 6 *Excultibrachium oligoklados* sp. nov.

4. NS/4-1; 14.8/106.3; X500.
5. same specimen; X500; phase-contrast.
6. NS/4-5; 19.3/85.0; X500; holotype.

7,8 *Peteinosphaeridium nannofurcatum*

7. OV/UHS/1-2; 20.3/94.0; X1200.
8. same specimen at X500.

9,10 *Peteinosphaeridium heteromorphicum*

9. OV/AS/1-1; 12.2/116.6; X1200.
10. same specimen at X500; note both simple and bifurcating processes present on a single vesicle.

PLATE 15

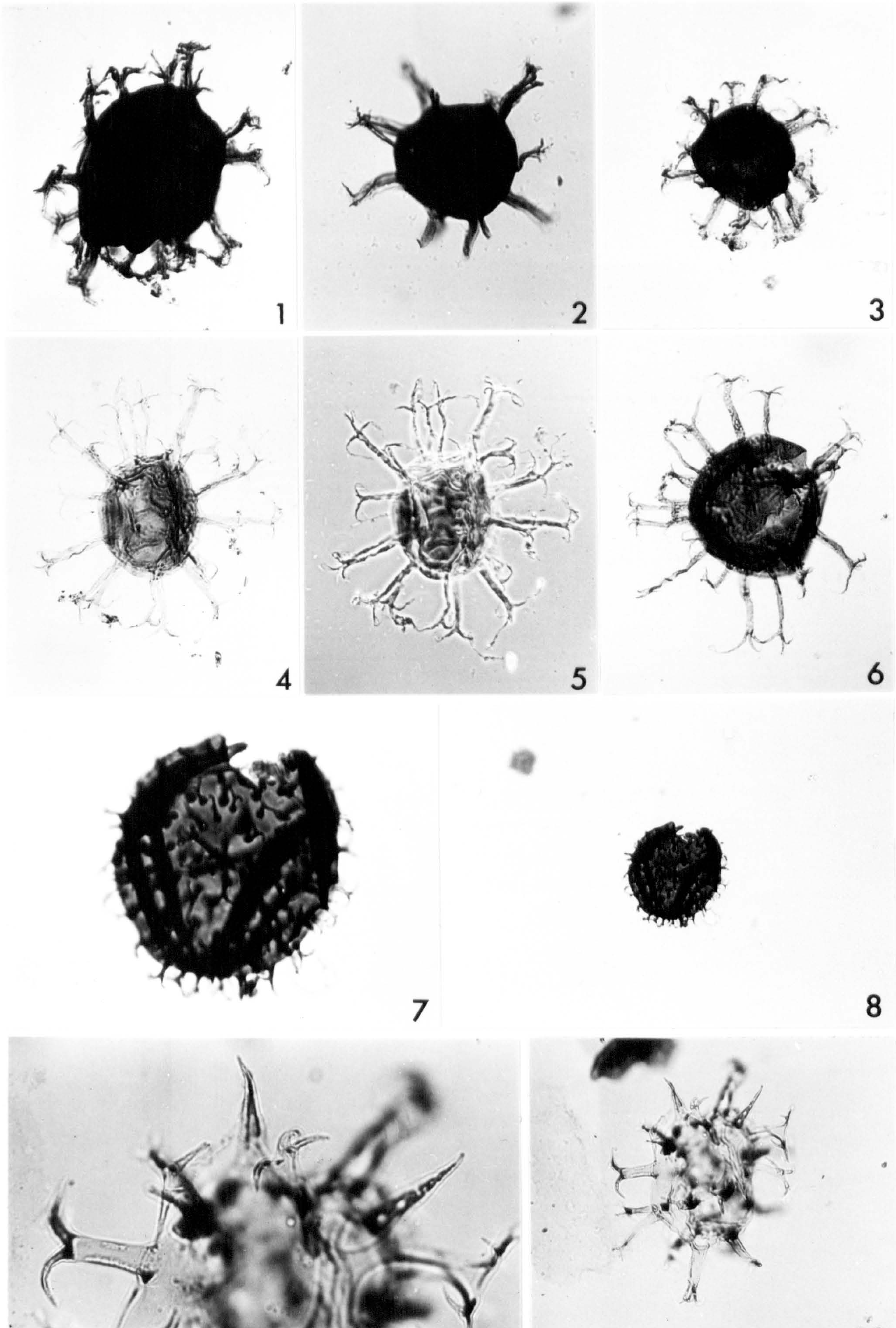


PLATE 16

1 - 3 *Peteinosphaeridium* *trifurcatum* subsp. *intermedium*

1. OV/LHS/2a-2; 16.5/100.0; X1200; specimen having a pylome with a thickened raised collar.

2. OV/A/2a-13; 17.6/115.0; X500.
3. OV/A/2a-1; 17.9/104.3; X1200; specimen having a pylome with a raised collar.

4 *Peteinosphaeridium* *trifurcatum* subsp. *breviradiata*

OV/LHS/2b-1; 10.2/107.7; X500.

5 - 8 *Peteinosphaeridium* *trifurcatum* subsp. *intermedium*

5. OV/LHS/1-7; 19.1/98.2; X1200; specimen having a pylome with a thickened rim.

6. OV/A/2b-1; 15.6/105.5; X500; specimen having a simple pylome.

7. same specimen at X1200.
8. detail of fig. 2 at X1200.

PLATE 16

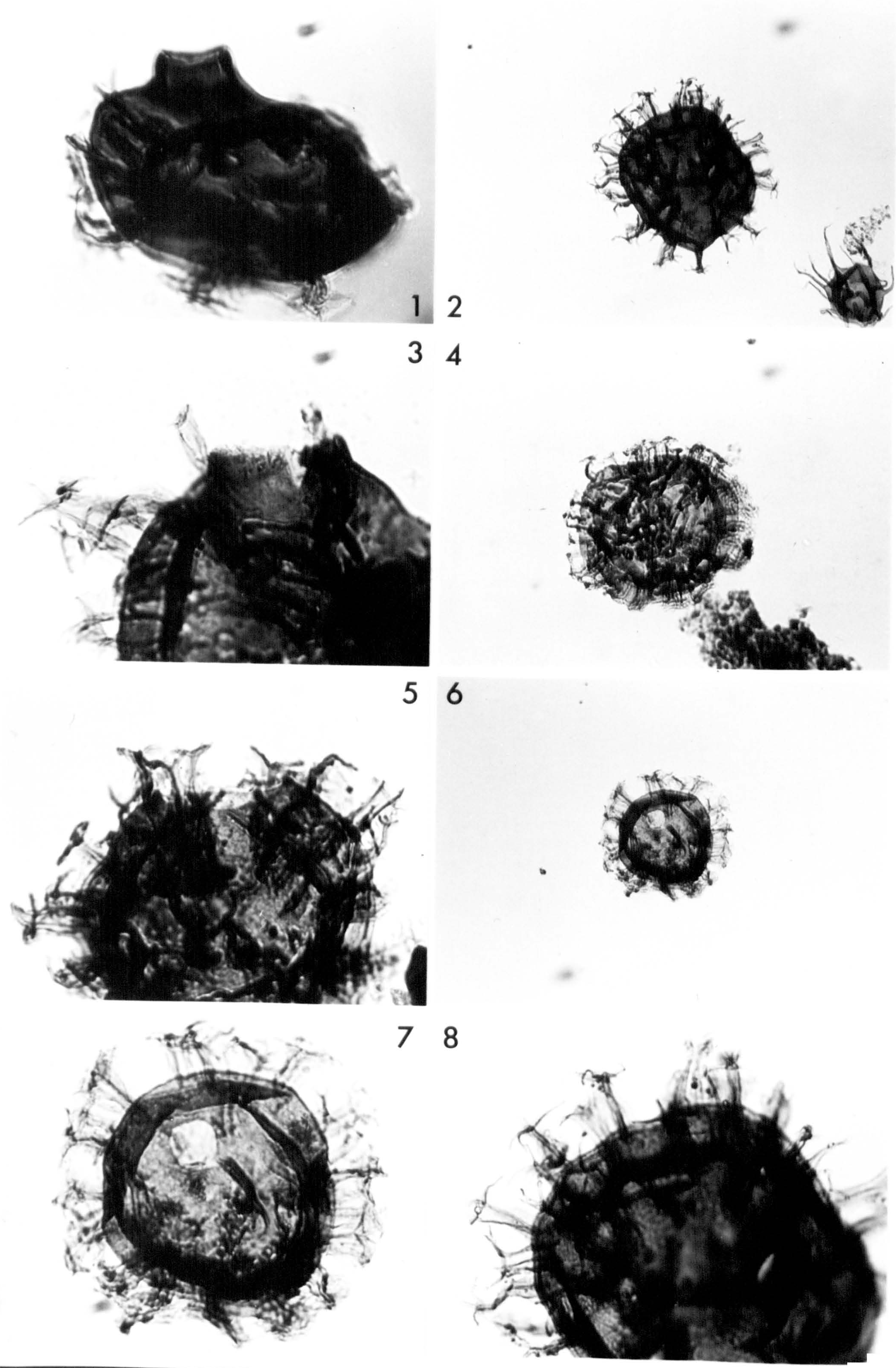


PLATE 17

All magnifications at X500

1 *Veryhachium trispinosum*

OV/HS/1-1; 19.9/113.9.

2 *Veryhachium trispinosum*

OV/AS/1-9; 13.1/93.4;

3 *Veryhachium downiei*

OV/AS/2-9; 17.4/96.3.

4 *Veryhachium* cf. *downiei*

OV/LHS/1-13; 15.5/125.4.

5 - 7 *Veryhachium trisulcum*

5. OV/UCL/1-1; 3.1/134.3.
6. OV/A/2b-1; 19.4/94.6.
7. OV/O/1-7; 17.6/105.7.

8-11 *Epistomium trirhethium* gen. et sp. nov.

8. OV/A/1a-1; 15.2/117.4; holotype.
9. OV/HS/1-1; 17.9/121.8.
10. OV/A/2b-1; 20.2/118.6.
11. OV/LHS/2a-4; 12.2/104.7; specimen with a well developed simple split type epityche.

PLATE 17

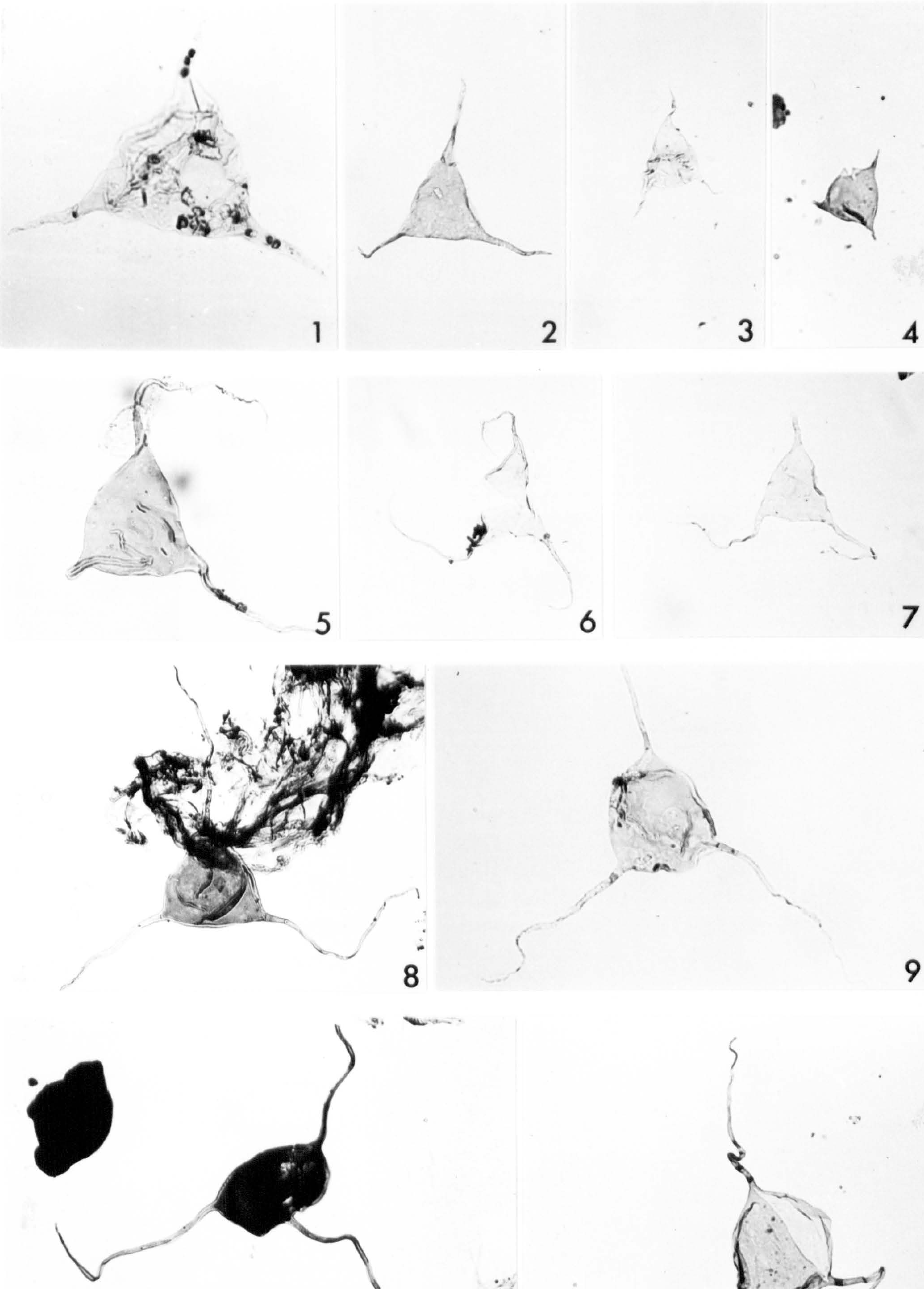


PLATE 18

1,2 *Veryhachium triangulatum*

1. OV/LHS/2b-6; 12.3/119.5; X500.
2. OV/LHS/2b-1; 12.2/125.6; X500.

3,4,7 *Veryhachium irroratum*

3. NS/4; S.E.M. photomicrograph; X2000.
4. detail of fig. 3 showing the vesicle wall ornament; X10,000.

7. OV/AS/1; S.E.M. photomicrograph; X3000; specimen with less dense vesicle wall ornament.

5,6,8 *Villosacapsula setosapellicula*

5. OV/A/2a-13; 8.3/111.4; X1200; phase-contrast.
6. same specimen at X500 in bright-field illumination.
8. OV/A/2a-13; 9.5/96.6; X1200; phase-contrast; note the fine hair-like vesicle and process wall ornament.

PLATE 18

PLATE 19

1,2 Veryhachium minutum

1. OV/UCL/1-25; 8.7/107.5; X500; phase-contrast.
2. OV/LHS/2a-7; 10.3/89.7; X1200; phase-contrast.

3 Veryhachium lairdi

OV/A/2a-13; 4.9/97.2; X500.

4,5 Veryhachium longispinosum

4. OV/HS/2-1; 16.3/101.6; X500; phase-contrast.
5. same specimen at X500 in bright-field illumination.

6 Veryhachium cf. longispinosum

OV/HS/2-1; 20.9/121.3; X500.

7-10 Veryhachium oklahomense

7. OV/AS/1-14; 11.9/109.8; X500; phase-contrast.
8. OV/UCL/1-13; 17.9/110.4; X500.
9. OV/UCL/1-25; 7.8/100.0; X500.
10. OV/A/2a-13; 10.3/99.3; X500.

11-13 Veryhachium rhomboidium

11. OV/UCL/1-13; 11.0/108.4; X500.
12. OV/UCL/1-13; 11.0/120.4; X500.
13. OV/UCL/1-13; 11.3/109.4; X500.

PLATE 19

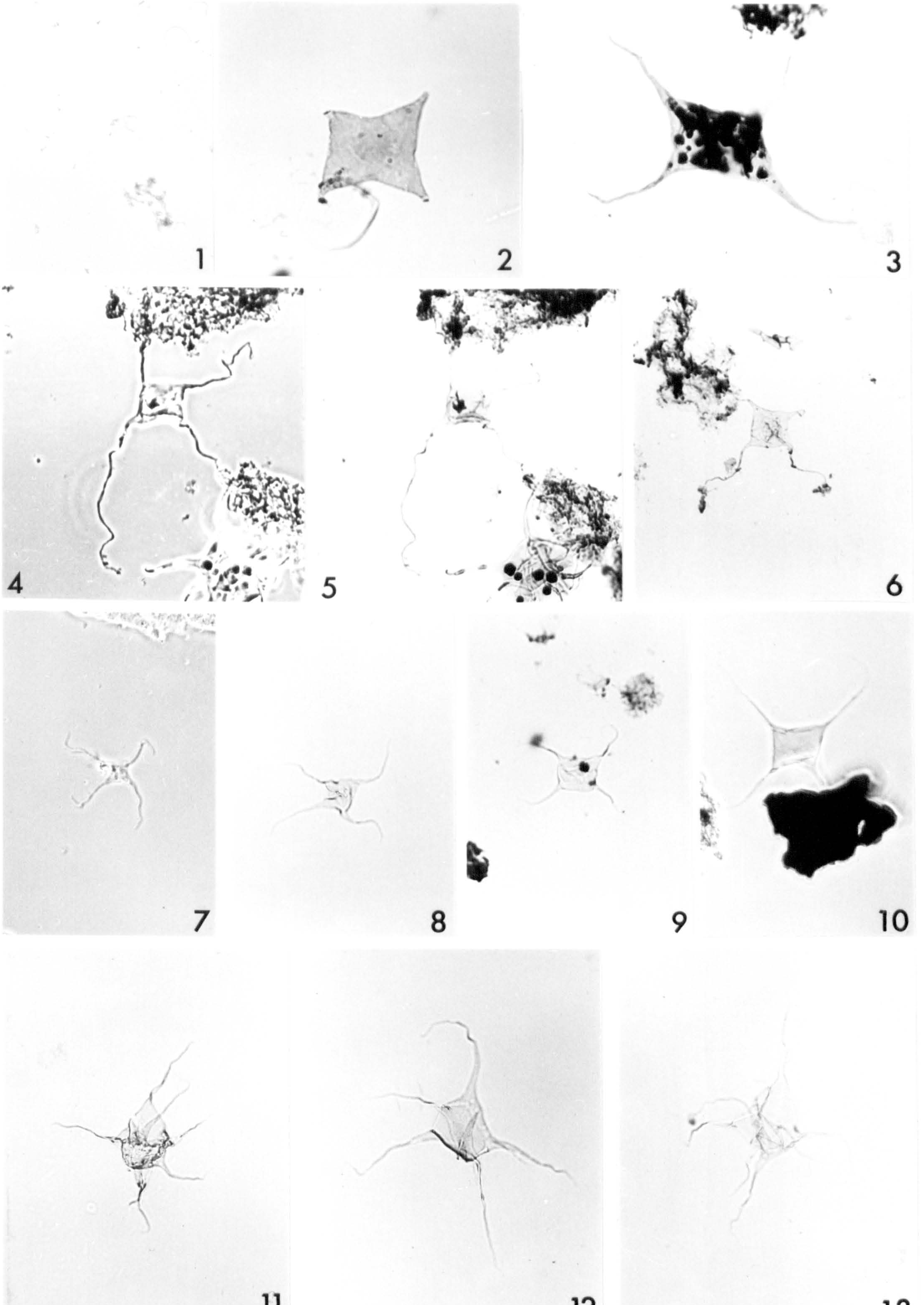


PLATE 20

1 - 3 Leiofusa fusiformis

1. OV/LHS/2b-6; 5.3/94.1; X500.

2. OV/LHS/2b-4; 11.0/126.4; X500.

3. OV/LHS/2b-6; 15.4/94.0.

4,7,8 Veryhachium sp. B.

4. OV/UCL/1-26; 13.7/110.2; X1200; phase-contrast.

7. OV/UCL/1-25; 8.3/85.2; X1200; phase-contrast.

8. OV/UCL/1-26; 8.1/98.8; X1200; phase-contrast.

5 Pheoclosterium fuscinulaegerum

NS/4-6; 11.7/125.0; X500.

6,9 Eupoikilofusa cabottii

6. OV/HS/2-1; 19.9/130.9; X500.

9. OV/O/1-7; 20.6/105.3; X500.

PLATE 20

PLATE 21

1 - 3 Astropheos celestum

1. OV/LHS/1-8; 17.6/87.8; X500.

2. same specimen at X500; phase-contrast.

3. OV/HS/2-1; 4.9/122.8; X500; phase-contrast.

5,6 Astropheos cf. celestum

5. OV/HS/2-1; 20.3/100.2; X500.

6. OV/HS/2-1; 20.0/105.1; X500; this rare form is smaller than A. celestum, has shorter more slender processes and bears less strongly developed lateral spines.

4,7,8 Astropheos brachyskolos sp. nov.

4. OV/HS/2-1; 19.2/107.3; X1200; phase-contrast.

7. OV/LHS/1-11; 20.7/109.7; X1200; phase-contrast; holotype.

8. same specimen at X500 in bright-field illumination.

PLATE 21

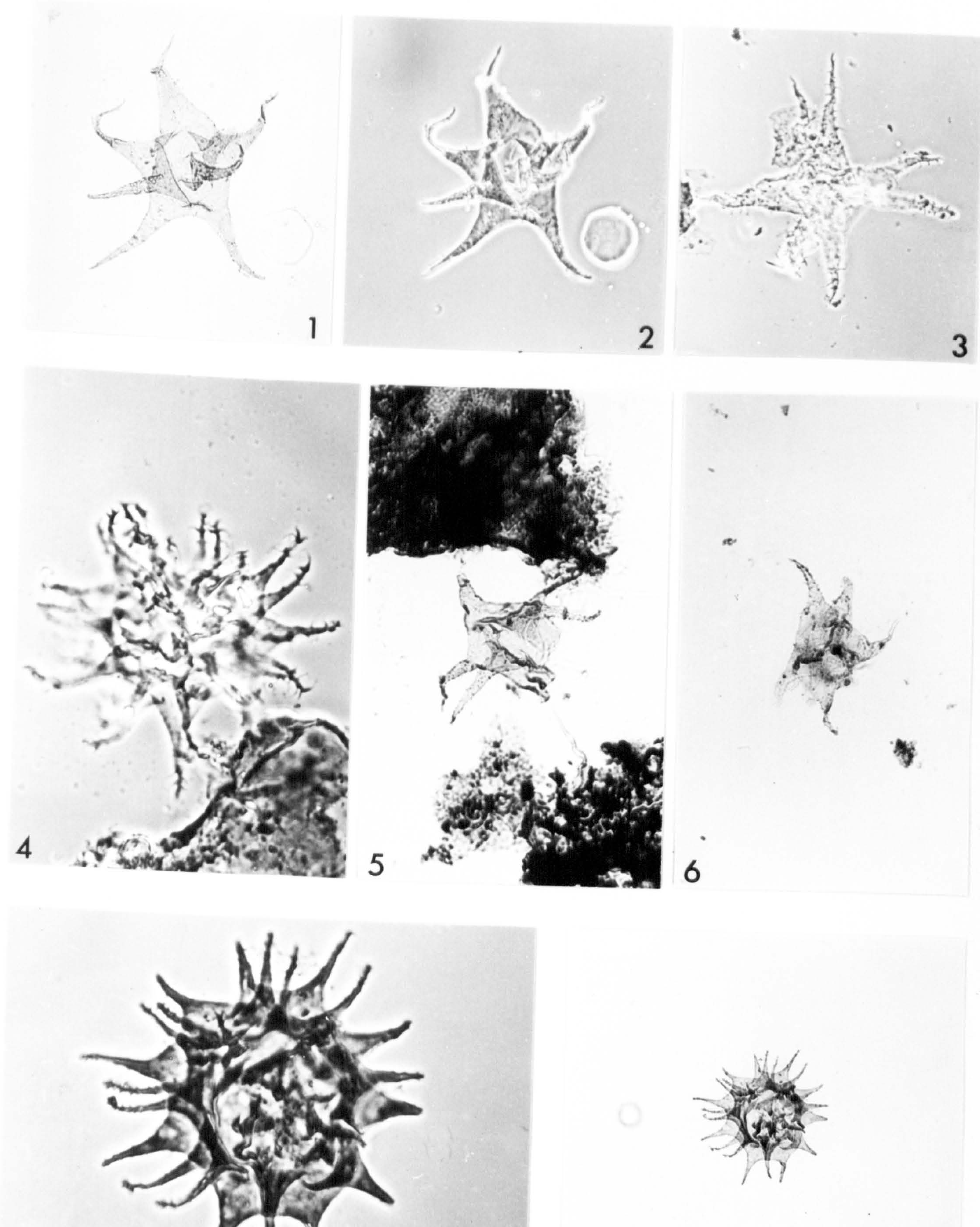


PLATE 22

1,2 Goniosphaeridium connectum

1. NS/3-6; 12.1/94.4; X500.

2. OV/LHS/2b-7; 18.6/105.8; X500.

3 - 5 Goniosphaeridium sp.A.

3. OV/LHS/1-12; 6.4/84.8; X500.

4. NS/4-1; 21.1/115.8; X500.

5. NS/4-1; 21.5/124.4; X500.

6,7 Solisphaeridium nanum comb.nov.

6. NS/4-1; 16.3/129.1; X500.

7. OV/HS/2-1; 20.2/111.0; X500.

8 cf. Astropheos helosa sp.nov.

OV/LHS/2b-7; 19.6/107.8; X500.

9-11 Astropheos helosa sp.nov.

9. OV/O/4-1; 21.2/105.4; X500.

10. same specimen at X1200; phase-contrast.

11. OV/AS/1-1; 21.9/85.5; X500; holotype.

PLATE 22

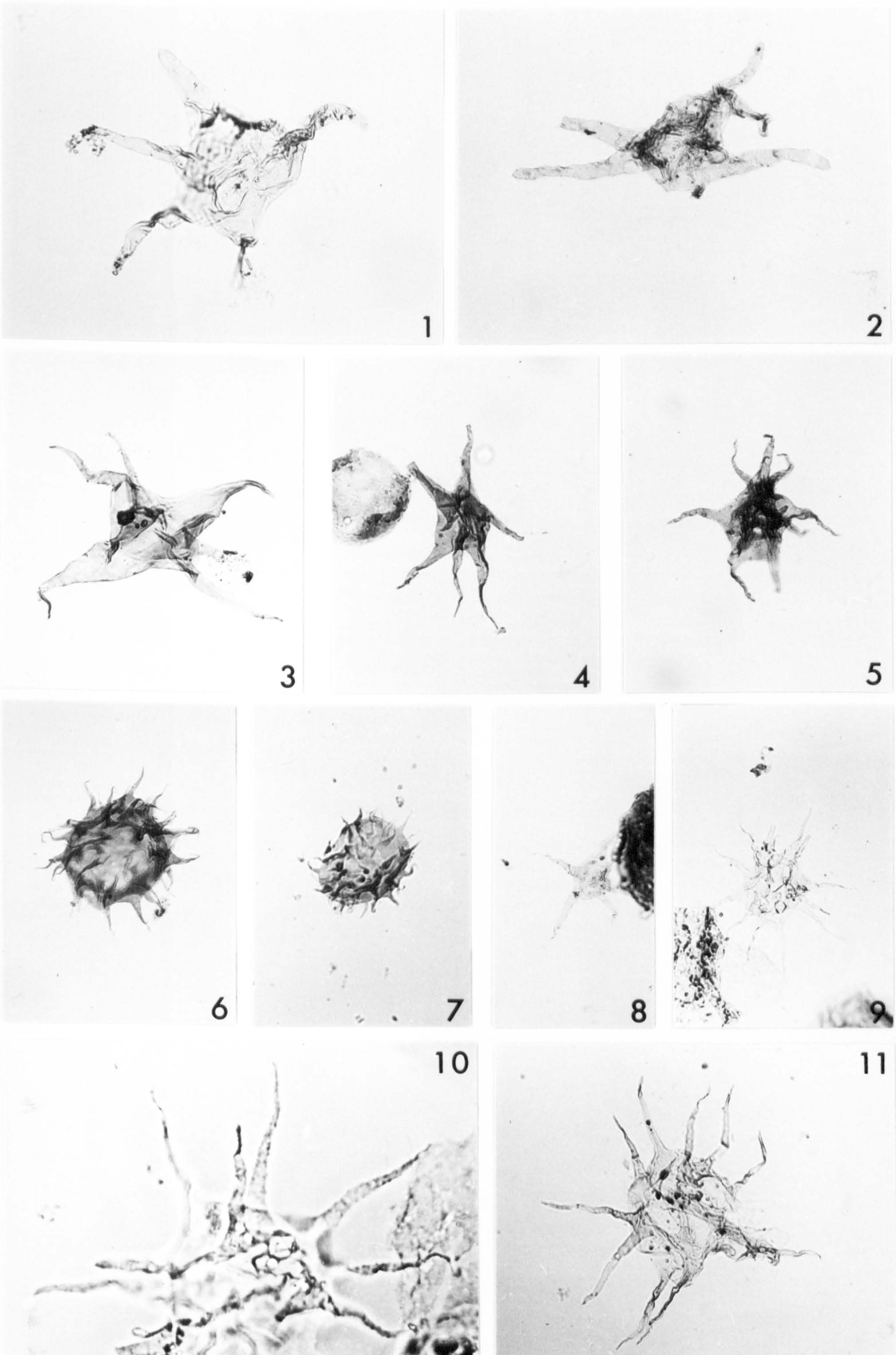


PLATE 23

All magnifications X500

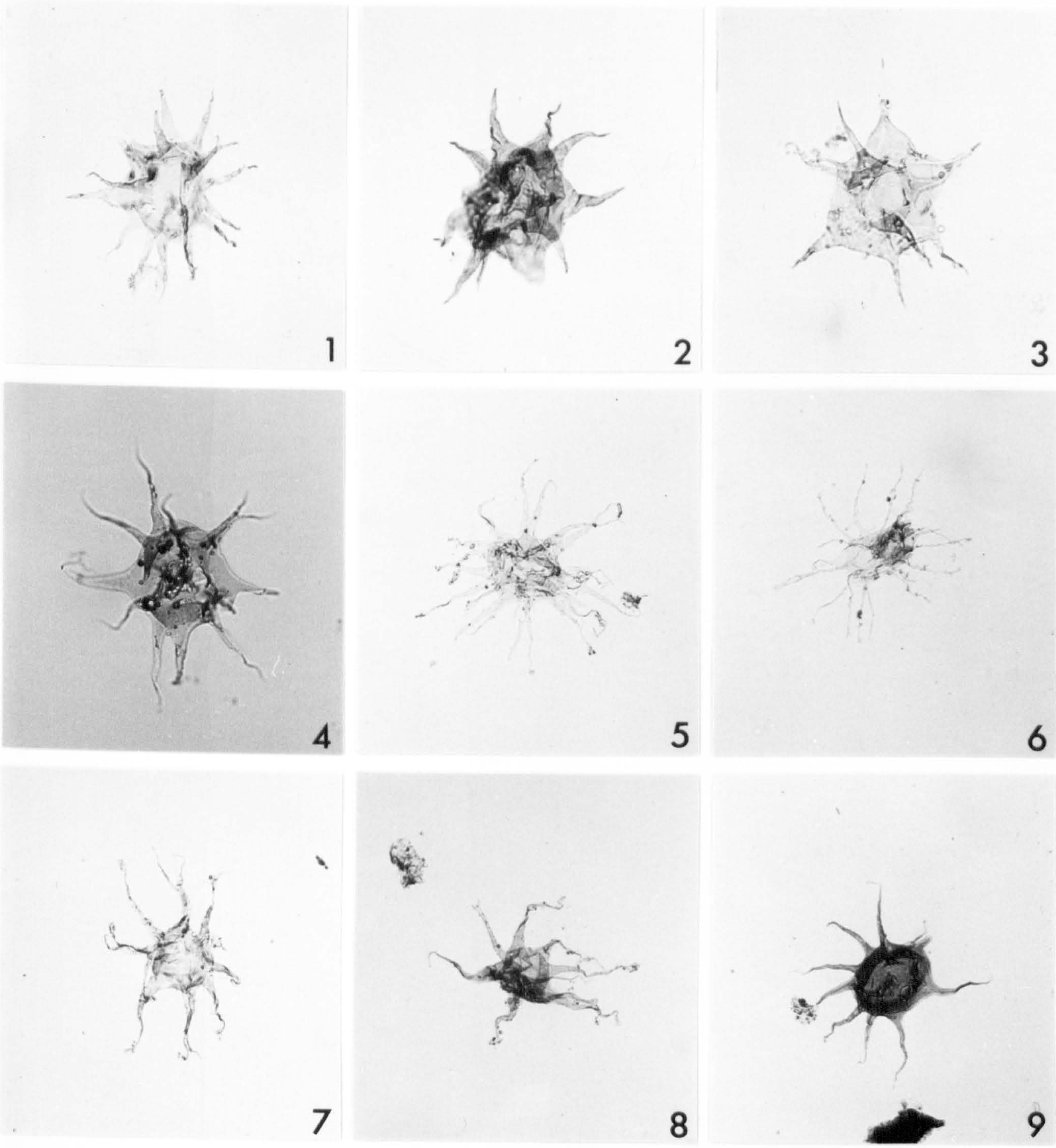
1 - 4 *Goniosphaeridium splendens* comb.nov.

1. NS/4-6; 13.6/118.5.
2. NS/4-6; 7.6/90.2.
3. OV/LHS/2b-7; 21.9/95.6.
4. OV/O/4-1; 19.1/124.6.

5-12 *Goniosphaeridium elongatum* sp.nov.

5. NS/3-3; 6.2/96.0; holotype.
6. OV/LHS/2b-7; 19.9/114.9.
7. NS/4-4; 20.4/109.7.
8. NS/4-6; 15.8/120.4.
9. NS/4-6; 8.9/127.0.
10. NS/4-1; 20.2/101.4.
11. NS/4-4; 14.5/130.3.
12. NS/4-6; 8.9/127.0.

PLATE 23



1 - 3 Micrhystridium equaspinosum sp.nov.

1. OV/LHS/2a-7; 10,2/85.9; X1200; phase-contrast; holotype.

2. same specimen at X500; phase-contrast.

3. NS/4-13; 19.3/123.3; X500.

4 - 6 Micrhystridium acum var. brevispinum var. nov.

4. OV/UCL/1-25; 5.4/109.6; X1200; phase-contrast.

5. NS/4-13; 20.9/127.4; X1200; phase-contrast.

6. OV/LHS/2a-9; 14.7/98.6; X1200; phase-contrast.

10. Micrhystridium cf. acum var. brevispinum

OV/LHS/1-13; 15.2/109.8; X1200; phase-contrast.

7-9,11-13 Micrhystridium aremoricanum

7. OV/LHS/2b-13; 16.0/88.8; X1200.

8. OV/LHS/2b-13; 16.6/119.1; X1200.

9. OV/LHS/2b-13; 10.2/122.7; X500.

11. OV/LHS/2b-13; 10.6/119.1; X1200; phase-contrast.

12. OV/LHS/2b-13; 16.0/88.8; X1200. phase-contrast.

13. OV/LHS/2b-13; 10.2/122.7; X1200; phase-contrast.

14,15 Palaiosphaeridium sp. A.

14. OV/UCL/1-25; 5.6/121.7; X1200; phase-contrast.

15. NS/3-7; 20.2/98.4; X1200; phase-contrast.

PLATE 24

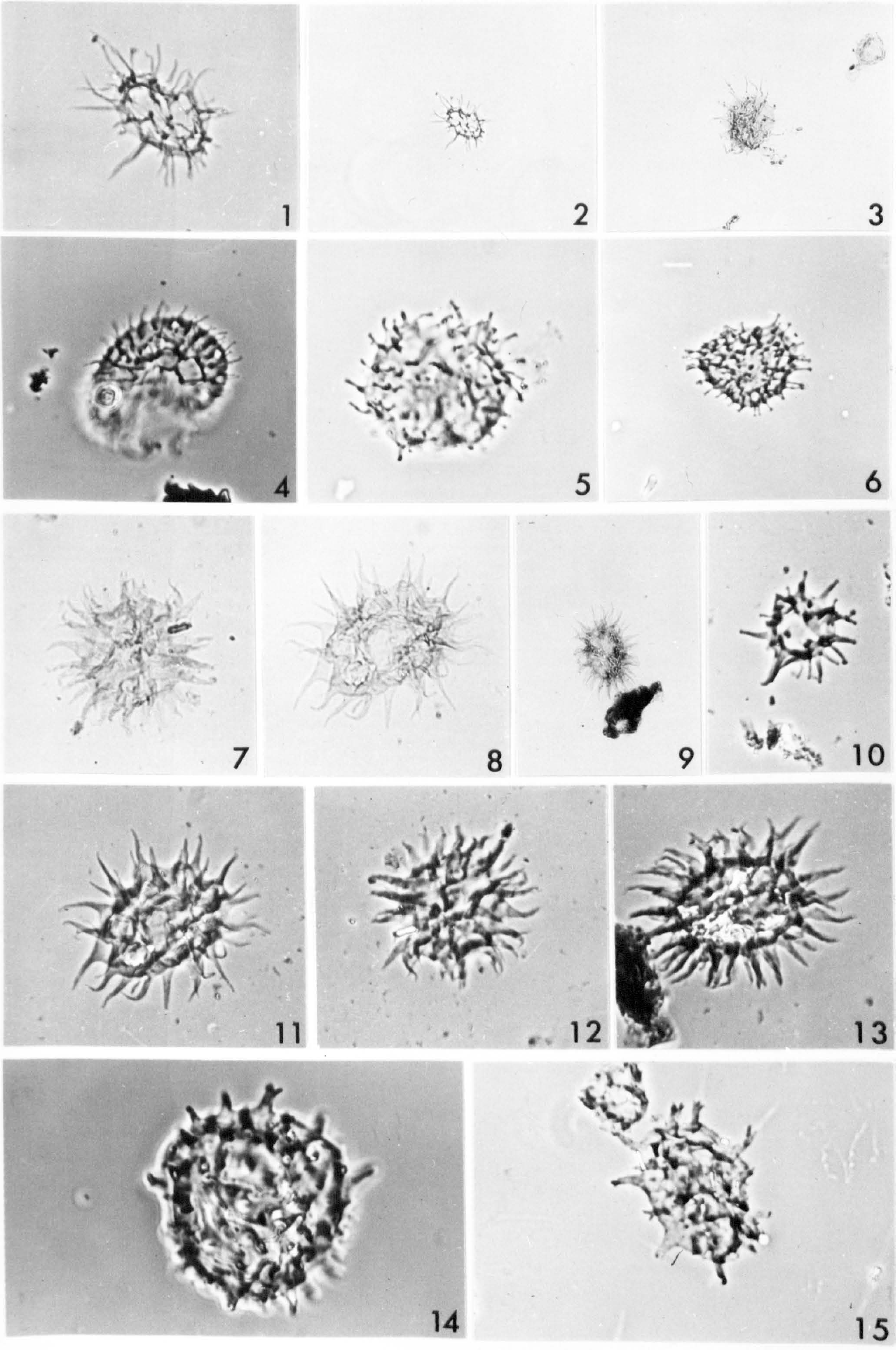


PLATE 25

All magnifications X500

1,2,4 Leiosphaeridia ketcheniata sp.nov.

1. OV/LHS/1-8; 5.2/89.6; X500; low focus.
2. same specimen; high focus.
4. NS/3-6; 12.1/131.2; X500; holotype; note the large pylome and the detached operculum which has fallen into the vesicle.

3,5 Leiosphaeridia tenuissima

3. NS/2-1; 18.6/114.2; X500.
5. NS/4-1; 9.2/100.0; X500.

7 Leiosphaeridia cf. voigti

NS/4-1; 15.7/92.7; X500.

6,8 Dichaisphaira caradocium sp.nov.

6. NS/4-6; 7.5/125.0; X500; holotype.
8. NS/4-4; 5.4/97.5; X500.

PLATE 25

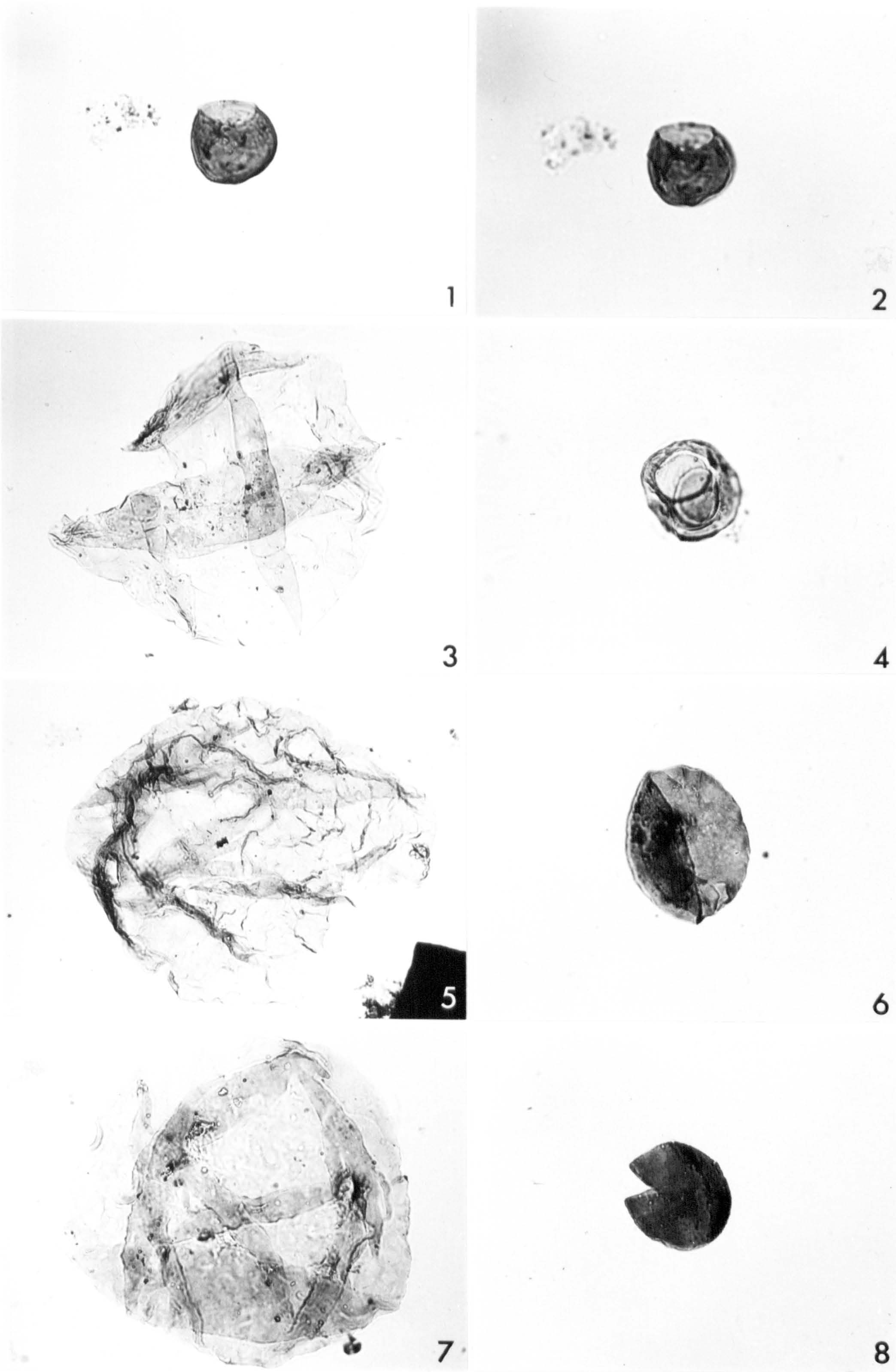


PLATE 26

1 - 2 <u>Actinotodissus</u> spp.

1. FF/LF/1b-14; 3.5/95.5; X1200.
2. FF/MSE/1a-7; 7.4/85.3; X1200.

3 - 6 <u>Leiofusa</u> sp.A.

3. FF/M.a./2-2; 5.0/110.2; X1200.
4. Araeth; 8.0/90.9; X500.
5. FF/M.a./2-2; 4.8/106.0; X1200.
6. Araeth; 12.8/105.9; X1200.

7 - 8 <u>Dichasphaira</u> form-group C.

7. FF/ML/2-9; 6.6/130.0; X1200.
8. same specimen at X500.

PLATE 26

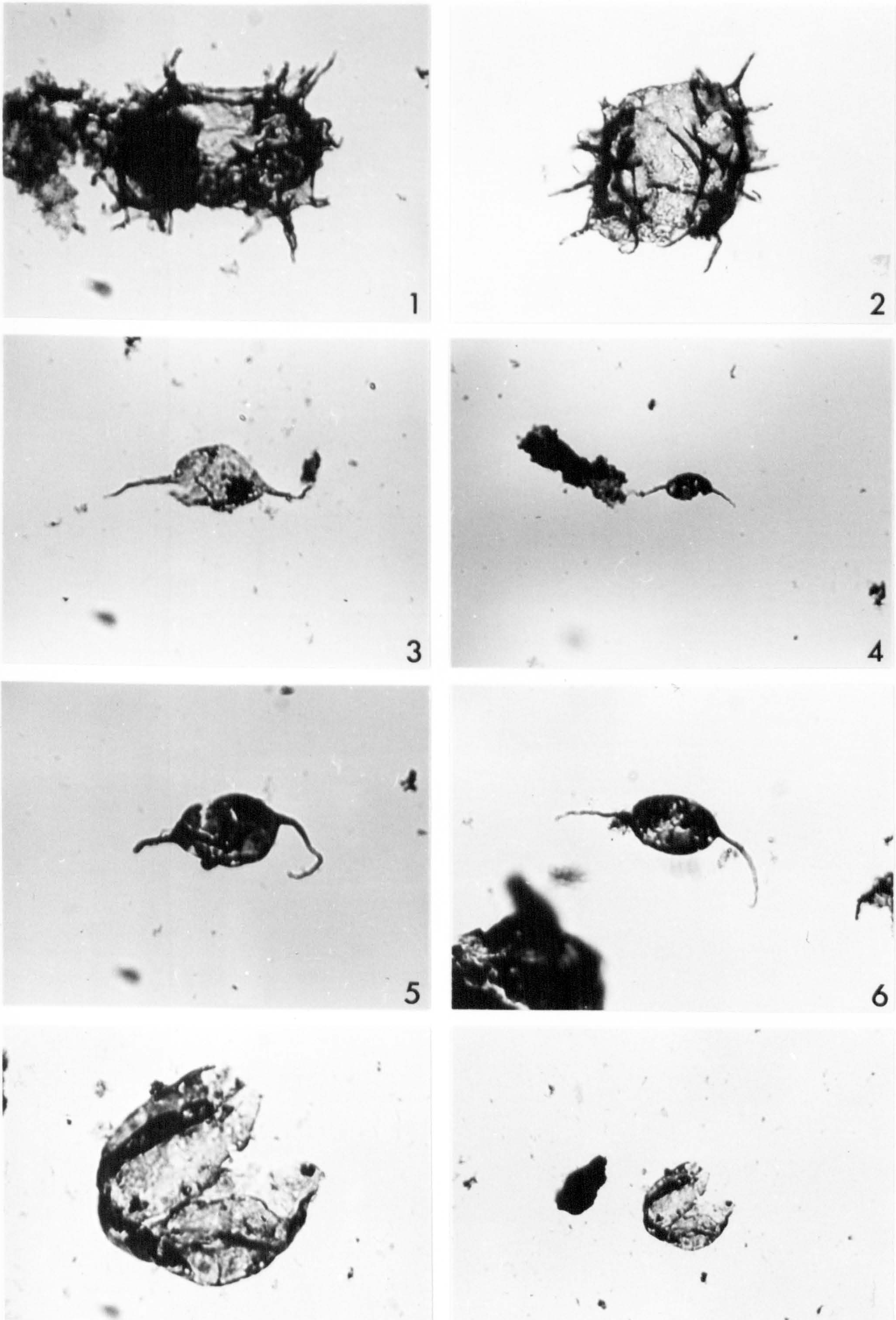


PLATE 27

All magnifications X1200

1,2,4 *Astropheos celestum*

1. FF/SF/1c-6; 8.7/127.6
2. FF/LF/1b-7; 7.7/116.0.
4. FF/M.a./2-2; 13.5/120.8.

3,5,6 *Astropheos llandeilensis* sp.nov.

3. FF/LF/1b-7; 3.8/105.7.
5. FF/M.a./2-2; 9.2/123.0.
6. FF/M.a./2-2; 8.5/94.7; holotype.

7,8 *Acritarch* sp.A.

7. FF/M.a./2-1; 18.3/101.4.
8. FF/LF/1b-7; 7.1/85.2.

note the characteristic solid processes of figs. 7 and 8.

PLATE 27

PLATE 28

All magnifications X1200

1 - 3 Goniosphaeridium splendens sp.nov.

1. Araeth; 11.4/92.3.

2. Araeth; 10.9/130.3.

3. FF/MSE/1a-7; 18.7/100.8.

4. Goniosphaeridium ? sp.A.

5,6 Goniosphaeridium cf. sp.B.

5. FF/LF/1b-14; 5.1/100.7.

6. FF/LF/1b-7; 8.3/106.1.

This rare form is similar to Goniosphaeridium sp.B. but has a more spherical vesicle bearing more numerous shorter processes.

7 - 9 Goniosphaeridium sp.B.

7. FF/LF/1b-7; 9.4/129.0.

8. FF/M.a./2-13; 5.7/102.3.

9. FF/LF/1b-14; 6.2/96.2.

PLATE 28

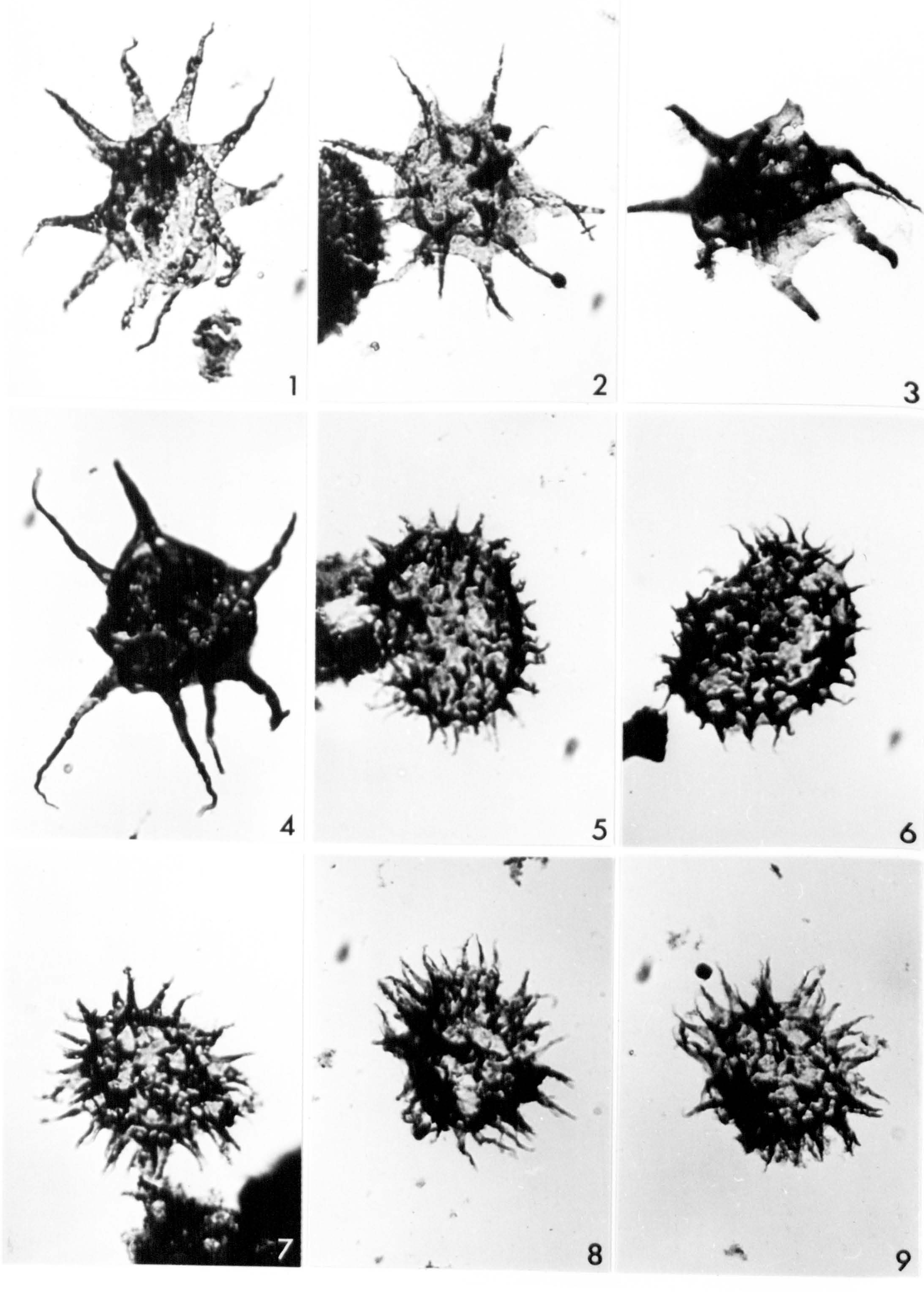


PLATE 29

1,2 Baltisphaeridium ? cf. latiradiatum

1. Araeth; 14.2/110.4; X1200.

2. same specimen at X500.

3 - 6 Baltisphaeridium longispinosum subsp. delicatum subsp.nov.

3. FF/M.a./2-2; 8.3/91.4; X1200.

4. same specimen at X500.

5. FF/M.a./2-2; 4.4/113.7; X1200.

6. same specimen at X500.

7,8 cf. Baltisphaerosum bystrentos comb.nov.

7. FF/M.a./2-1; 10.3/108.9; X1200.

8. same specimen at X1200; phase-contrast; the granular process ornament is clearly visible.

PLATE 29

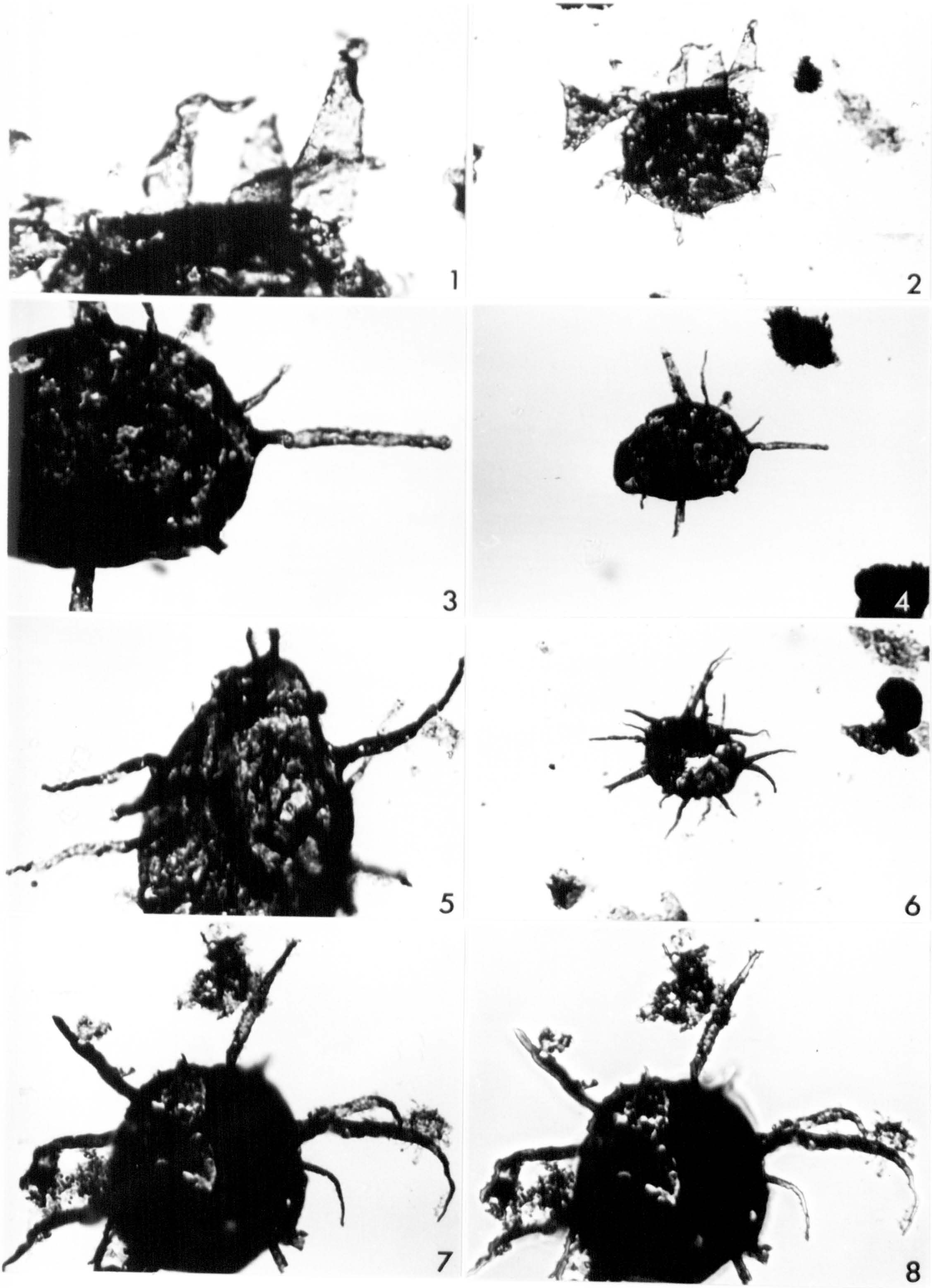


PLATE 30

All magnifications X1200

1,2 Baltisphaerosum onniensis gen. et sp.nov.

1. FF/LF/1b-1; 22.6/121.1.
2. FF/LF/1b-7; 6.5/88.5.

3,4 Solisphaeridium nanum comb.nov.

3. FF/MSE/1a-9; 10.0/112.7.
4. FF/ML/2-9; 2.9/105.4.

5 - 8 Solisphaeridium lucidum comb.nov.

5. FF/MSE/1a-9; 8.2/117.7.
6. FF/LF/1b-7; 11.1/85.5.
7. FF/LF/1b-7; 14.3/90.0.
8. FF/MSE/1a-9; 3.5/108.3.

PLATE 30

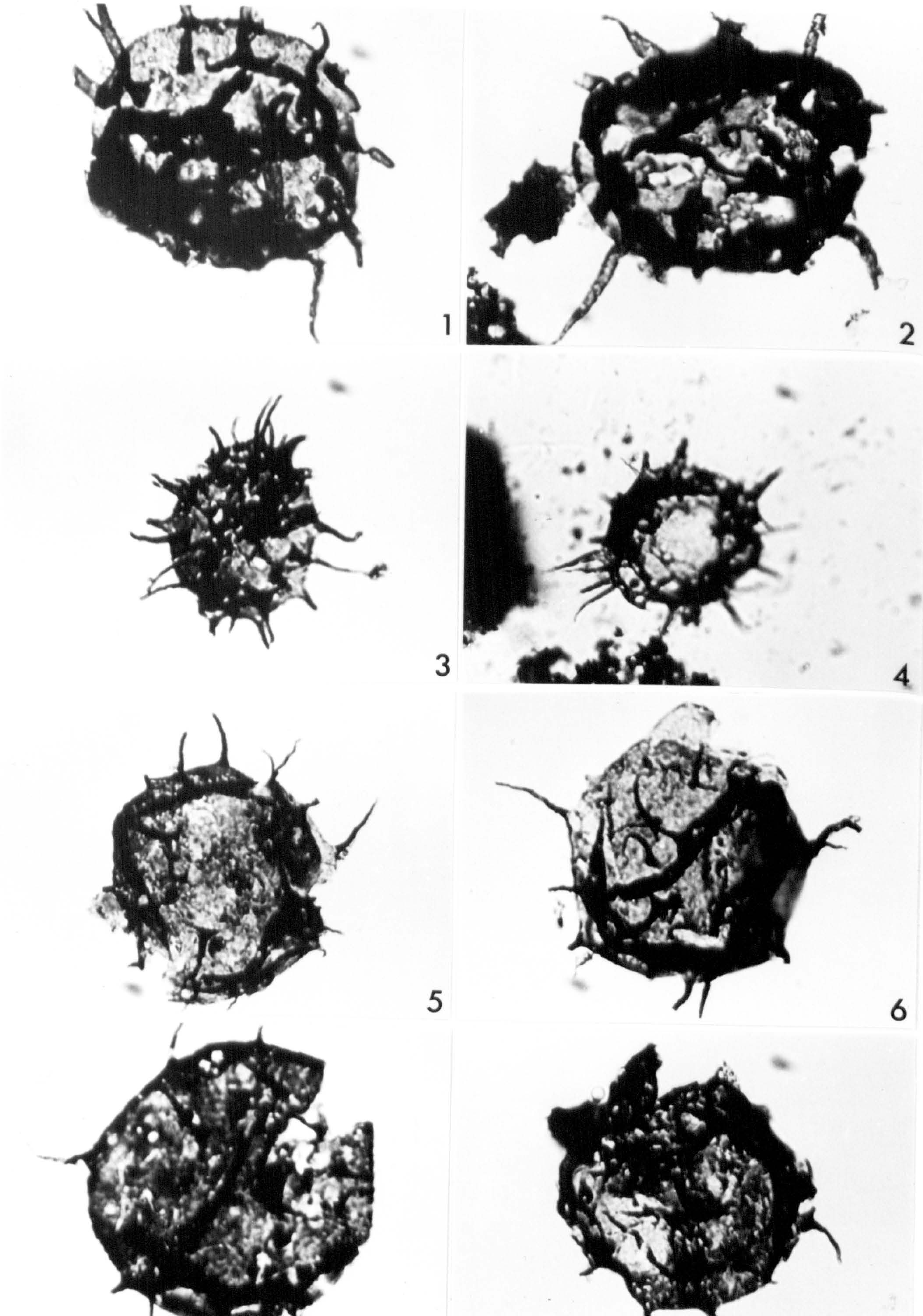


PLATE 31

All magnifications X1200

1 - 3 Multiplicisphaeridium raspa

1. FF/SF/1c-9; 6.4/93.2.

2. FF/LF/1b-14; 7.3/114/1.

3. FF/LF/1b-7; 9.4/91.4.

4 - 6 Multiplicisphaeridium cf. ramusculosum

4. FF/LF/1b-7; 4.1/108.3.

5. FF/ML/2-9; 2.9/116.2.

6. Araeth; 20.8/87.4.

7 - 9 ? Nothooidium sp.A.

7. FF/M.a./2-1; 18.9/102.9.

8. Araeth; 7.6/110.6.

9. Araeth; 10.6/106.7.

PLATE 31

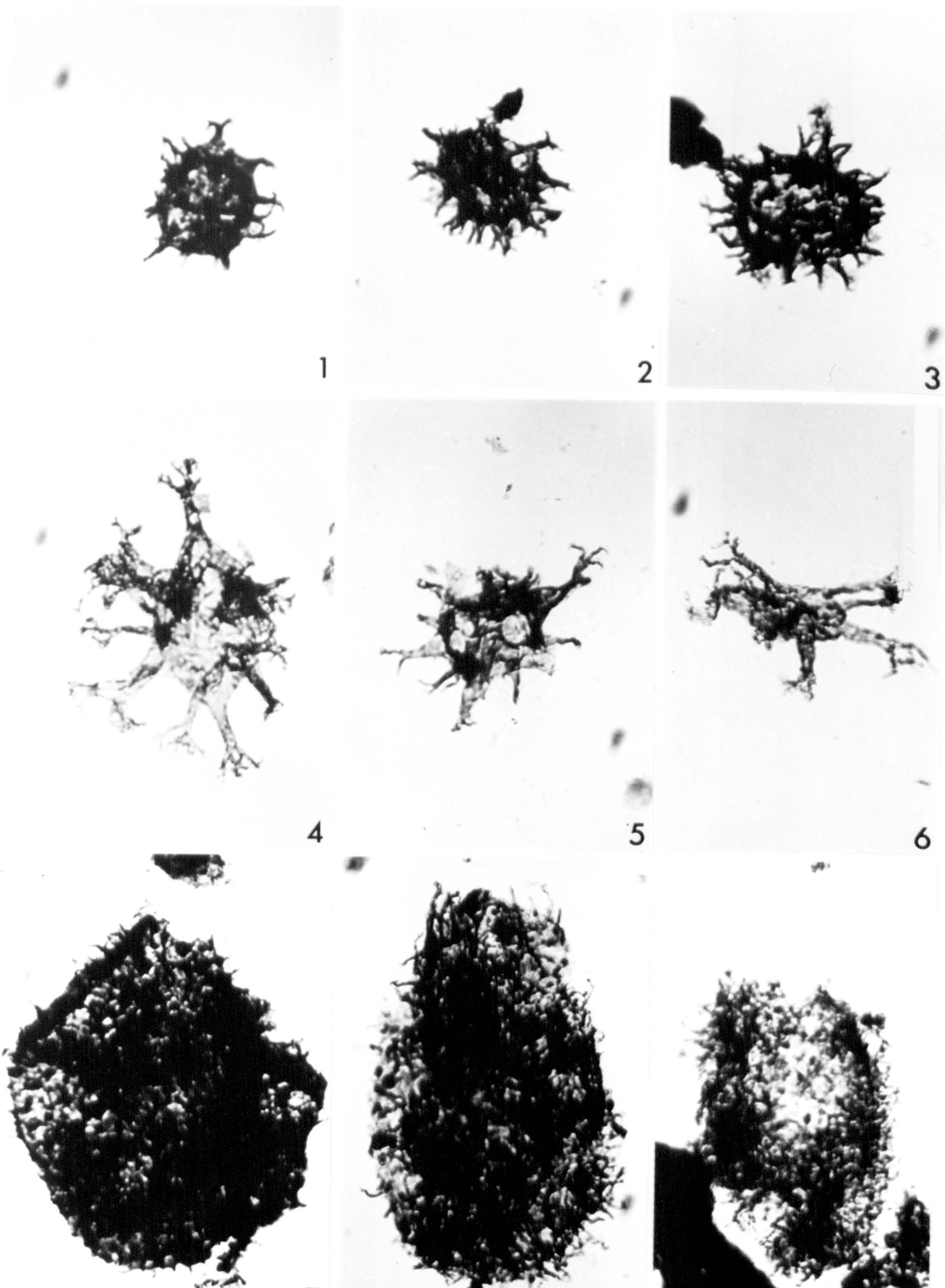


PLATE 32

All magnifications X1200

1 *Micrhystridium aremoricanum*

FF/LF/1b-14; 3.0/86.9.

2 *Micrhystridium henryi*

FF/SF/1c-9; 16.7/96.0.

3 *Micrhystridium aremoricanum*

FF/SF/1c-9; 12.5/120.4.

4 - 6 *Micrhystridium henryi*

4. FF/SF/1c-9; 6.6/108.4.

5. FF/ML/2-9; 5.7/119.1.

6. Araeth; 10.7/93.5.

7 - 9 *Micrhystridium equaspinosum*

7. Araeth; 21.1/102.9.

8. Araeth; 10.6/103.8.

9. Araeth; 10.2/87.4.

10-11 *Micrhystridium acum* var. *brevispinum* var.nov.

10. FF/LF/1b-7; 3.0/124.4.

11. FF/LF/1b-14; 2.3/114.4.

12 *Micrhystridium* sp.

FF/ML/2-9; 3.2/81.9.

PLATE 32

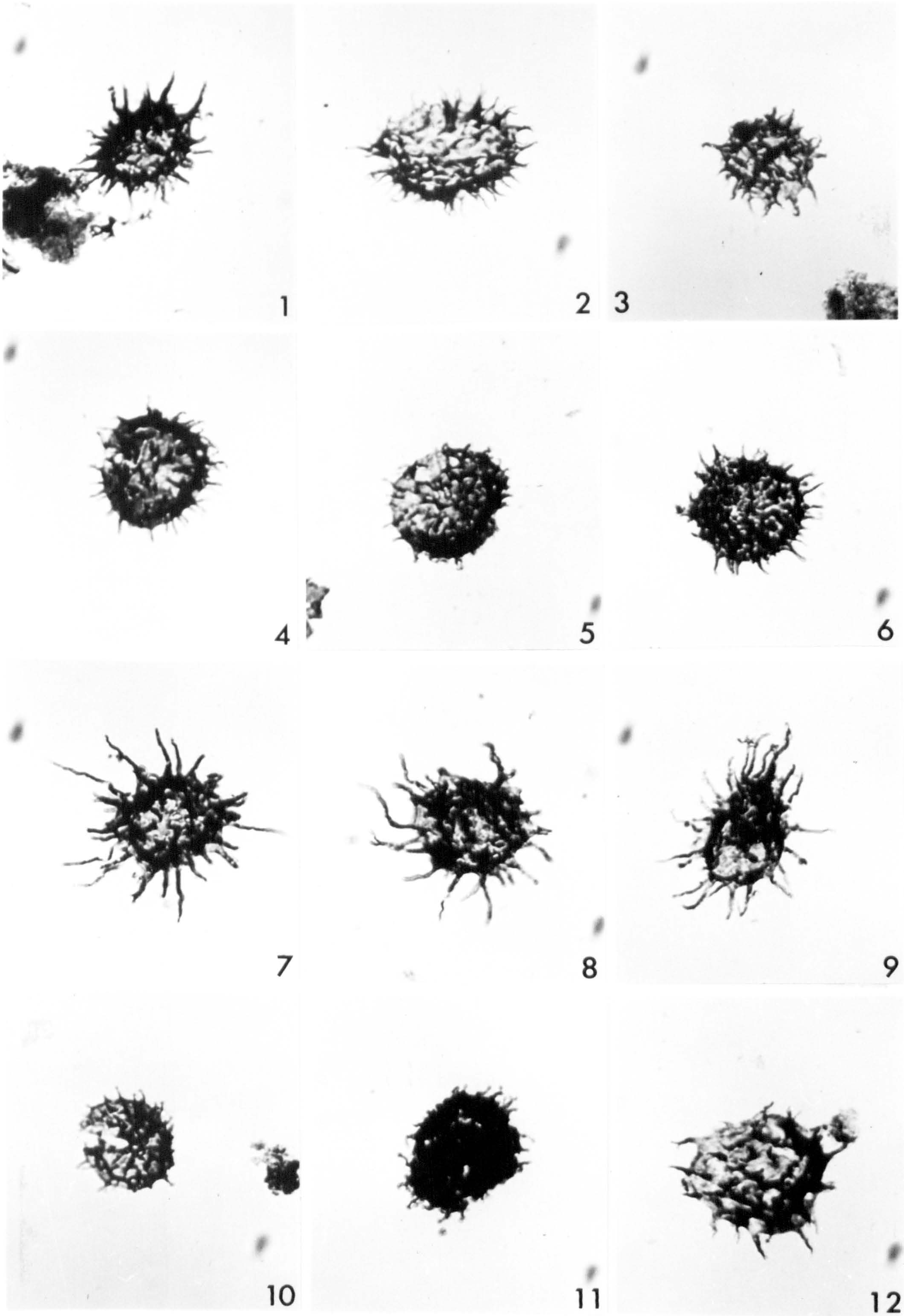


PLATE 33

1. *Peteinosphaeridium* *trifurcatum* subsp. *trifurcatum*
Araeth; 8.4/124.2; X1200.

2. *Peteinosphaeridium* *trifurcatum* subsp. *intermedium*
FF/LF/1b-1; 19.4/132.7; X1200.

3. ? *Ordovicidium* *elegantulum*
FF/LF/1b-7; 20.3/118.2; X1200. phase-contrast; note the granular ornament of the distal process branches.

4. *Peteinosphaeridium* *nudum*
FF/LF/1b-1; 5.7/99.4; X500.

5. ? *Ordovicidium* *elegantulum*
FF/LF/1b-7; 20.3/118.2; X1200.

6. *Peteinosphaeridium* *trifurcatum* cf.subsp.*breviradiata*
Araeth; 15.5/109.1; X500.

7. detail of fig.4 at X1200; note the smooth distal process branches.

8. *Peteinosphaeridium* *trifurcatum* subsp.*breviradiata*
FF/MSE/1a-9; 14.8/119.4; X1200.

PLATE 33

PLATE 34

All magnifications X1200

1 - 4 *Stelliferidium striatulum*

1. FF/LF/1b-7; 21.7/124.5.
2. FF/MSE/1a-7; 6.5/108.7.
3. FF/M.a./2-1; 21.8/111.8; specimen with an abnormally large pylome.
4. FF/LF/1b-7; 20.0/115.7.

5 *Barakella fortunata*

FF/LF/1b-7; 6.8/94.3.

6 *Pirea nervata*

FF/LF/1b-7; 18.8/126.4.

7 *Leiosphaeridia* sp.

FF/ML/2-9; 6.9/89.9.

8 *Lophosphaeridium* sp.

FF/ML/2-9; 2.8/127.8.

PLATE 34

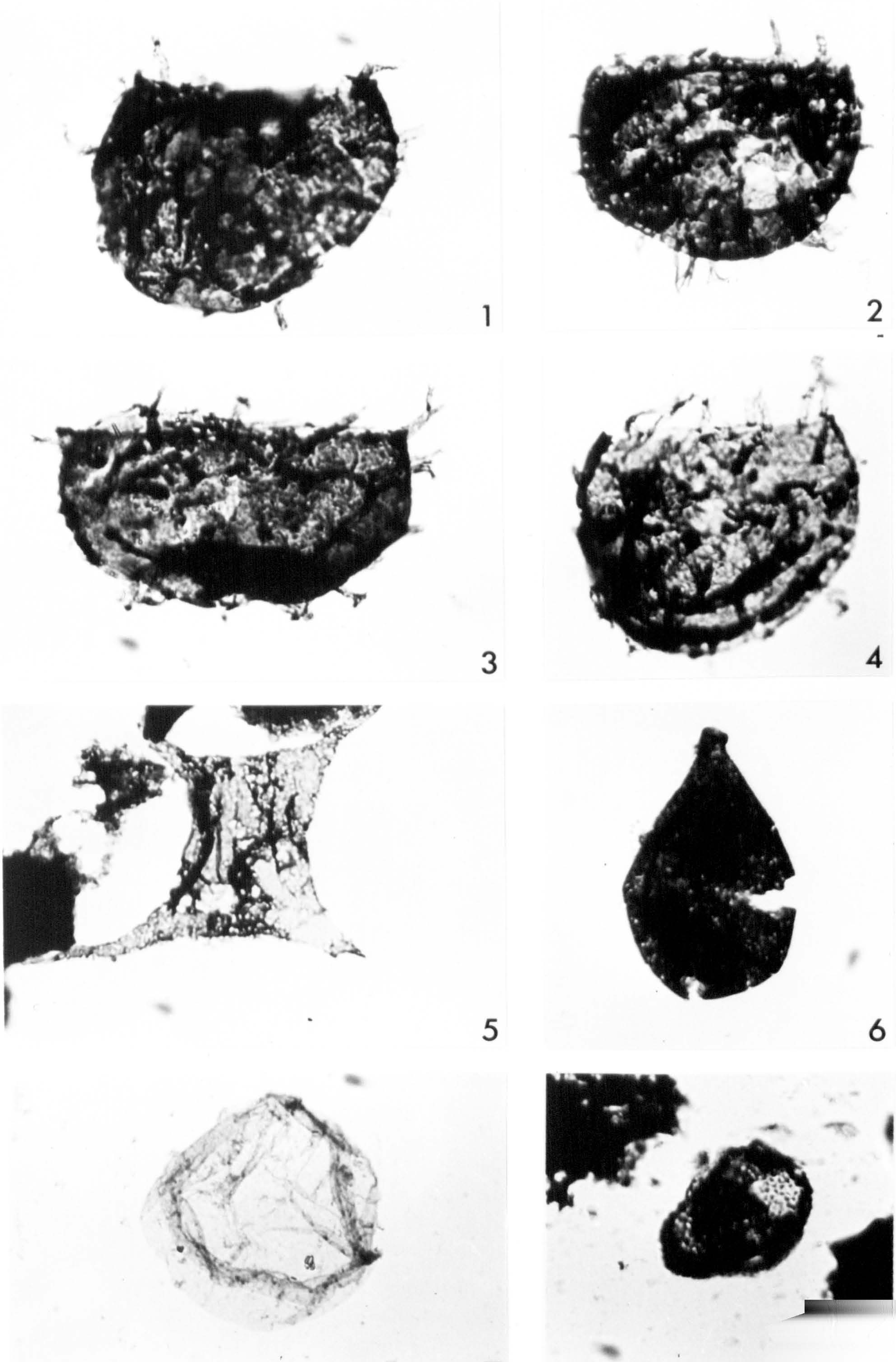


PLATE 35

1 - 3 Veryhachium downiei

1. FF/M.a./2-13; 6.0/88.4; X1200.

2. FF/M.a./2-13; 3.5/89.2; X1200.

3. Araeth; 8.4/131.8; X500. specimen with an epityche.

4 Veryhachium trispinosum

FF/LF/1b-7; 9.3/92.3; X1200.

5 - 8 Veryhachium sp.A.

5. Araeth; 19.4/120.4; X1200.

6. FF/M.a./2-13; 6.2/131.1; X1200.

7. Araeth; 10.8/106.9; X1200.

8. Araeth; 7.5/90.3; X1200.

9,10 Veryhachium lairdi

9. Araeth; 9.5/87.5; X1200.

10. Araeth; 20.4/129.8; X1200.

11,12 Veryhachium minutum

11. FF/MSE/1a-13; 8.9/131.1; X1200.

12. Araeth; 13.1/127.3; X1200.

PLATE 35