Lower Ordovician Acritarchs from successions in England and North Wales.

by

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To my parents

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ABSTRACT

Lower Ordovician Acritarchs from successions in England and North Wales.

G.A. Booth.

One hundred and thirty eight acritarch taxa are described from the organic residues of samples collected in North Wales, Shropshire, and the Lake District. The species occur in one or more of 16 microfloral assemblages, selected from 88 prepared samples. Three new genera and seven new species are proposed. Range charts are presented which show the occurrence and distribution of all the species described in detail.

On the basis of these results, five microfloral zones and two subzones are proposed. Each zone or subzone is characterised by an assemblage of species, and equates to part of the established Lower Ordovician graptolite zonation.

The proposed biostratigraphical scheme is applied to microfloral assemblages from several localities in the English Lake District, most of which were either previously undated or doubtfully dated.

Comparisons are made with Arenigian and Llanvirnian assemblages described from the European area, by other authors. Tentative conclusions are drawn as to the possible continuity of the British province with other European areas during Arenigian and Llanvirnian times.

Factors affecting the preservation of acritarchs are discussed and a visual classification scheme is presented which takes into account fragmentation, degree of corrosion, and colour.

INTRODUCTION

The study of organic-walled microfossils of the kind termed acritarchs (Gr. akritos, uncertain, and arche, origin; see Evitt, 1963), dates from the time of Ehrenberg (1838) and White (1842). However, not until the early 1930's did research into the stratigraphical occurrence, distribution and nature of acritarchs, seriously begin. Eisenack (1931 et seq.) then published a series of papers on microfossils from the Palaeozoic rocks of the Baltic province. Deflandre (1942 et seq.) followed with his studies on the Ordovician and Silurian strata of the Montagne Noire. Further research was undertaken by Deunff (1951 et seq.) who described assemblages from the Ordovician and Silurian rocks of Brittany. More recently, there have been major contributions by Martin (1969), Cramer (1964b) and Rauscher (1974a). Their work was based on Belgian, Spanish and French material, respectively.

Apart from a study of Caradocian microfossils by Lewis (1940), which included description of several acritarch species, the investigation of British Lower Palaeozoic microfloras began with Downie (1958) who described a well preserved acritarch assemblage from the Tremadocian Shineton Shales. Later, Downie (1959, 1963) showed the Silurian Wenlock Shales to also contain well preserved acritarchs. This work was continued by Rasul (1971 MS., 1974, 1976), Lister (1968 MS., 1970b) and Hill (1974 MS.). However, no detailed studies of Ordovician acritarchs were undertaken, although Jenkins (1965 MS.) noted their occurrence in the Ordovician rocks of Shropshire, and assemblages were recorded by Lister (1969, unpublished); Lister, Burgess and Wadge (1969), Lister, Cocks and Rushton (1969); Lister and Holliday (1970); Wadge et al. (1967, 1970); Downie and Soper (1972). Only the material studied by Lister (1969, unpublished) and Wadge et al. (1967, 1970) was reliably dated by graptolites. Consequently the use of

acritarchs as stratigraphic indicators in British Ordovician rocks, has relied principally upon the French and German studies of continental material. Even in these studies the material investigated has often been of uncertain age or not dated beyond assignment to the Lower Ordovician, Caradocian etc. No clear picture has therefore developed as to the ranges of Ordovician acritarch species.

A principal aim of this study has been to improve knowledge of the stratigraphic occurrence of key Lower Ordovician acritarch species from British rocks. Material for the investigation was first obtained from an area to the west of Bassenthwaite in the English Lake District. This region was studied in great detail by Jackson (1956 MS., 1961, 1962) who identified at several localities the Subzones of Didymograptus deflexus, D. nitidus, and Isograptus gibberulus, and the Zone of D. hirundo. Unfortunately all the samples from these graptolite localities proved to contain only highly carbonised acritarch fragments. Other localities were therefore selected in Shropshire and North Wales. Details of all the samples collected are given in Chapter 1.2.

Sufficient acritarch bearing material was eventually acquired to enable, after analysis, the proposal of a biostratigraphic scheme of five acritarch zones (see Chapter 5.1). The information has been used in the dating or reassessment of several samples from the English Lake District. These results are presented and discussed in Chapter 6.

Most of the acritarchs examined were unfortunately severely affected by the natural processes of oxidation and decay, crystal growth, or the effects of thermal metamorphism. The interplay of these factors is briefly discussed in Chapter 7.

CHAPTER 1 LOWER ORDOVICIAN STRATIGRAPHY

1.1. GENERAL CONSIDERATIONS

The Ordovician system was proposed by Lapworth (1879a) for strata previously included in the Silurian by Sedgwick and in the Cambrian by Murchison. The upper and lower boundaries of the type section in the Arenig - Bala district of North Wales were well defined, but confusion arose because of a stratigraphical inconsistency introduced by Hicks (1872), and continued by Hopkinson and Lapworth (1875) (see Whittington and Williams, 1964, for discussion). Consequently a dual classification developed with the Tremadocian being assigned to either the Ordovician or Cambrian. Pending international agreement, the Lower Palaeozoic Era Subcommittee of the Geological Society of London has proposed that the base of the Arenig be taken as the base of the Ordovician (Holland, 1971). Their recommendation is followed in this study.

Biostratigraphical subdivision of the Ordovician was established by Lapworth (1879b) using graptolites. His work was subsequently revised by Elles (1904, 1922a, 1925 and 1933), and Elles and Wood (1901-1918). The scheme of Elles (1933) dealt primarily with zonal assemblages in the Skiddaw Group of the English Lake District (Text-fig. 1A). Her proposals did not receive the support of all geologists (see Bulman, 1941, and Jackson, 1962).

Elles' case for including the Zone of Bryograptus kjerulfi in her scheme was based on the occurrence of the many-branched graptolites B. kjerulfi and B. cumbriense at one locality (Barf). Since 1933 there has been an increasing realisation that these species, and related forms, range well into the Arenigian. Consequently they are no longer considered to be of such zonal significance. Taking account of the whole assemblage

Text-fig. 1

A. The zonal scheme of Elles (1933) based on graptolites and produced essentially for the Skiddaw Group

Llanvirn	Didymograptus bifidus	
Arenig	D. hirundo	
	D. extensus	Subzone of Isograptus gibberulus
		Subzone of D. nitidus
		Subzone of D. deflexus
		Upper Subzone of Tetragraptus (reclined)
Tremadoc	Dichograptus	Lower Subzone of Tetragraptus (horizont.)
		Lower part (unnamed)
	Bryograptus kjerulfi	

B. A currently accepted graptolite zonal scheme (from Eastwood et al., 1968)

Llanvirn	Didymograptus murchisoni	
	D. bifidus	
Arenig	D. hirundo	
	D. extensus	Subzone of Isograptus gibberulus
		Subzone of D. nitidus
		Subzone of D. deflexus
	(Tetragraptus approximatus)	
Tremadoc	Anisograptidae and ?Graptoloidea)	
	Dictyonema flabelliforme and Anisograptidae (Bryograptus)	
	D. flabelliforme (D. sociale)	

Jackson (1962) re-interprets Elles' B. kjerulfi locality as representing the Subzone of Didymograptus nitidus in the Zone of D. extensus.

With regard to the Zone of Dichograptus Elles (1933) comments that there does not appear to be any reason for doubting its occurrence since it appears to be developed across a wide tract of country. However, Jackson (1962), after re-appraisal of the graptolites obtained from Elles' localities, concludes that the assemblages are not older than the Subzone of Didymograptus deflexus in the Zone of D. extensus.

The upper Subzone of Tetragraptus is recorded by Elles from only one locality (Great Knott). Eastwood et al. (1968) consider that if graptolites found at other localities in the vicinity of Great Knott are taken into account, then the fauna as a whole indicates the Subzone of Isograptus gibberulus.

It is now generally accepted (Jackson 1961, 1962; Skevington, 1963; Eastwood et al., 1968; Williams et al., 1972) that there is no firm indication of a fauna older than the Subzone of D. deflexus in Skiddaw Group. In fact the lowest part of the Arenigian, characterised in North America, Australia and Scandinavia by a Tetragraptus approximatus fauna, does not appear to be present in the British Ordovician succession. Alternatively it may be present but lacks graptolites. (note, however, Jackson, 1964, who records a single graptolite of the T. approximatus type from a formation at the base of the Skiddaw Group).

The area first selected for investigation during this study was in the English Lake District, where rocks of the Skiddaw Group formed a reasonably complete, well dated, succession through the Arenigian. The results of this investigation were disappointing as the samples yielded very few acritarchs, all of which were highly carbonised.

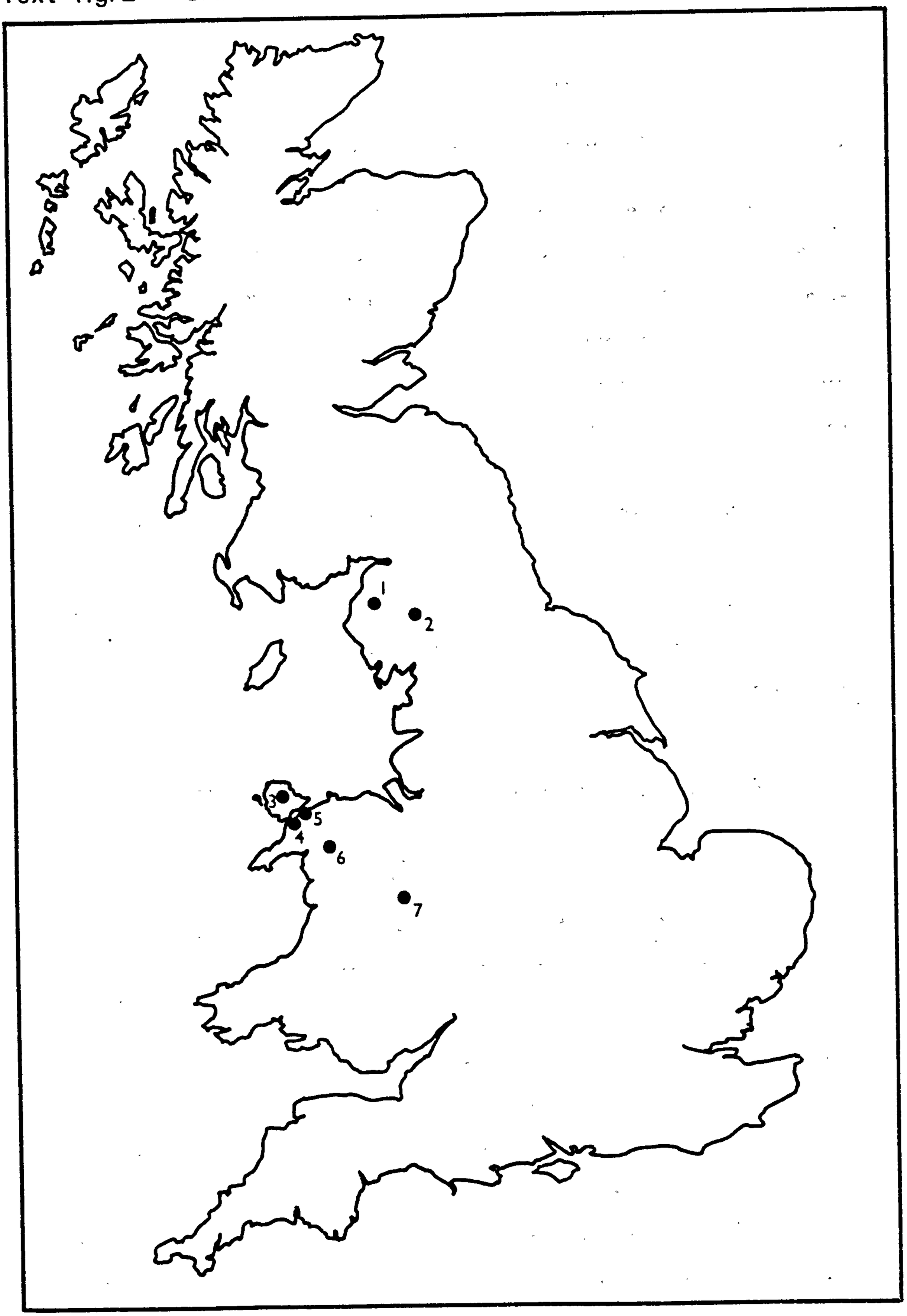
Attention was therefore turned to outcrops of Arenigian and Llanvirnian age in other areas. Many localities in North Wales were considered, but most were rejected as evidence as to their age was often based on the occurrence of a single graptolite or on doubtful identifications. Both Elles (1933) and Jackson (1956 MS.) have emphasised the need to consider complete assemblages and to also take into account the relative abundance of each species. A number of localities at Bangor and on Anglesey were sampled, together with a section along the Afon Saint at Caernarvon, and a recently exposed road section at Arenig. In order to improve and extend coverage into the Llanvirn a number of localities in the vicinity of Hope, Shropshire, were sampled. Although shales of Didymograptus bifidus age from this latter area yielded relatively good acritarch assemblages, rocks of similar lithology from the Zone of D. murchisoni were almost barren. Acritarchs of D. murchisoni age were eventually obtained from samples provided by the Institute of Geological Sciences, Leeds, from the Tarn Moor tunnel, Westmorland. The Institute also provided samples of D. bifidus age from the Tailbert-Llanshaw tunnel, Westmorland.

The stratigraphy and palaeontology of the seven areas from which samples were collected are considered in the second part of this chapter. Approximate geographical locations are given in Text-fig. 2. The areas are reviewed separately, and, in each case a brief account of lithology and biostratigraphy is followed by details regarding the location of individual sample sites, specific sample lithologies, micropalaeontological content, and preservation. The majority of this information is presented in the form of maps, sections and tables. For the interpretation of symbols used in the preservation column, reference should be made to Chapter 7, Table 14.

Key to Text-fig. 2

1.	Lake District	-	Wythop, Barf, Swinside, Derwent Fells, Mungrisdale.
2.	Lake District	-	Tarn Moor, Tailbert-Llanshaw.
3.	Northern Anglesey	-	Treiorwerth, Llandyfrydog, Dulas Bay, Llanbabo.
4.	Caernarvon	-	Afon Saint.
5.	Bangor	-	Garth Point, Penrhyn Park Shore, Menai.
6.	Arenig	-	Nant-ddu, Taihirion.
7.	Shropshire	-	Hope, Whitsburn, Lyde, Rorrington.

Text-fig. 2 SAMPLE AREAS



1.2 STRATIGRAPHY OF THE SAMPIE LOCALITIES

Lake District - Wythop, Barf, Swinside, Derwent Fells, Mungrisdale.

Sample localities in these areas were selected on the basis of work by Jackson (1956, MS., 1961 and 1962). The stratigraphical subdivision of the Skiddaw Group proposed by Jackson (1961) and the corresponding graptolite zonation have been used in the compilation of Text-fig. 8. This stratigraphical scheme differs from one previously suggested by Rose (in Hollingworth et al., 1955) by the inclusion of an additional formation, the Hope Beck Slates. A more recent interpretation by Simpson (1967), involved an eight-fold subdivision of the Skiddaw Group, but Webb (1975, MS.), who has undertaken a detailed structural investigation of the Buttermere - Newlands area, concludes that the stratigraphy advocated by Jackson (1961 and 1962) is correct and that the somewhat complex stratigraphy of Simpson (1967) probably arose through misinterpretation of the regional structure.

The graptolite zonal scheme with which the stratigraphic section is correlated differs from that proposed for the Skiddaw Group by Elles (1933) by exclusion of the Upper Subzone of Tetragraptus, and Zones of Dichograptus and Bryograptus kjerulfi. A detailed discussion of the development of biostratigraphic zonation in the Skiddaw Group is given in Eastwood et al. (1968).

In his account of the stratigraphy of the Skiddaw Group Jackson (1961) describes the Hope Beck Slates as consisting of blue-black and blue-grey, striped, silty mudstones with occasional beds of current-bedded siltstone. The base of the formation is not seen. Above, the conformable contact with the Loweswater Flags is gradational and therefore difficult to define. Jackson (1961) used the incoming of arenites, three inches or more

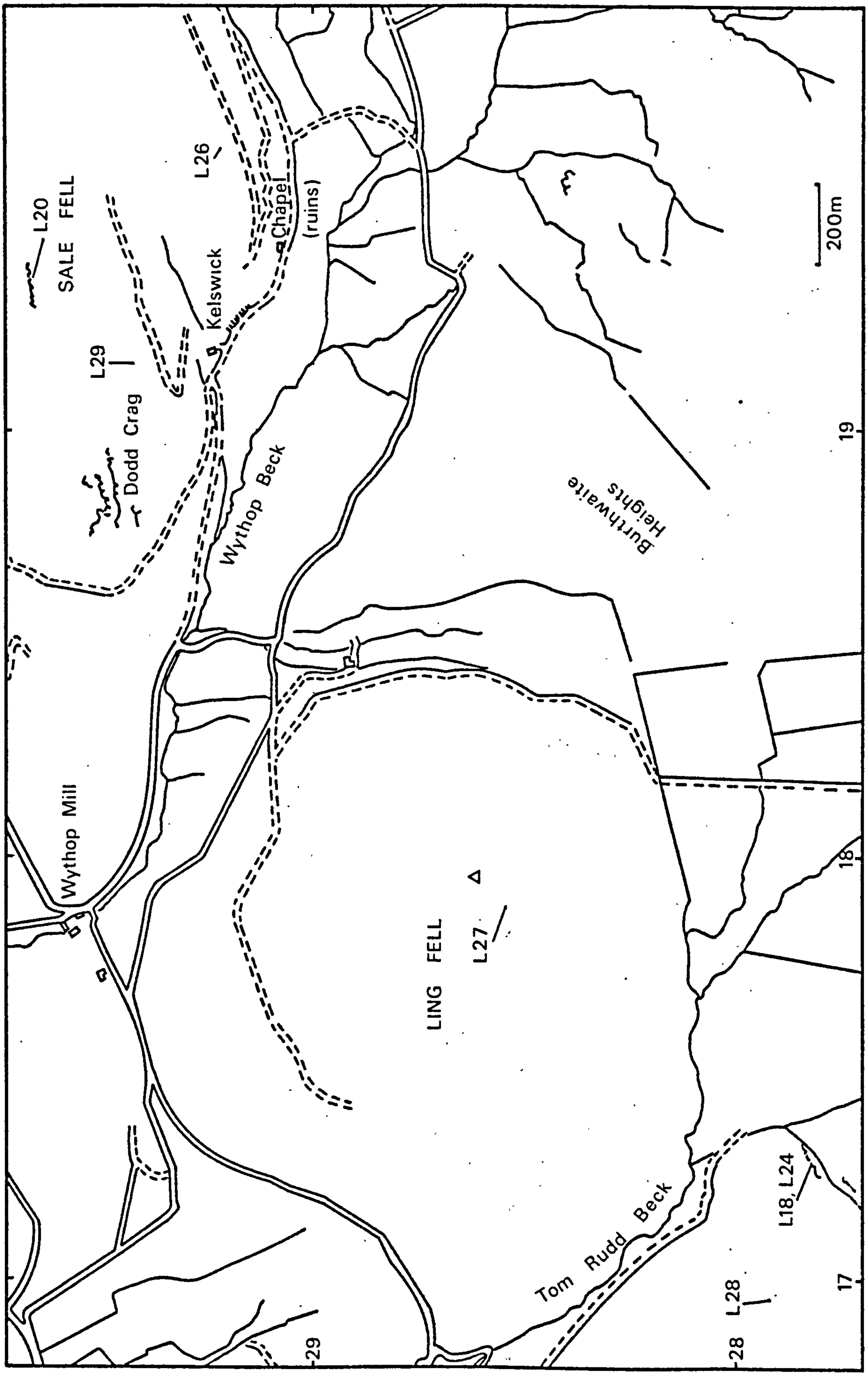
in thickness, as a method for separating the two rock units. The Hope Beck Slates are generally unfossiliferous and have not yet yielded satisfactory palaeontological evidence as to their age. Consequently, where exposure is poor and the structure complicated by faulting and folding, they cannot be distinguished from unfossiliferous horizons in the lithologically similar Mosser - Kirk Stile Slates.

The Loweswater Flags are estimated by Jackson (1961) to be in the region of 915m. thick, and are described by him as a 'greywacke suite comprising shales, siltstones, sandstones, grits and conglomerates' in rhythmic alternation. The arenaceous beds range in thickness from less than one inch to several feet. Both upper and lower boundaries are transitional, the top of the formation grading into silty mudstones. The boundary is arbitrarily defined by Jackson (1961) as the point where the arenites decrease in thickness to less than three inches. Small scale sedimentary structures (flute and lode casts, current and graded bedding) are not uncommon. Diachroneity of the boundaries and lateral variation are difficult to assess, owing to the structural complexities, and lack of palaeontological control and marker horizons. The Loweswater Flags are considered by Jackson (1961) to be wholly within the Zone of Didymograptus extensus.

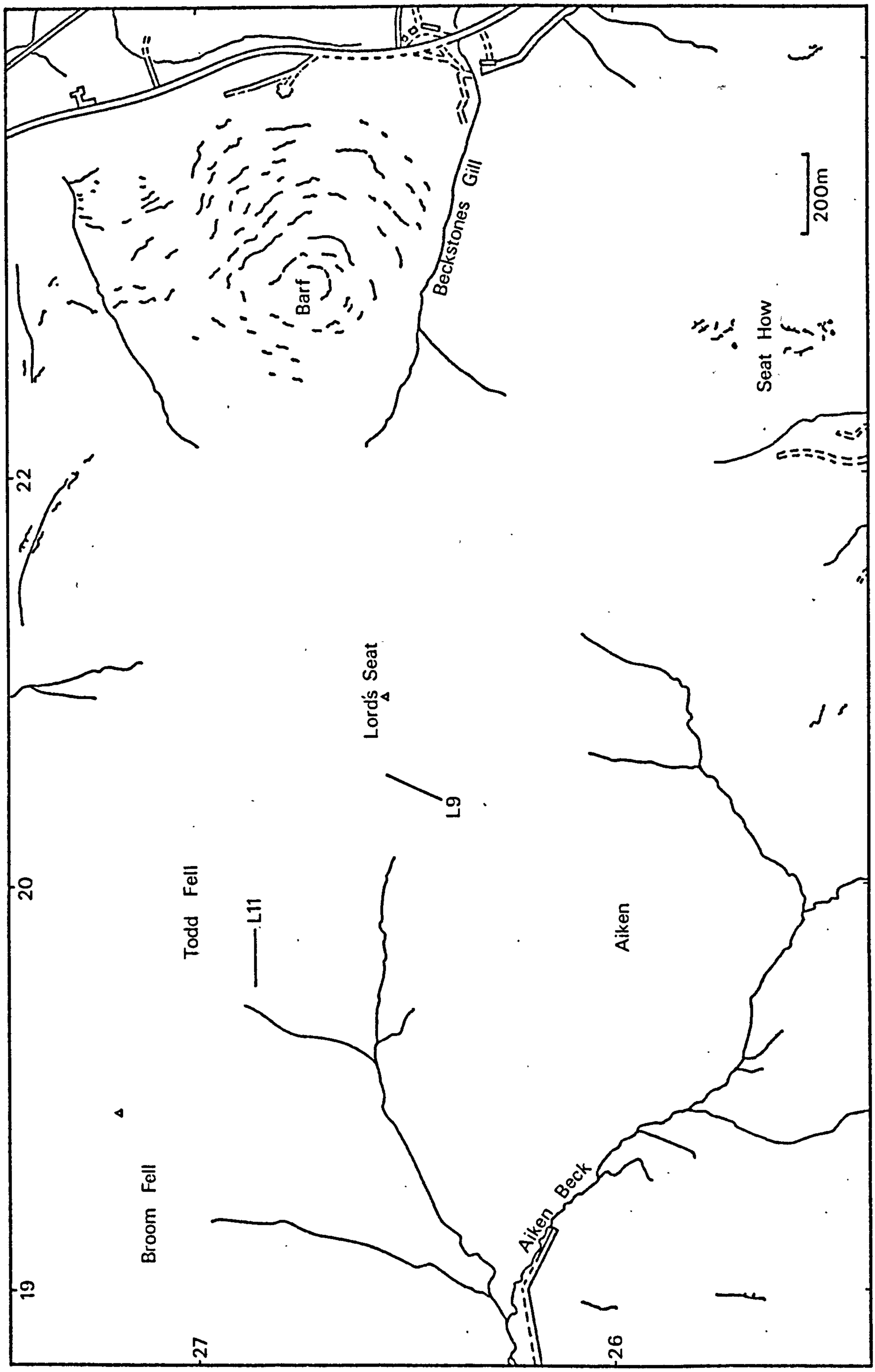
The Mosser - Kirk Stile Slates are lithologically indistinguishable from the Hope Beck Slates and consist of blue-grey or blue-black mudstones with variable amounts of silty material and occasional small dark nodules. Jackson (1961) estimated a thickness of approximately 760m. The lower boundary is transitional to the Loweswater Flags. Within the Lorton - Outerside area the Mosser - Kirk Stile Slates are not overlain by higher formations, but south of Ennerdale a sandstone unit (Latterbarrow Sandstone = ? Redmain Sandstone) is generally believed to be superimposed, and at

various other localities a conformable or tectonically disturbed contact with the Borrowdale Volcanic Group may be observed. Jackson (1961) comments that disconformities are probably present within the formation 'in view of the occurrence of mudstone breccias'. The lowest horizons lie within the Zone of Didymograptus extensus while the upper parts lie predominately within the Zone of D. hirundo.

The localities from which twenty-nine samples were collected are recorded in Text-Figs. 3-7. Grid references, correlation with the graptolite localities of Jackson (1956, MS.), and details of lithology and micro-palaeontological content are given in Table 1. The samples are correlated to a stratigraphic horizon in Text-fig. 8. The relative positions of samples within the Subzones of Didymograptus deflexus, D. nitidus and Isograptus gibberulus, and Zone of D. hirundo, are not known.

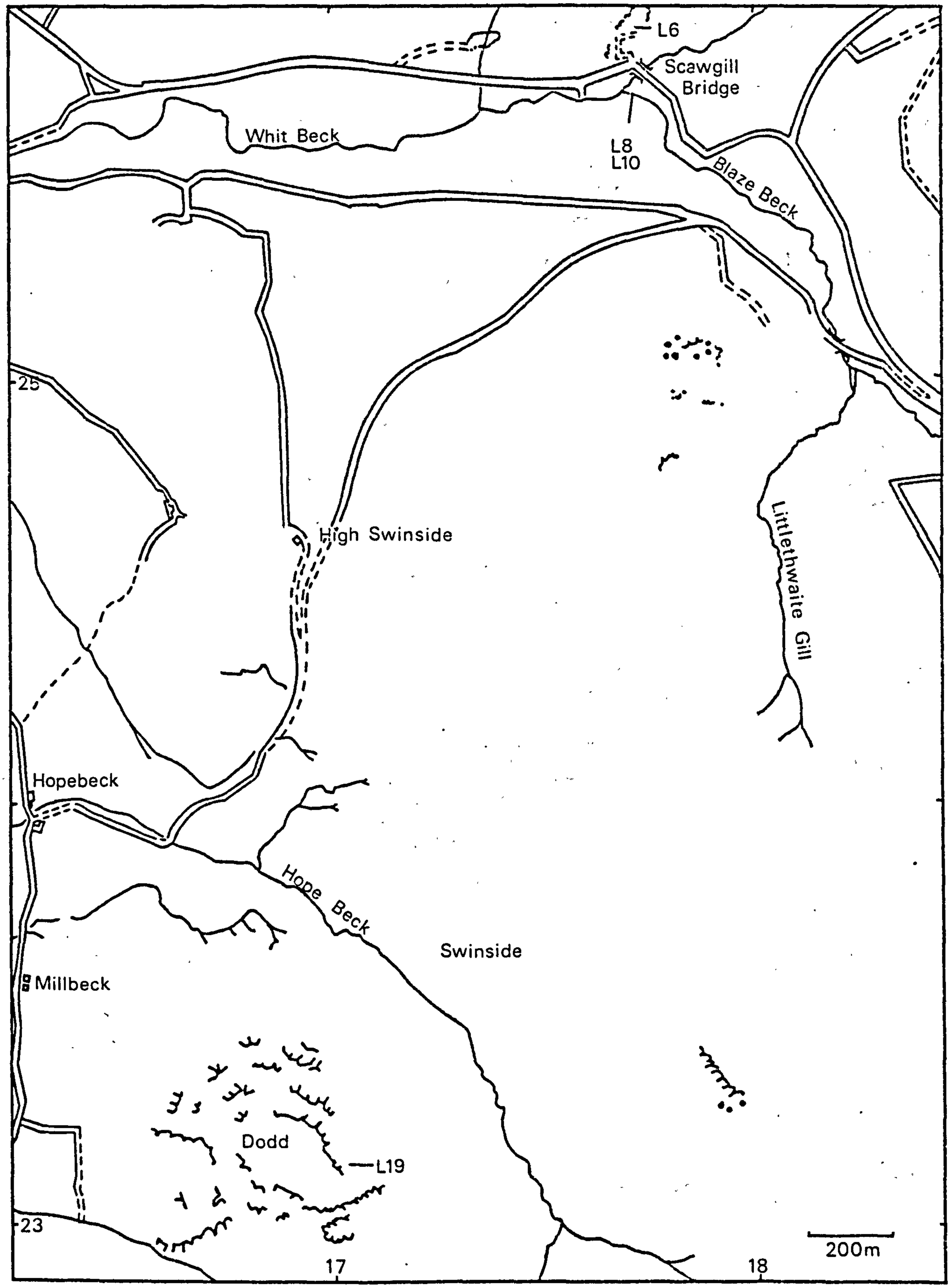


Text-fig.3 LAKE DISTRICT, WYTHOP

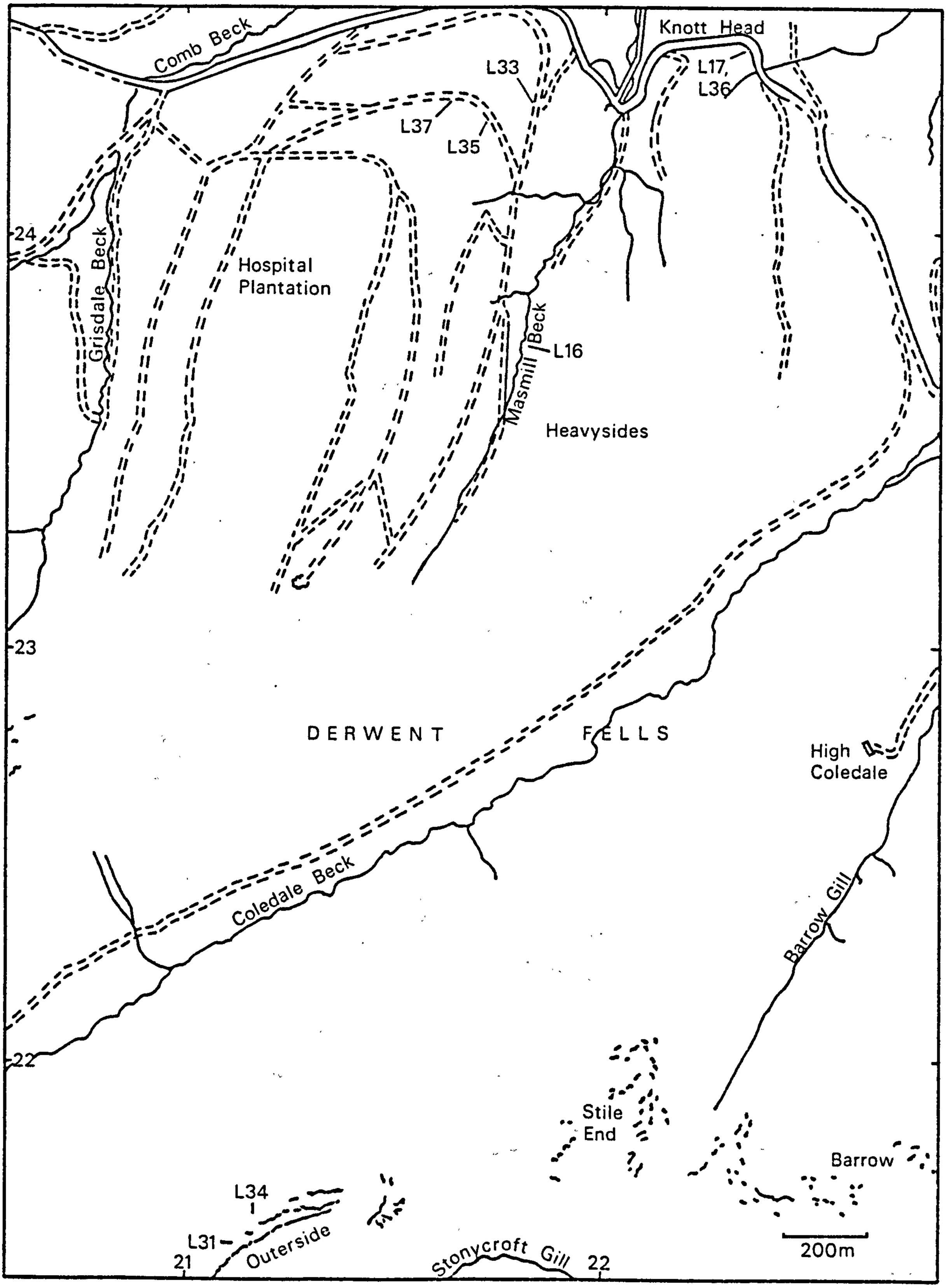


Text-fig.4 LAKE DISTRICT, BARF

Text-fig. 5 LAKE DISTRICT, SWINSIDE



Text-fig.6 LAKE DISTRICT, DERWENT FELLS



Text-fig.7 LAKE DISTRICT, MUNGRISDALE

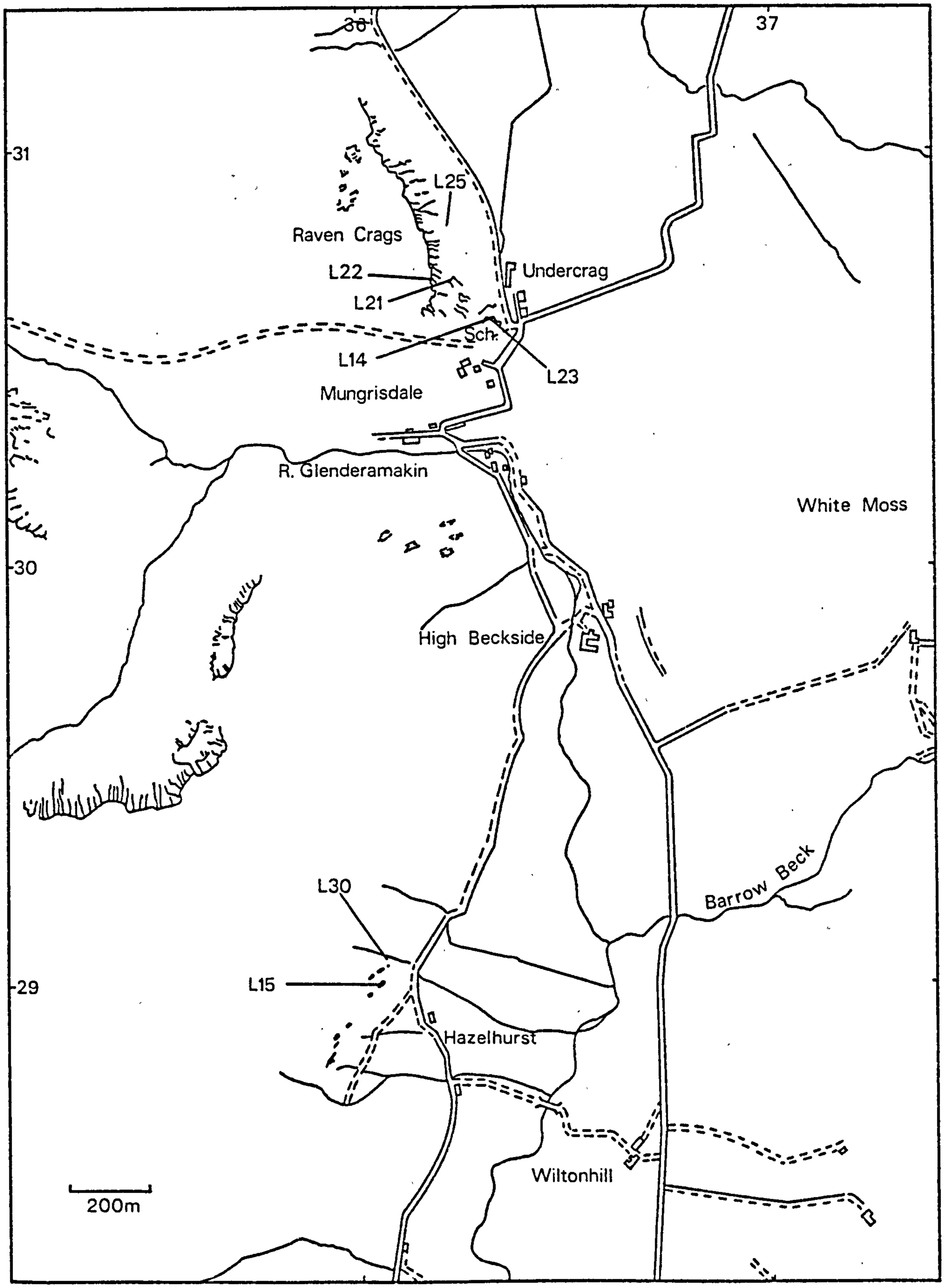


Table 1 Lake District - Wythop, Barf, Swinside, Derwent Fells, Mungrisdale.

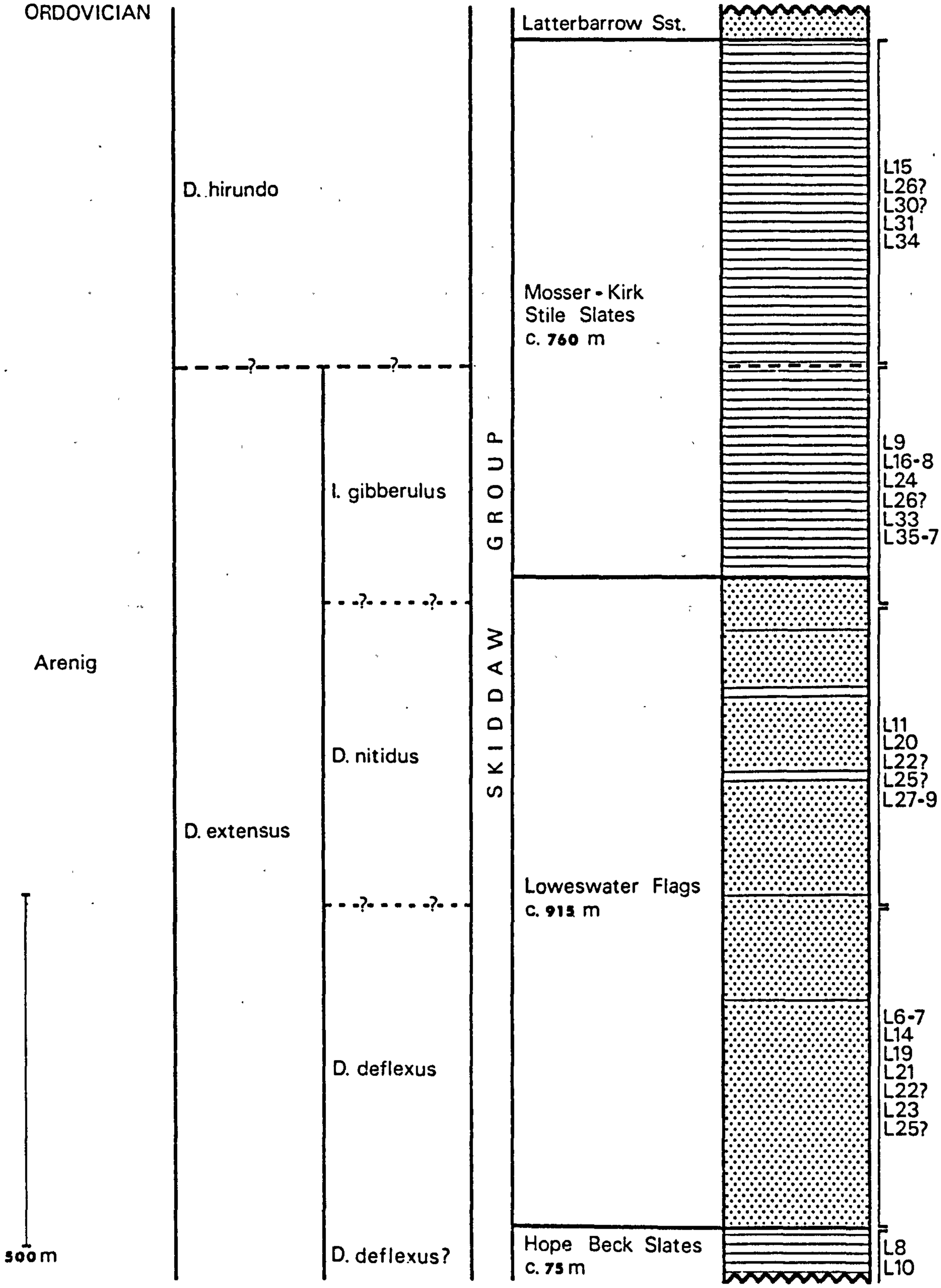
Sample	Location	N.G.R.	Lithology	Content	Preservation
L6	Scawgill Quarry, Lorton; quarry spoil heap.(J.764)	17732582	Dark grey silty mudstone	Fragmentary chitinozoa, rare acritarchs, organic debris.	5 E/F c
L8	90m. S. of Scawgill Bridge in the south bank of Blaze Beck.	17732564	Dark grey silty mudstone	Organic debris.	6
L9	180m. W. of Lord's Seat summit. (J.426)	20272655	Grey silty mudstone	Rare acritarchs, organic debris.	5 F d
L10	95m. S. of Scawgill Bridge in the south bank of Blaze Beck.	17732563	Dark grey silty mudstone	Organic debris	5/6
L11	450m. S.E. of Broom Fell summit. (J.831).	19722689	Dark grey silty mudstone	Fragmentary chitinozoa, rare acritarchs, organic debris.	5 E/F c
L14	Quarry, 45m. N.N.E. of the old school house, Mungrisdale. (J.2157).	36333058	Dark grey-black silty mudstone	Fragmentary chitinozoa, rare acritarchs, organic debris.	5 E/F c
L15	Scree, 135m. N.W. of Hazelhurst, Souther Fell. (J.2150).	36042899	Dark grey silty mudstone	Fragmentary chitinozoa, rare acritarchs, organic debris.	5 E/F c
L16	365m. N.W. of Heavy-sides summit, on east side of Masmill Beck (J.1036b)	21822373	Grey striped siltstone	Rare acritarchs, organic debris.	5 E/F c

L17	Quarry to W. of road, Knott Head. (J.1034).	22332444	Dark grey striped mudstone	Rare acritarchs, organic debris.	5	E/F	c
L18	N. bank of tributary to Tom Rudd Beck, 500m. N.W. of old reservoir, Wythop Moss. (J.603).	17282783	Dark grey striped siltstone	Organic debris.	6		
L19	E. slope of Dodd at 1250' O.D. (J.1047).	17042314	Grey striped silty mudstone	Fragmentary chitinozoa, rare acritarchs, organic debris.	5	E/F	c
L20	Quarry, 115m. W.S.W. of Sale Fell summit. (J.279).	19362967	Grey striped silty mudstone	Rare acritarchs, organic debris.	5	F	c
L21	Raven Crags, 135m. W. of Undercrag.	36253065	Grey striped silty mudstone	Frequent acritarchs, organic debris.	5	C/E	c
L22	Raven Crags, 180m. W. of Undercrag.	36203065	Dark grey silty mudstone	Frequent acritarchs, organic debris.	5	D/E	c
L23	Quarry 55m. N.N.E. of the old school house, Mungrisdale.	36343058	Dark grey silty mudstone	Rare acritarchs, organic debris.	5	E	c
L24	N. bank of tributary to Tom Rudd Beck, 500m. N.W. of old reservoir, Wythop Moss. (J.603).	17292783	Grey striped siltstone	Rare acritarchs, organic debris.	5	E/F	c
L25	Raven Crags, 180m. N.W. of Undercrag.	36253080	Dark and light grey silty mudstone.	Rare acritarchs, organic debris.	5	E/F	c
L26	270m. N.N.E. of chapel ruins, Wythop. (J.328).	19662922	Grey striped silty mudstone	Rare acritarch and chitinozoa fragments, organic debris.	5	E/F	c

L27	Small quarry, 90m. S.W. of Ling Fell summit. (J.450?)	17902853	Grey striped mudstone	Rare acritarchs, organic debris.	5	E/F	c
L28	Small quarry, 730m. S. of High Side Farm. (J.583).	16972792	Grey striped silty mudstone	Acritarchs rare to frequent, organic debris.	5	E/F	c
L29	200m. N. of Kelswick, Sale Fell. (J.301).	19192944	Dark grey silty mudstone	Fragmentary chitinozoa, rare acritarchs, organic debris.	5	E/F	c
L30	200m. N.W. of Hazelhurst, Souther Fell, S. bank of tributary to R. Glenderamakin.	36062906	Dark grey silty mudstone	Rare acritarchs, organic debris.	5	F	c
L31	90m. N. of Outerside summit, Derwent Fells. (J.1062).	21122157	Dark grey siltstone	Frequent acritarchs, organic debris.	5	D/E	c
L33	550m. W.S.W. of Knott Head to W. of track in Hospital Plantation.	21822432	Dark grey striped mudstone	Rare acritarchs, organic debris.	5	F	c
L34	140m. N.N.E. of Outerside summit at 1600' O.D. (J.1061?).	21172164	Grey striped siltstone	Rare acritarchs, organic debris.	5	F	c
L35	670m. W.S.W. of Knott Head, quarry S. of track, Hospital Plantation.	21722427	Grey mudstone	Rare acritarchs, organic debris.	5	F	c
L36	Quarry to W. of road, Knott Head (repeat of L17) (J.1034).	22332444	Dark grey mudstone	Rare acritarchs, organic debris.	5	F	c

L37	730m. W.S.W. of Knott Head, S. of track, Hospital Plantation.	21632432	Dark grey striped siltstone	Rare acritarchs, organic debris.	5	F c

Text-fig.8 SUCCESSION IN THE LAKE DISTRICT BETWEEN BUTTERMERE AND MUNGRISDALE (after Jackson, 1961)



Lake District – Tarn Moor, Tailbert - Llanshaw

Samples were provided by the Institute of Geological Sciences, Leeds, from two localities in the eastern Lake District, in the Skiddaw Group.

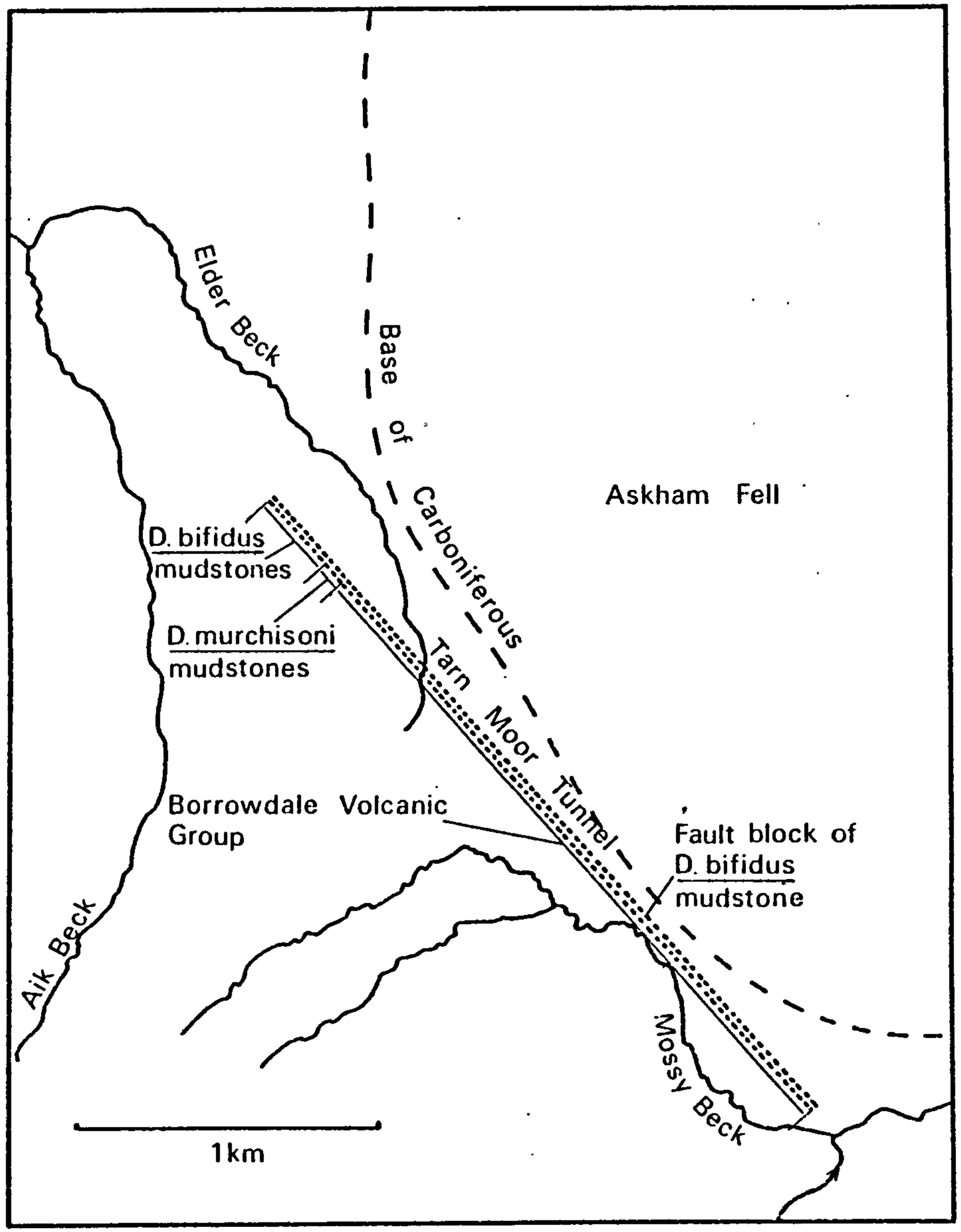
As a part of a Manchester Corporation Waterworks scheme a tunnel was excavated beneath Tarn Moor, between Heltondale and Ullswater (Text-fig. 9A). Although passing chiefly through rocks of the Borrowdale Volcanic Group, the tunnel penetrated dark grey shales and mudstones containing a fauna representative of the Didymograptus murchisoni Zone between 2311m. and 2399m. from the southern portal (Wadge et al., 1970). The samples supplied (SAL 2778–82) were from tip material matched lithologically with the tunnel section between 2311m. and 2343m.

A second tunnel, to the west of Shap, driven between the streams Tailbert and Llanshaw (Text-fig. 9B), encountered grey-black shales, yielding abundant well preserved graptolites (Skevington, 1964 and 1970). The graptolites are characteristic of the Zone of Didymograptus bifidus. The samples (SAL 383-90) were collected from the south-east part of the tunnel.

Locations, rock lithologies and details of micropalaeontological content and preservation are summarised in Table 2.

Text-figs 9A-B LAKE DISTRICT

A. Tarn Moor Tunnel (after Wadge et al, 1969)



B. Tailbert-Lanshaw Tunnel (after Skevington, 1970)

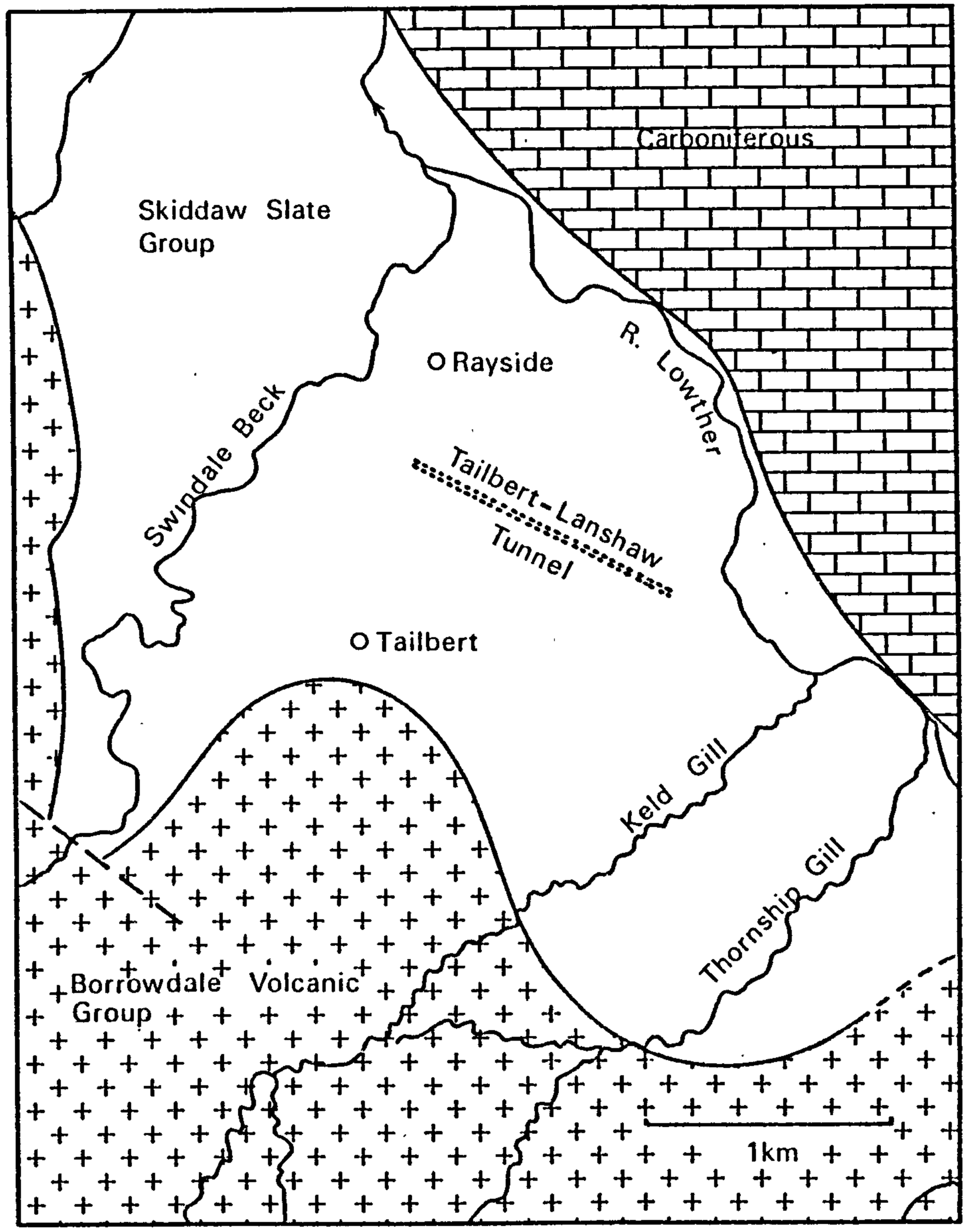


Table 2 Lake District - Tarn Moor, Tailbert - Llanshaw

Sample	Location	N.G.R.	Lithology	Content	Preservation
SAL 2778	Tip material from Tarn Moor tunnel matched lithologically with tunnel section between 2311m. and 2343m.	49482068 (S. portal)	Dark grey shale	Frequent acritarchs and chitinozoa, organic debris.	4/5 D/E c/d
SAL 2781	..	..	..	..	..
SAL 389	S.E. half of Tailbert-Llanshaw tunnel	54601447 (S. portal)	Grey black shale	Frequent acritarchs and chitinozoa, organic debris..	4/5 D/E c/d
SAL 390	..	..	..	..	..

Northern Anglesey

Sample collection from localities on Anglesey was based on a recent resurvey of the Ordovician rocks by Bates (1972), and on the work of Greenly (1919). The succession proposed by Bates (1972) differs from earlier schemes primarily in the recognition of a transgression south of the Carmel Head Thrust, during Caradocian times.

The Ordovician rocks outcrop in a number of isolated areas, the most important being the 'Principal Area' (Greenly, 1919), a large T-shaped tract, faulted and folded into the Mona Complex. Lithologies are varied, and age ranges from Arenigian to Early Caradocian. Ordovician sedimentation commenced with an Arenigian transgression which deposited a series of grits and sandstones (Carmel Grit and Foel Grit). These are overlain by grits (Treiorwerth Grit), gritty shales (Nantannog Beds), or shales. Sedimentation continued into the Llanvirnian with the deposition of gritty shales (Nantannog Beds), grits (Bod Deiniol Grit), and shales. The Late Llanvirnian is wholly represented by shales. The above named lithostratigraphic units were introduced by Bates (1972), and refer to the Principal Area.

At a number of localities Bates (1972) was able to collect rich shelly faunas, correlatable to the Zones of Didymograptus hirundo, D. bifidus, and D. murchisoni. Five of these localities were selected for sampling. In addition samples were collected from two localities where Greenly (1919) records graptolites representative of the Zones of D. bifidus and D. murchisoni.

The seven sample localities are indicated in Text-fig. 10. Grid references, lithologies and details of micropalaeontological content and preservation are summarised in Table 3. The samples are correlated to stratigraphic horizons in Text-fig. 11, A-D.

Text-fig.10 NORTHERN ANGLESEY (after Bates, 1964 MS., and 1972)

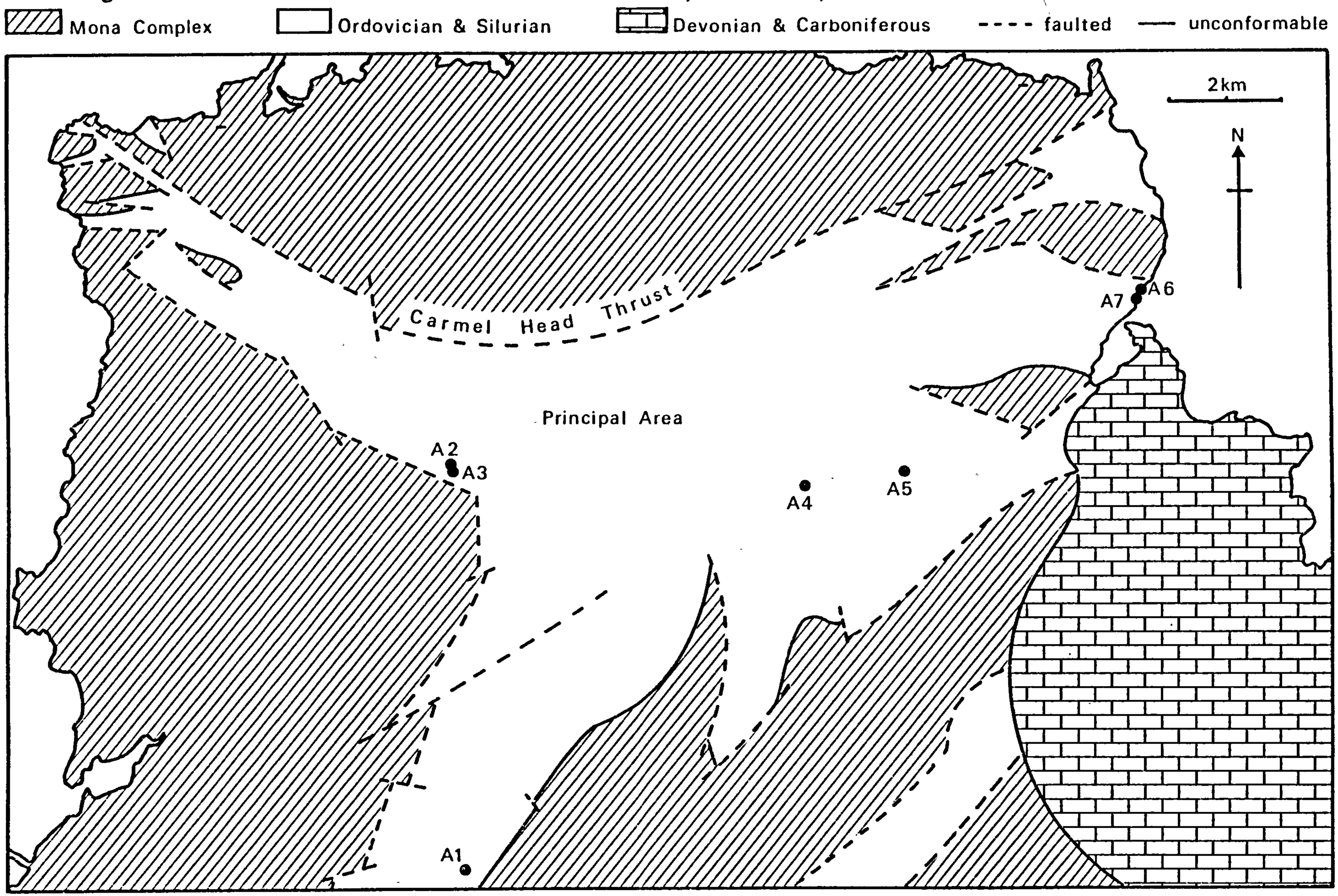
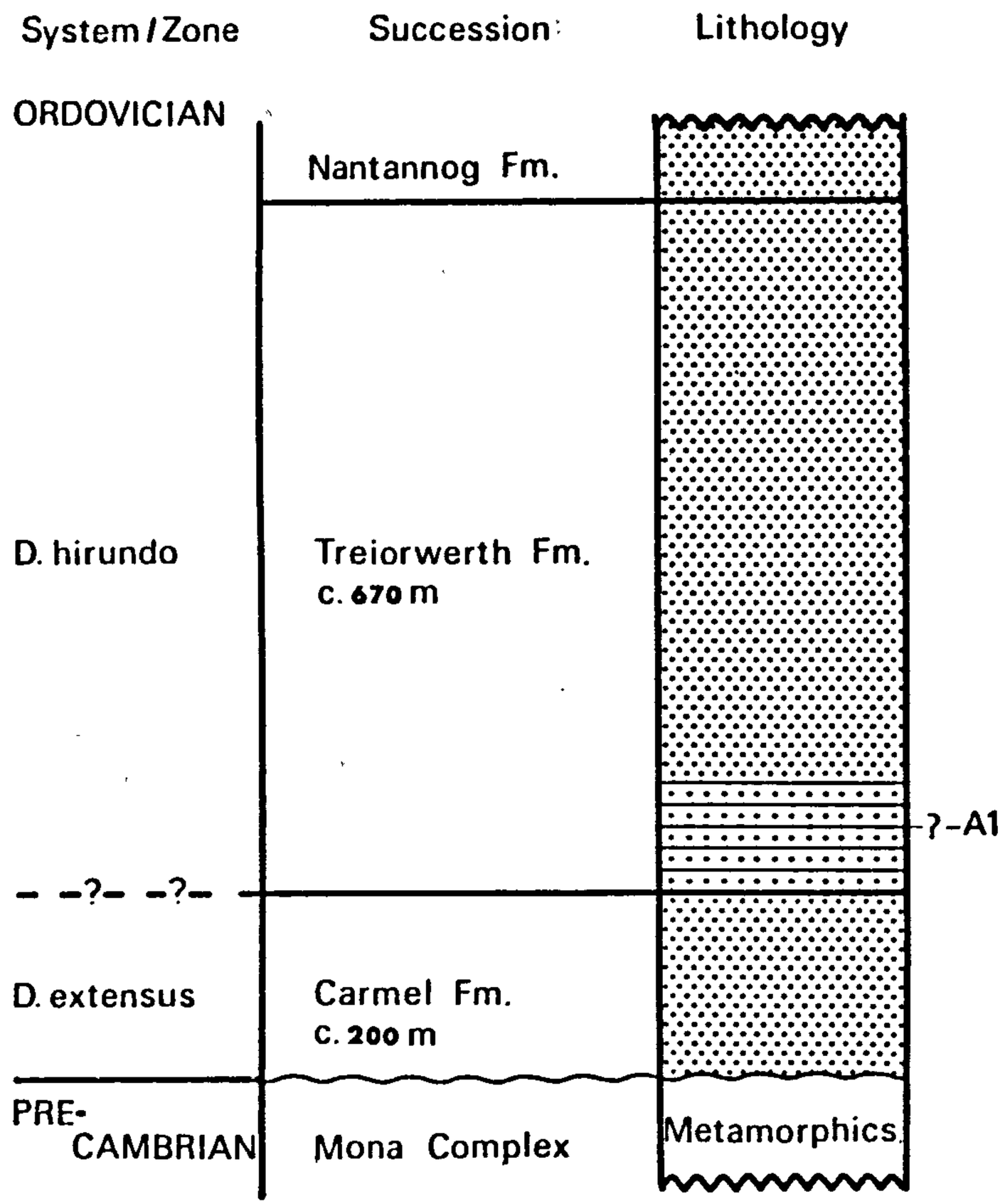


Table 3 Anglesey - Treiorwerth, Llandyfrydog, Dulas Bay, Llanbabo.

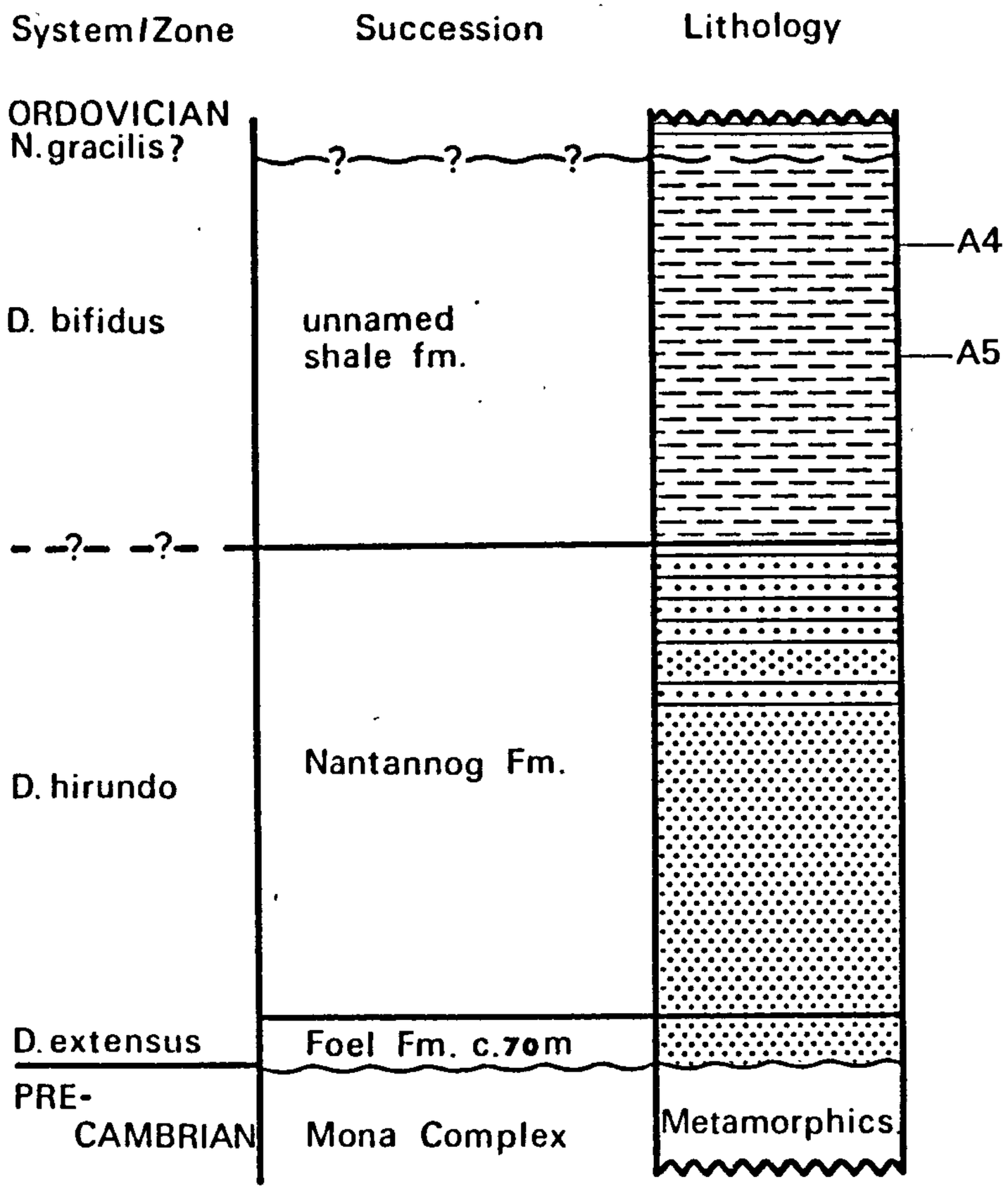
Sample	Location	N.G.R.	Lithology	Content	Preservation
A1	270m. S.E. of Ffynnon-y-mab, Trefor.	36557952	Grey-green sandstone	Organic debris	6
A2	180m. W. of Fferam-uchaf, Llanbabo, W. side of road, by old well.	36178667	Dark grey-black shale, iron stained	Rare fragmentary chitinozoa and acritarchs; organic debris.	4/5 E/F d
A3	225m. W.S.W. of Fferam-uchaf, Llanbabo, to E. of road, 10m. S. of stream.	36168655	Dark grey shale	Rare acritarchs and chitinozoa.	5 E/F c/d
A4	E. side of road at Cae-mawr.	42528615	Dark grey shale	Rare acritarchs and chitinozoa; organic debris.	5 E/F c/d
A5	Old quarry on N. bank of Afon Goch, S.E. of Tyddn-bach.	44358641	Blue-grey slatey shale with graptolites	Rare fragmentary chitinozoa, scolecodonts, and acritarchs; organic debris.	5 E/F c/d
A6	155m. N.E. of bathing house, Dulas.	48658953	Dark grey shale	Rare fragmentary chitinozoa, scolecodonts, and acritarchs, organic debris.	5 E/F c/d
A7	At bathing house, Dulas.	48588943	Dark grey shale	Rare scolecodonts and chitinozoa, organic debris.	5 E/F c/d

Text-fig.11 A-D SUCCESSIONS IN ANGLESEY (after Bates, 1964 MS., and 1972)

A. Treiorwerth area



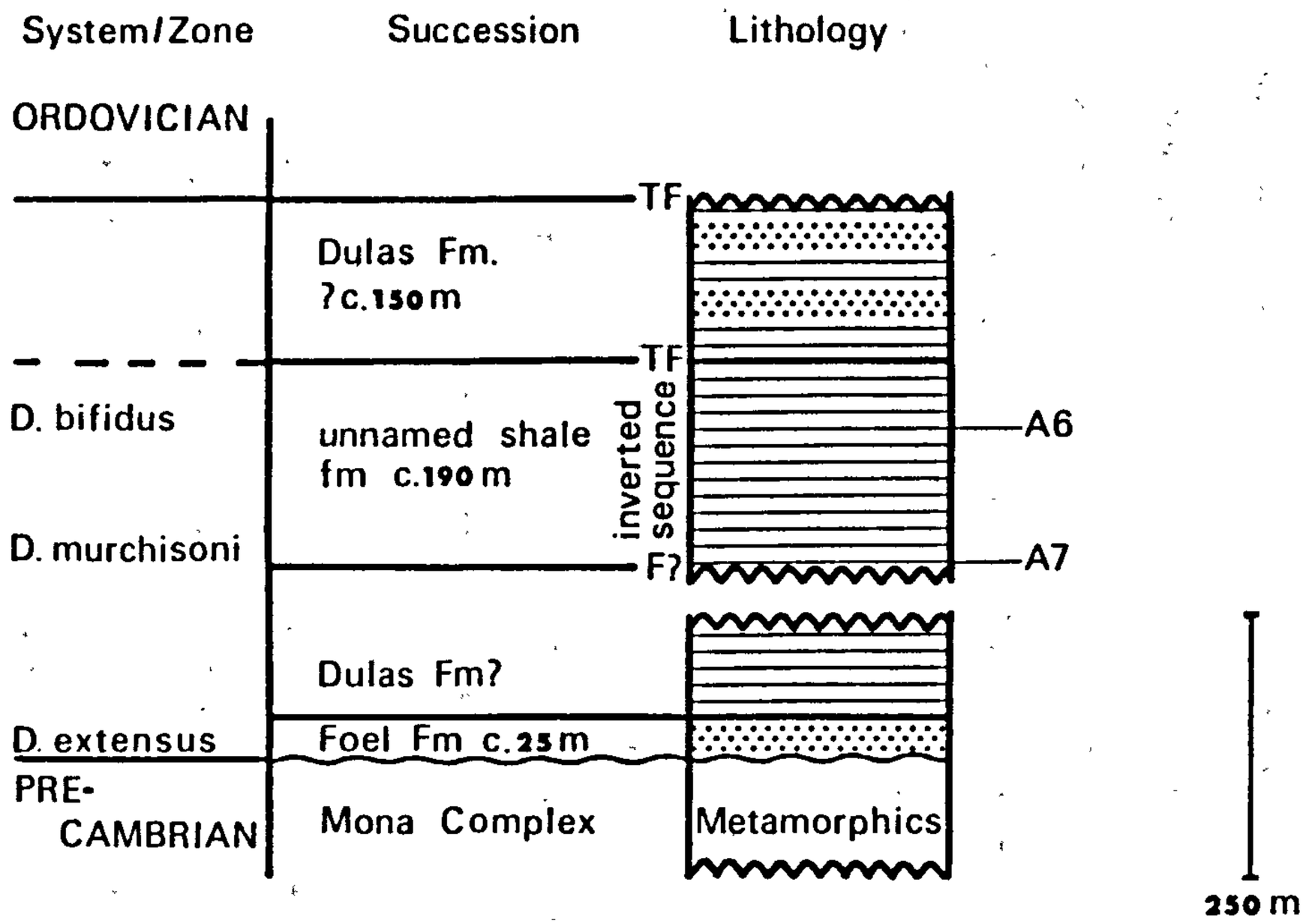
B. Llandyfrydog area



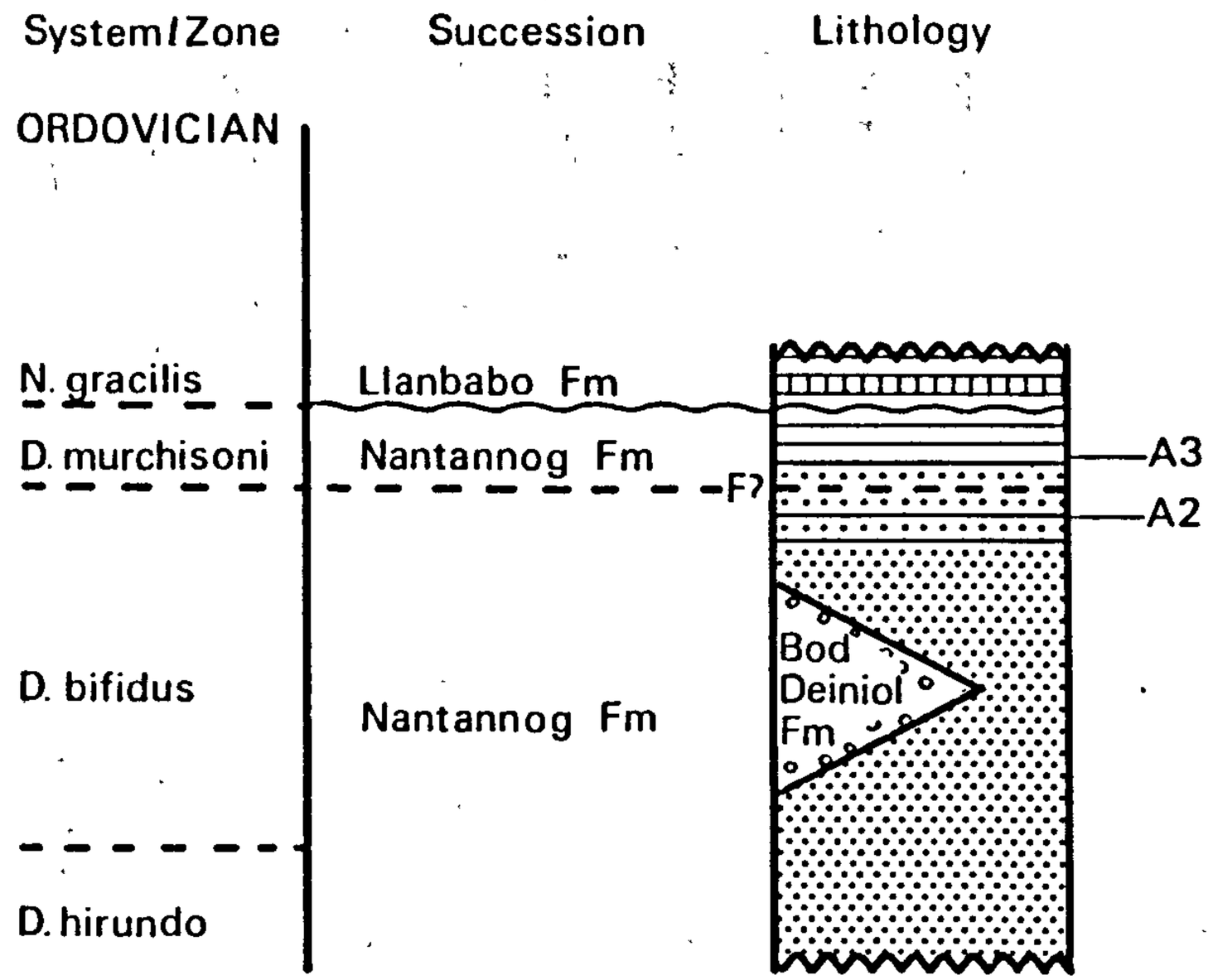
Section generalised. Thicknesses of the Nantannog Formation and unnamed shale formation not known with certainty.

Text-fig. 11 continued

C. Dulas Bay



D. Llanbabo area



Caernarvon - Afon Saint

Samples were collected from an almost continuous section along the west bank of the Afon Saint, Caernarvon, which was first described in detail by Elles (1904), Elles recognised the presence of three clearly defined graptolite faunas, representing the Zones of Didymograptus extensus, D. hirundo and D. bifidus.

Prior to Elles investigation Ramsey (1866) had recorded the occurrence of Didymograptus murchisoni, and Marr (1876), the presence of D. bifidus and other forms, in beds near the top of the sequence. More recently Greenly (1944) considered the locality in a general geological discussion of the rocks of the Arvon district, but added little to the work of Elles (1904).

The strata show some variation in dip and strike and a roughly developed fracture cleavage may be detected in some outcrops. Downstream the succession along the west bank commences with a series of mudstones, siltstones and shales in which Elles records only Phyllopods. These beds dip to the W.N.W. and their relationshop to the upstream exposures, where dip is to the S.E., is obscured by drift. The exposure recommences 150m. upstream with blue-black mudstones and shales containing a graptolite faunule dominated by Didymograptus extensus and therefore assigned by Elles (1904) to the Zone of D. extensus. Higher in the succession the lithology becomes more varied with the introduction of occasional beds of micaceous sandstone. Here the most abundant graptolite is D. hirundo, and these beds are therefore considered to represent the Zone of D. hirundo. Towards the top of the sequence the beds are often more sandy in composition and have yielded a mixed assemblage of fossils dominated by the graptolite D. bifidus. The

beds are consequently assigned to the Zone of D. bifidus.

Sample site locations are given in Text-fig. 12. Grid references, correlation with the sample localities of Elles (1904), and a summary of micropalaeontological content and preservation are given in Table 4. Sample positions within the succession are given in Text-fig. 13.

Text-fig.12 CAERNARVON

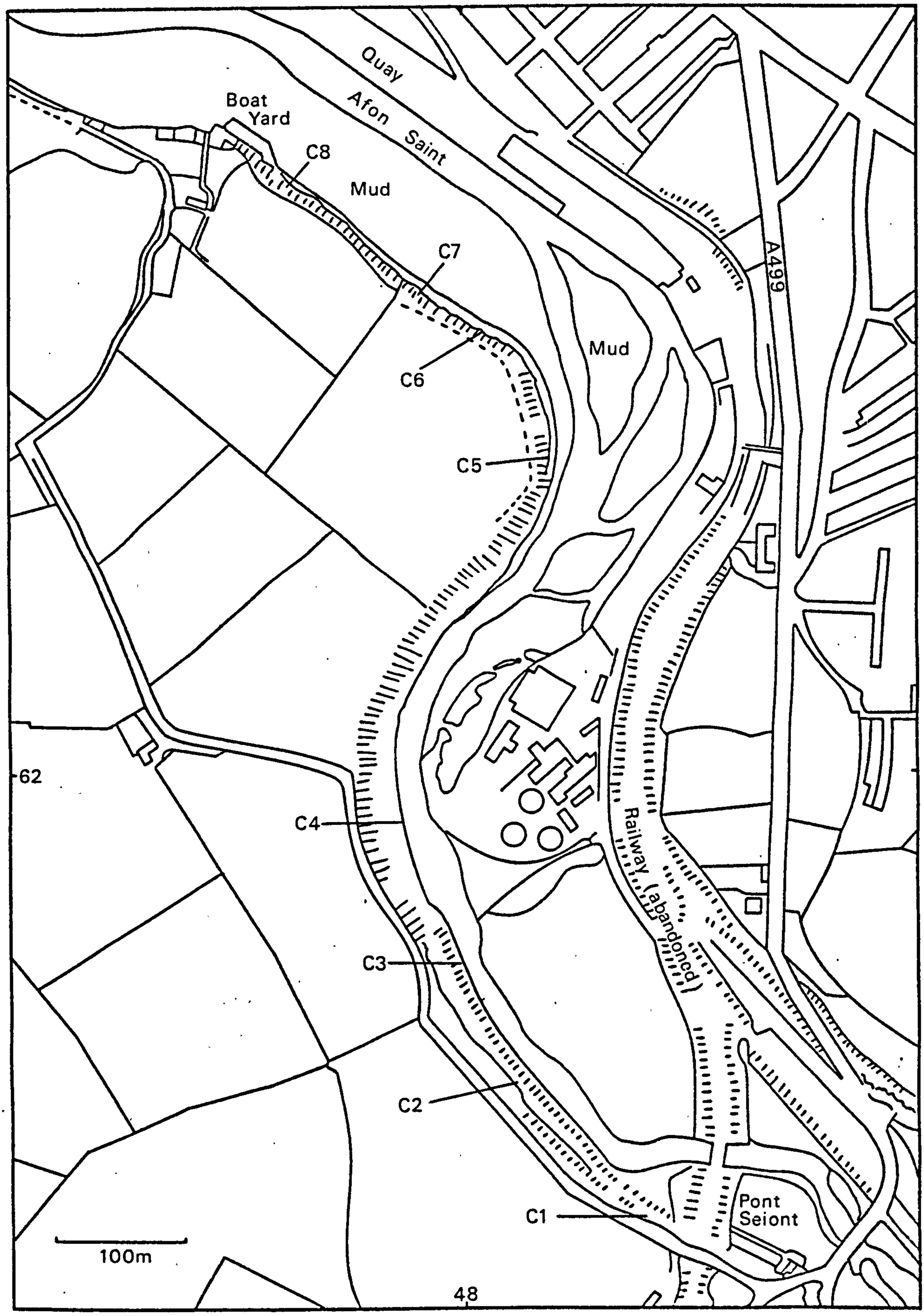
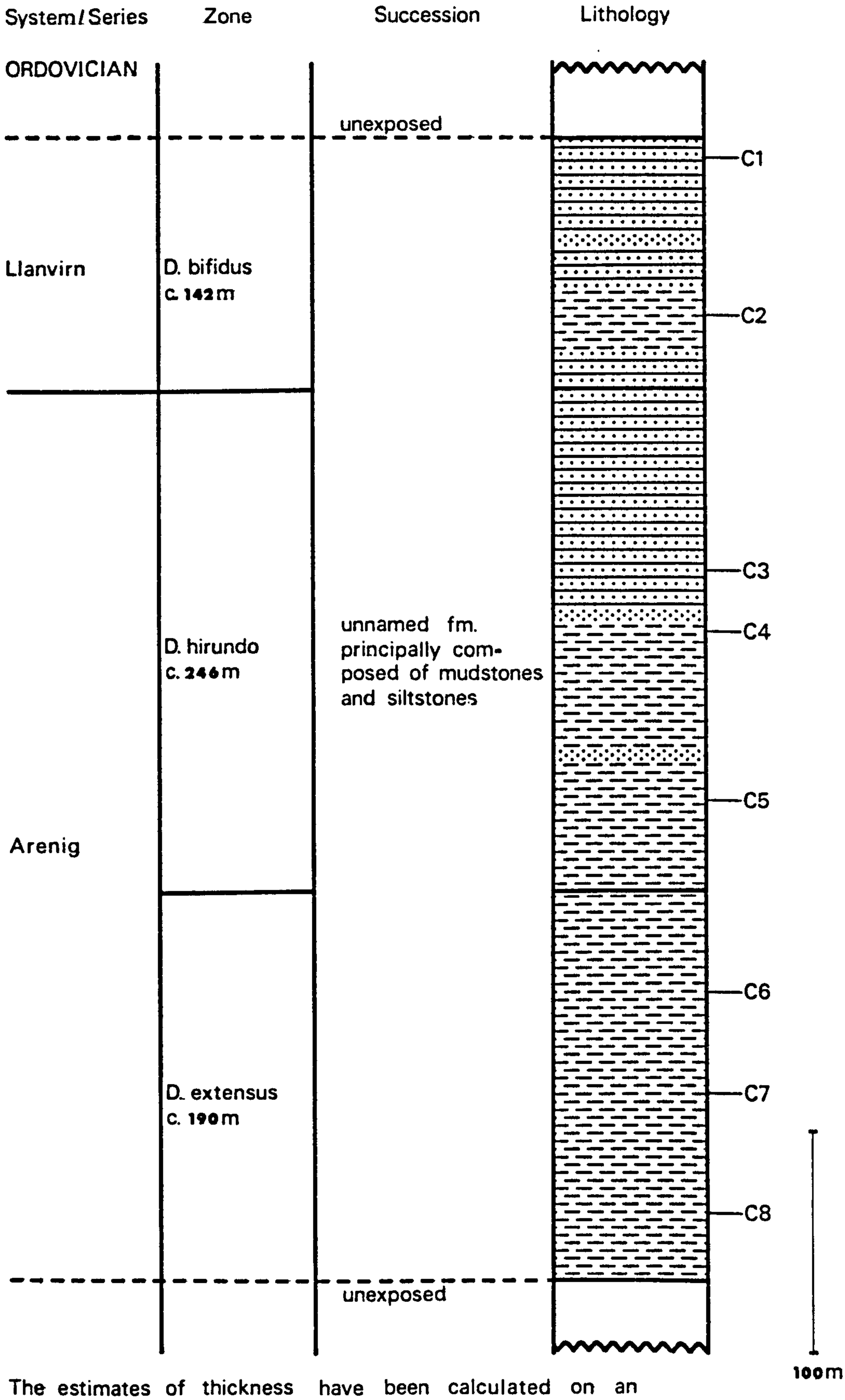


Table 4 Caernarvon Afon Saint

Sample	Location	N.G.R.	Lithology	Content	Preservation
C1	Nantle Tramway cutting, 10m. from beginning of exposure (a. of Elles, 1904)	48136168	Dark grey siltstone	Rare chitinozoa and acritarchs; organic debris.	4/5 D/E c/d
C2	Nantle Tramway cutting, 150m. from beginning of exposure (d. to e. of Elles, 1904)	48046177	Dark grey mudstone	Rare fragmentary chitinozoa, occasional acritarchs, organic debris.	4/5 E d
C3	At river level, bearing 202° on W.gasometer (approx. g. of Elles, 1904).	48006186	Grey and dark grey striped siltstone	Rare fragmentary chitinozoa, occasional acritarchs, organic debris.	4/5 D/E c/d
C4	At river level, bearing 96° on W. gasometer (h. of Elles, 1904)	47956196	Dark grey siltstone	Frequent acritarchs, organic debris	5 C/E c
C5	Low cliff, 290m. from beginning of S. end of boatyard (k. of Elles, 1904)	48066223	Grey and dark grey mudstone	Rare chitinozoa, frequent acritarchs, organic debris.	5 D/E c/d
C6	Low cliff, 195m. from beginning of exposure at S. end of boatyard. (m. of Elles, 1904)	48016233	Dark grey mudstone	Frequent acritarchs, organic debris.	5 D/E c/d

C7	Low cliff, 140m. from beginning of exposure at S. end of boatyard. (n. of Elles, 1904)	47976236	Dark grey mudstone	Rare chitinozoa, frequent acritarchs, organic debris.	4/5	D/E	c
C8	Low cliff, 20m. from beginning of exposure at S. end of boatyard. (o. of Elles, 1904)	47876244	Dark grey mudstone	Rare chitinozoan and scolecodont fragments; occasional acritarchs, organic debris.	4/5	E	c/d

Text-fig.13 SUCCESSION AT CAERNARVON (after Elles, 1904)



The estimates of thickness have been calculated on an averaged dip of 45°

Bangor - Garth Point, Penrhyn Park Shore, Menai

An account of the rocks outcropping in the vicinity of Garth Point and Penrhyn Park, Bangor, is given by Greenly (1919). At Garth Point, massive pale green and buff sandstones are overlain by dark shales and striped siltstones. Examination of the outcrops along the shore to the east of the pier indicates the shales and siltstones to have been faulted and folded. However, at two localities to the west of the pier (B1 and B2) the siltstones dip fairly constantly to the south-east and seem not to have suffered serious disruption. From their position they appear to lie only a few metres above pale greenish sandstones exposed further to the west, and,unless a major fault intervenes, must represent an horizon below the lowest beds exposed along the Afon Saint, Caernarvon, and probably also below the beds of the Menai inlier.

Greenly (1919) does not record the presence of graptolites at Garth Point, but in a later paper (Greenly, 1944), in which the tract is referred to as the 'Bangor Infold', he records Azygograptus eivionicus, Didymograptus extensus and D. gracilis. The assemblage is indicative of the Zone of D. extensus.

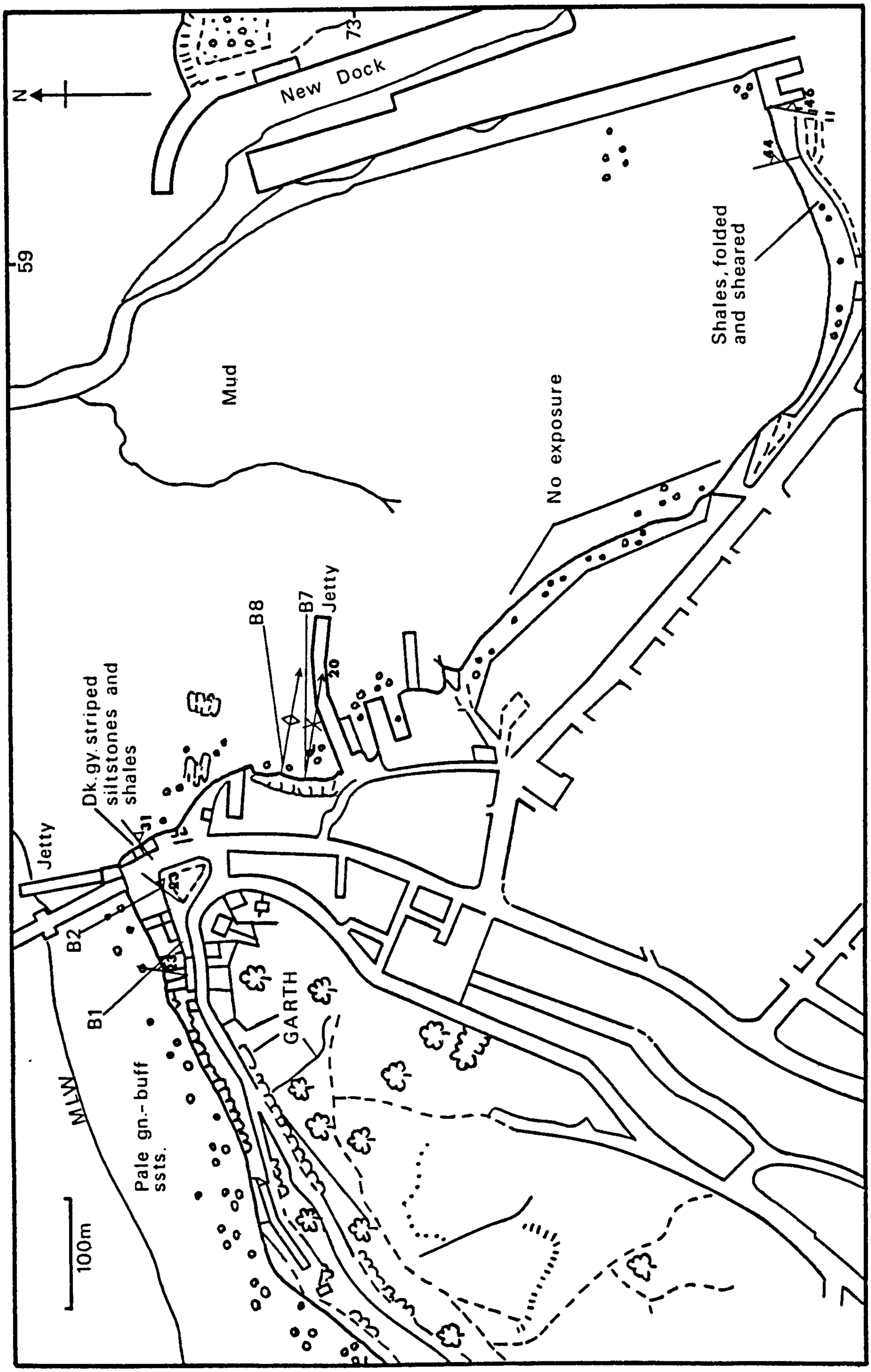
To the east of the Afon Cegin the shale-siltstone sequence is repeated. Greenly (1944) records Didymograptus hirundo and D. nitidus from the rocks outcropping along the shore of Penrhyn Park. The rocks are therefore considered to represent the Zone of D. hirundo.

Garth Point and Penrhyn Park Shore sample localities are given in Text-figs. 14 and 15. Grid references, lithologies and a summary of micropalaeontological content and preservation are given in Table 5. The samples are correlated to stratigraphic horizons in Text-fig. 17 A-B.

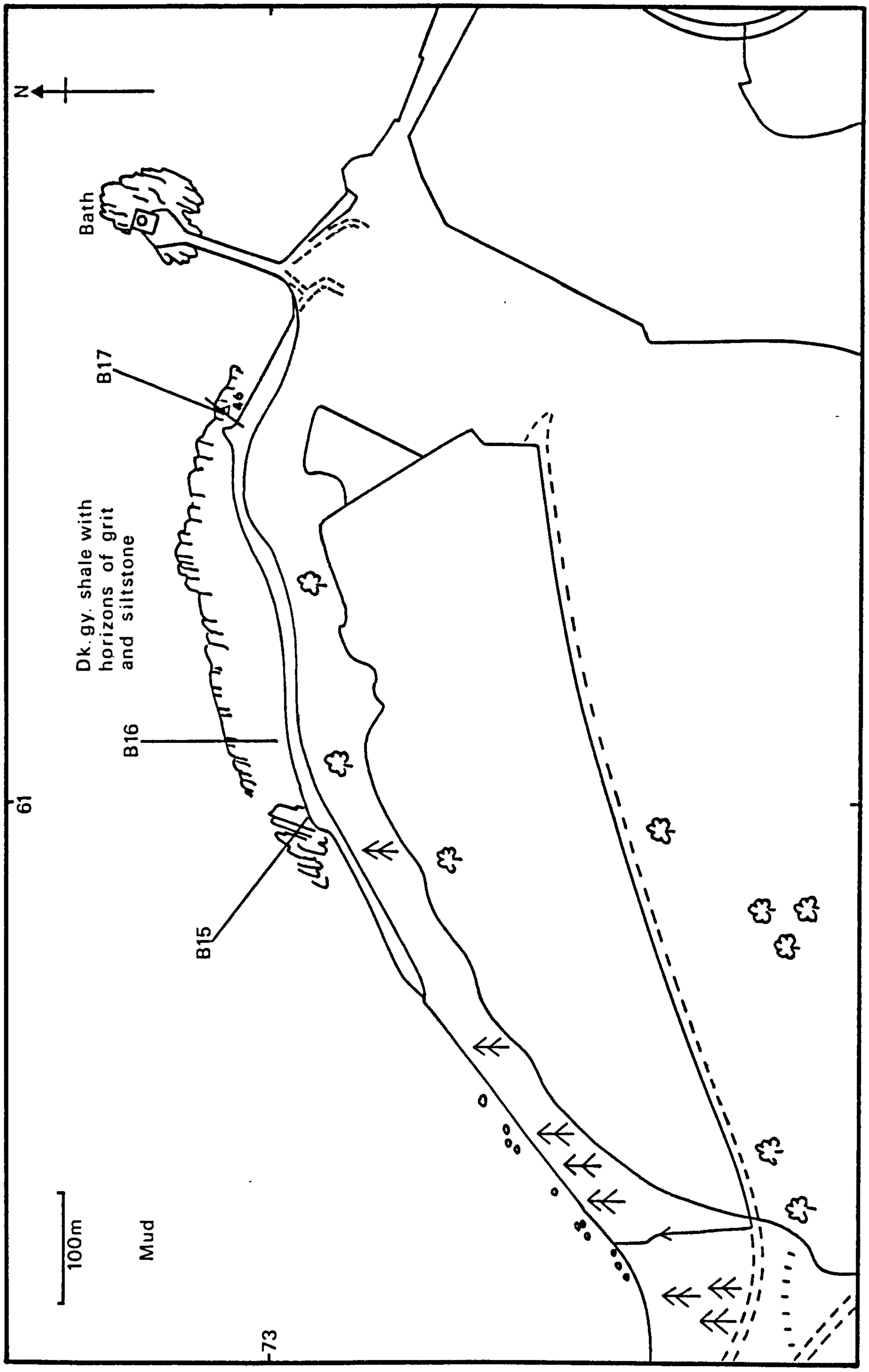
Greenly (1898) was the first to publish an account of the uncleaved black shales which outcrop beneath unconformable Carboniferous strata along the Menai Straits shoreline, between the two bridges, on the Caernarvonshire side. From this locality, Greenly (1898) obtained Didymograptus extensus and other graptolites. Elles (1904) later records a well preserved graptolite fauna including D. extensus, D. nicholsoni, D. nitidus, D. gibberulus, Tetragraptus serva, and T. amii. D. extensus was the most abundant species and Elles (1904) therefore considered these shales to represent the Zone of D. extensus. From the presence of the Tetragrapti she concluded 'that the beds are somewhat lower down in the Zone than those of the Seiont River'.

Greenly (1919) again referred to the locality in his comprehensive account of the geology of Anglesey. Later (1944), although unable to offer additional palaeontological evidence of the age of the outcrop he remarks that the basement grit 'cannot be many feet below'.

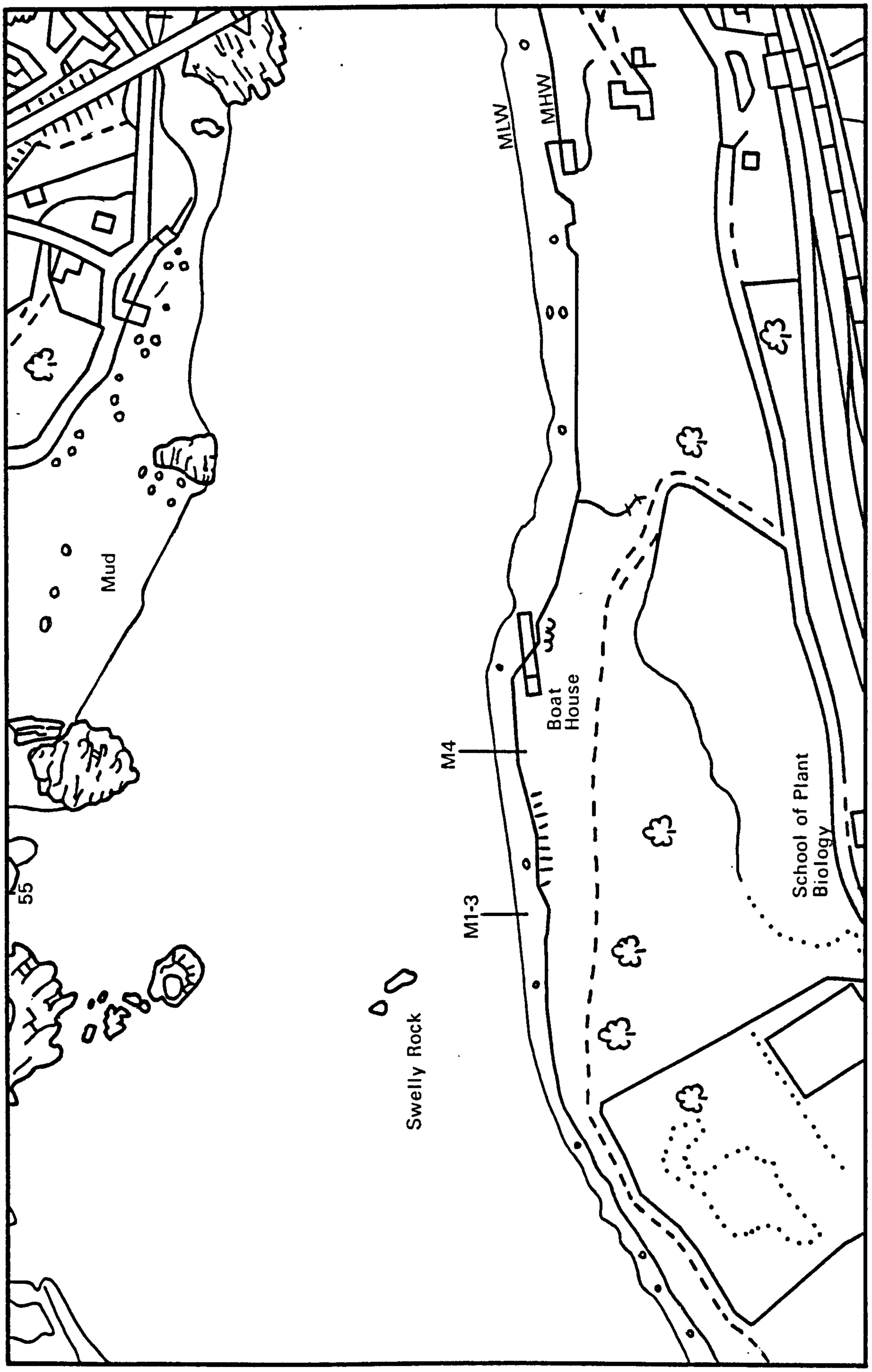
The localities of four samples collected along the Menai shoreline are given in Text-fig. 16. Grid references, lithologies, micropalaeontological content and preservation are summarised in Table 6. The samples are correlated to stratigraphic horizons in Text-fig. 17C.



Text-fig.14 BANGOR, GARTH POINT



Text-fig.15 BANGOR, PENRHYN PARK SHORE



Text-fig. 16 BANGOR, MENAI

Table 5 Bangor - Garth Point, Penrhyn Park Shore

Sample	Location	N.G.R.	Lithology	Content	Preservation
B1	Garth Point, small cliff facing N.N.W., west of hut and playground.	58387316	Dark grey and grey lightly striped siltstone	Rare chitinozoan and scolecodont fragments, frequent acritarchs, organic debris.	5 C/D c
B2	Garth Point, small cliff facing N.N.W., at rear of car park.	58437317	Dark grey striped siltstone, iron stained	Frequent chitinozoa, occasional acritarchs, organic debris.	5 D/E c/d
B7	Garth Point, between jetties, along axis of inner syncline.	58547305	Dark grey siltstone with micaceous horizons; iron stained	Rare chitinozoa, occasional acritarchs, organic debris.	4/5 E/F d
B8	Garth Point, between jetties along axis of minor anticline.	58547307	Dark grey siltstone with micaceous horizons; iron stained	Rare chitinozoa and scolecodonts, occasional acritarchs, organic debris.	4/5 E/F d
B13	Penrhyn Park Shore, 200m E.S.E. of the Bath.	59997296	Dark grey micaceous shale	Occasional acritarchs, organic debris.	4/5 D/E c/d
B14	Penrhyn Park Shore, 485m E.S.E. of the Bath.	60067298	Dark grey micaceous shale	Rare chitinozoa, occasional acritarchs, organic debris.	4/5 D/E c/d
B15	Penrhyn Park Shore 565m E.S.E. of the Bath, close to wall.	60357303	Dark grey siltstone	Rare scolecodonts, occasional acritarchs, organic debris.	4/5 D/E c/d

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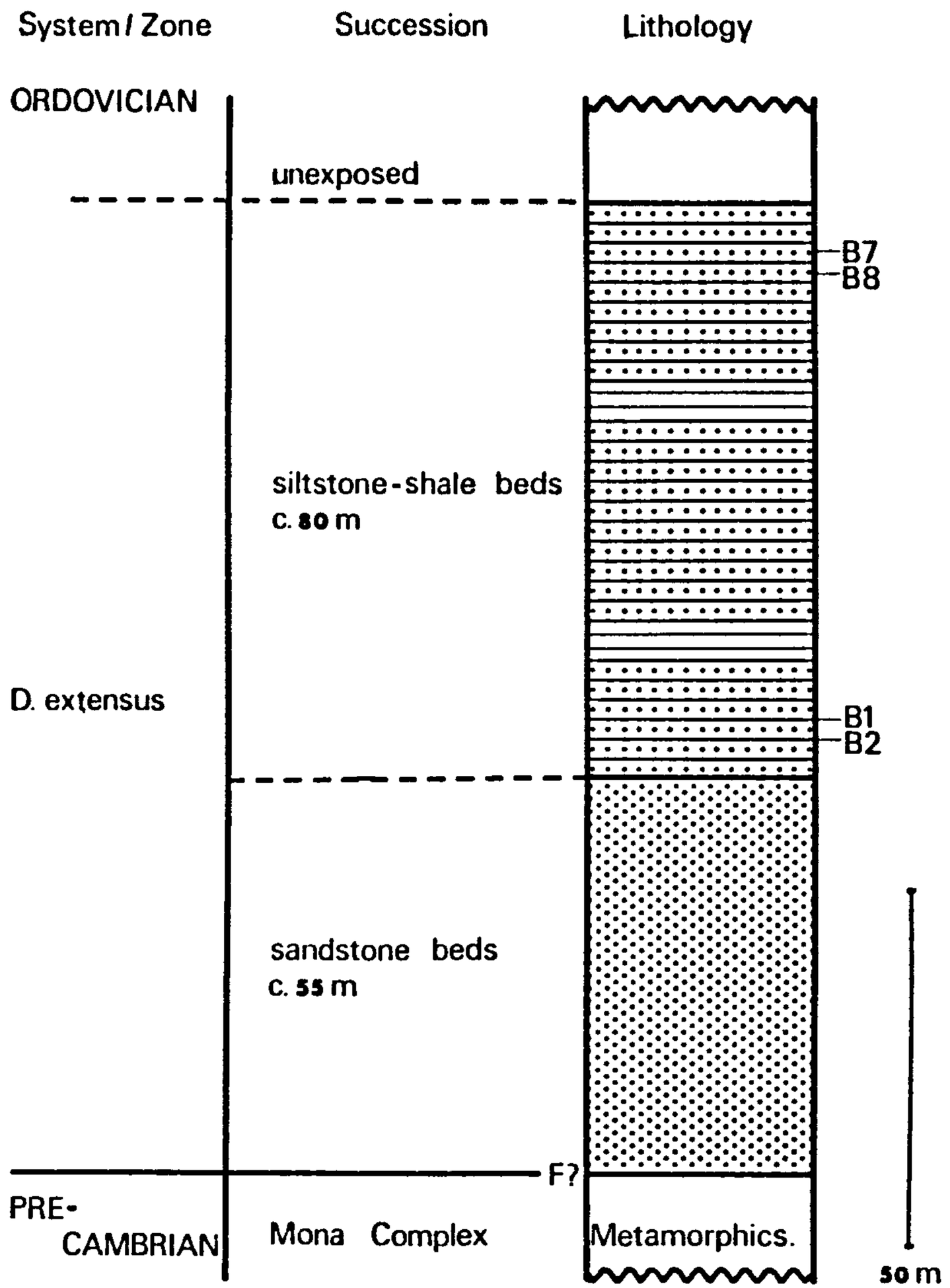
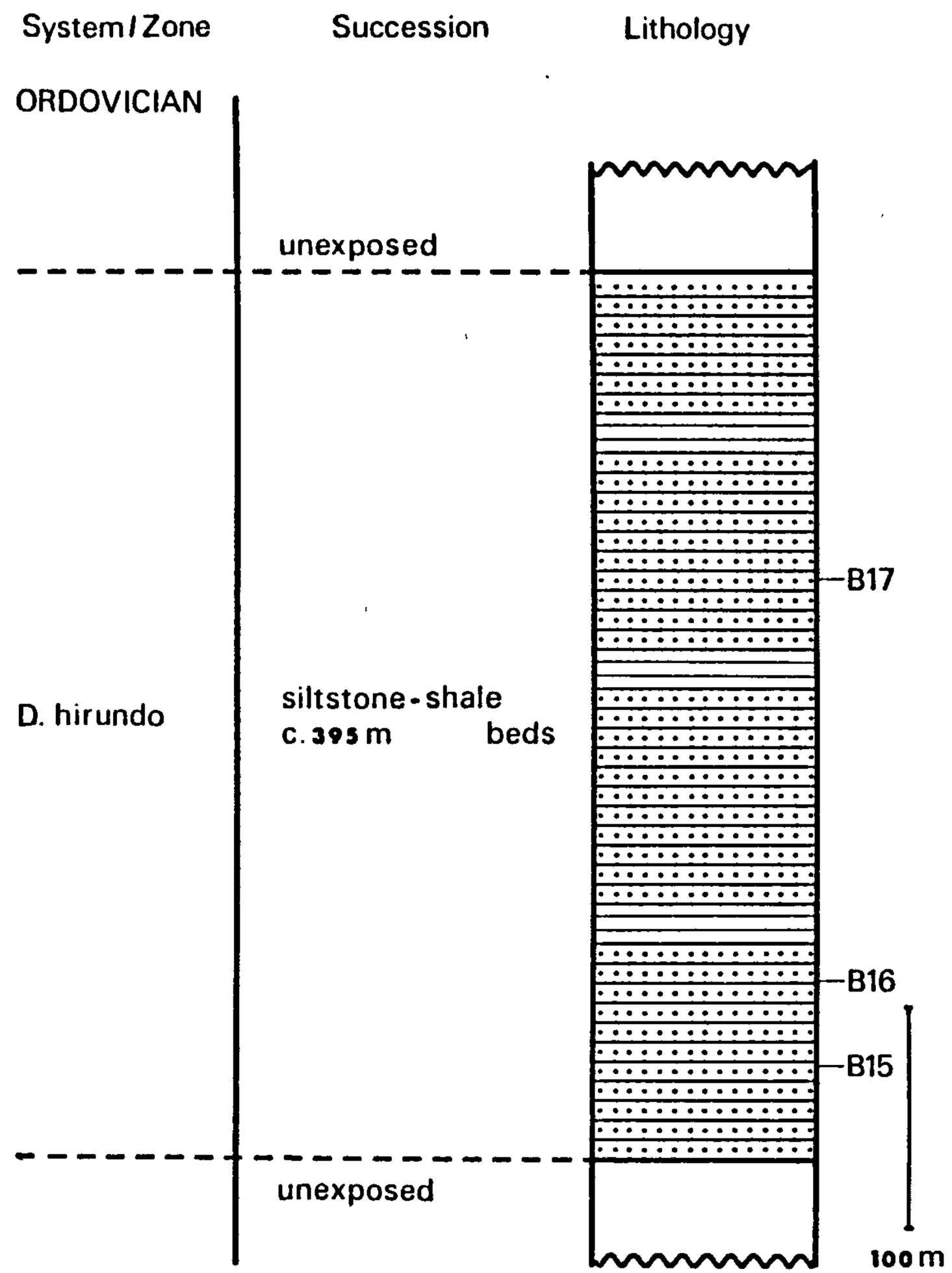
Table 6 Bangor - Menai

Sample	Location	N.G.R.	Lithology	Content	Preservation
M1	Base of low cliff exposed at low tide.	54987128	Dark grey to black micaceous siltstone, iron stained	Occasional acritarchs, organic debris.	4/5 D/E c/d
M2	1m stratigraphically above M1.	54987128	..	Frequent acritarchs, organic debris.	4/5 D/E c/d
M3	1m stratigraphically above M2.	54987127	..	Frequent acritarchs, organic debris.	4/5 D/E c/d
M4	0.5m below unconformity, 35m W. of boat house.	55107127	Dark grey micaceous shale with graptolites	Occasional acritarchs, organic debris.	4/5 D/E c/d

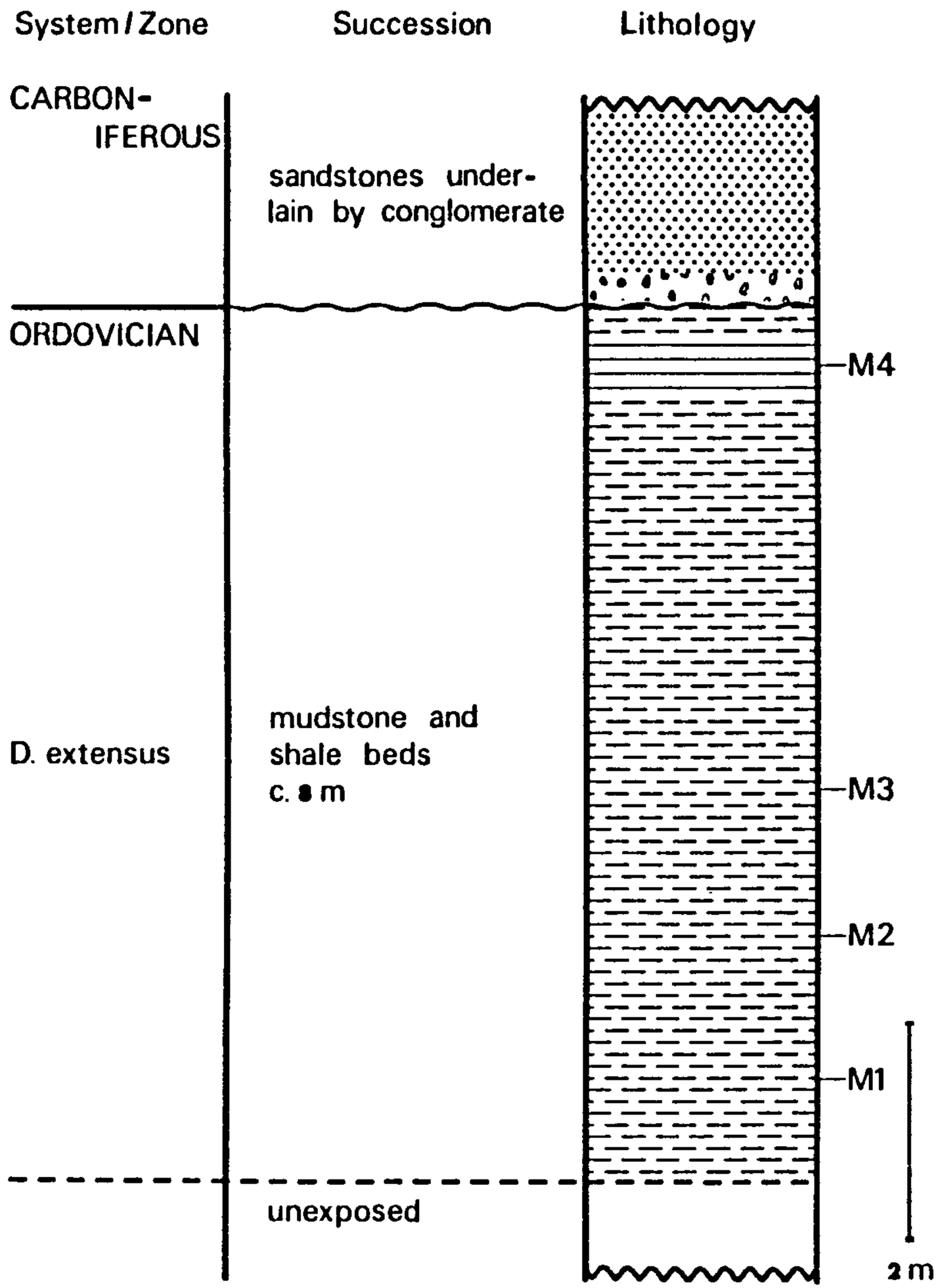
Text-fig.17 A-C SUCCESSIONS IN THE BANGOR AREA





Text - fig.17 continued

C. Menai Inlier



The thicknesses of the siltstone-shale beds in A and B have been calculated from dips of 24° and 46° respectively. The thickness of the sandstone beds in A is that given by Greenly (1944)

Arenig - Nant-ddu, Taihirion

Sample collection in the Arenig district was based on the work of Fearnsides (1905) and Lynas (1973).

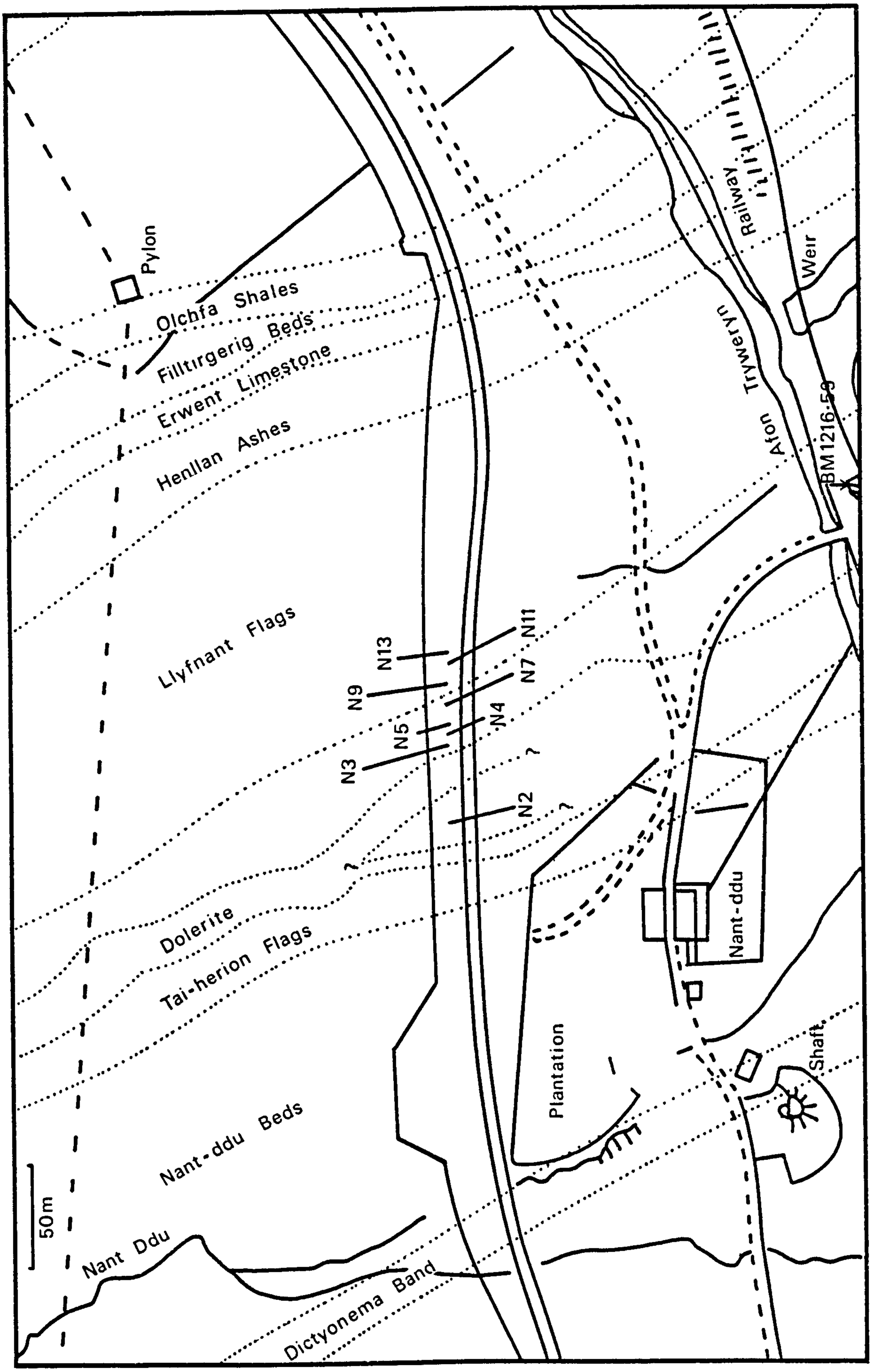
Tremadocian strata are unconformably overlain by an impersistent grit horizon. This is succeeded by the Llyfnant Flags which have yielded Didymograptus deflexus, D. extensus and other graptolites representative of the Subzone of D. deflexus in the D. extensus Zone (Skevington, 1969). The overlying Henllan Ash contains, in the component Erwent Limestone, a shelly fauna which can be correlated to the D. extensus Zone. Shaley horizons in succeeding strata, the Filltirgerig Beds, have yielded Didymograptus hirundo, D. nitidus, Azygograptus suecicus and Tetragraptus serra. The assemblage is indicative of the Zone of D. hirundo. Sedimentation in the Llanvirnian continued with deposition of the Olchfa Shales from which graptolite and shelly faunas characteristic of the Zone of D. bifidus have been obtained. The Olchfa Shales are overlain by unfossiliferous volcanic tuffs and agglomerates, which are in turn succeeded by Daerfawr Shales. The latter have yielded fossils which suggest an age high in the Zone of D. murchisoni.

Seven samples were obtained from a recently exposed road section north-east of Nant Ddu (Text-fig. 18). Although exposure is continuous, the basement grit is not seen, and Llyfnant Flags overlie Tai-Herion Flags without notable discordance of dip or change in lithology.

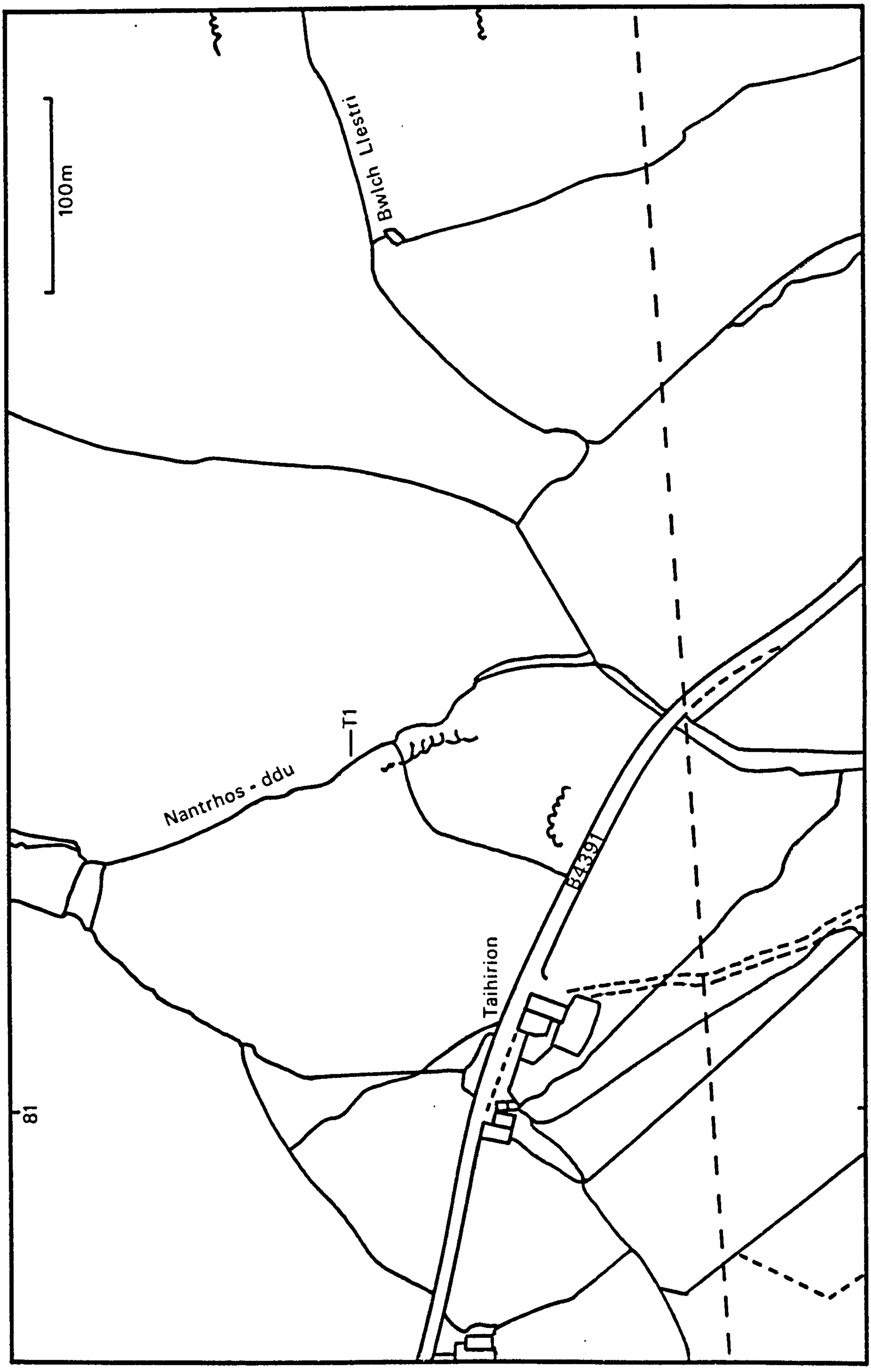
Samples were also collected from the beds exposed along the east bank of Nant Rhos ddu, a small stream rising on the south-western slopes of Arenig Fach (Text-fig. 19). The locality was described in detail by Elles (1904), but a new interpretation of the geology has recently been proposed by Lynas (1973). A shale horizon outcrops in which Didymograptus

bifidus, Diplograptus dentatus and Climacograptus confertus are found. The graptolites are representative of the Zone of D. bifidus.

Sample localities are given in Text-figs. 18 and 19. Grid references, lithologies and details of micropalaeontological content and preservation are summarised in Table 7. The samples are correlated to stratigraphic horizons in Text-fig. 20 A and B.



Text-fig.18 ARENIG, NANT DDU (after Fearnsides, 1905)



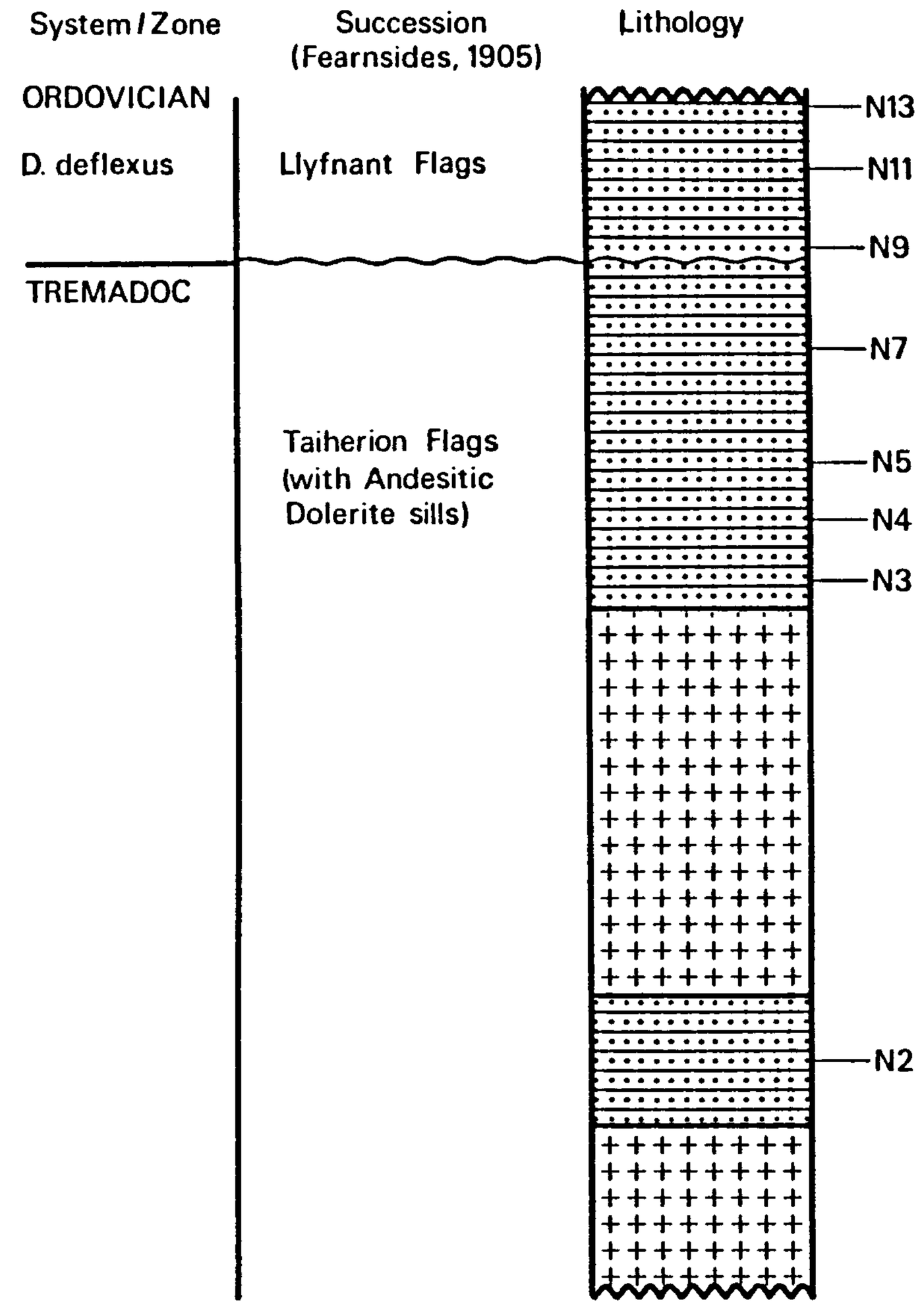
Text-fig. 19 ARENIG, TAIHIRION

Table 7 Arenig - Nant-ddu, Taihirion

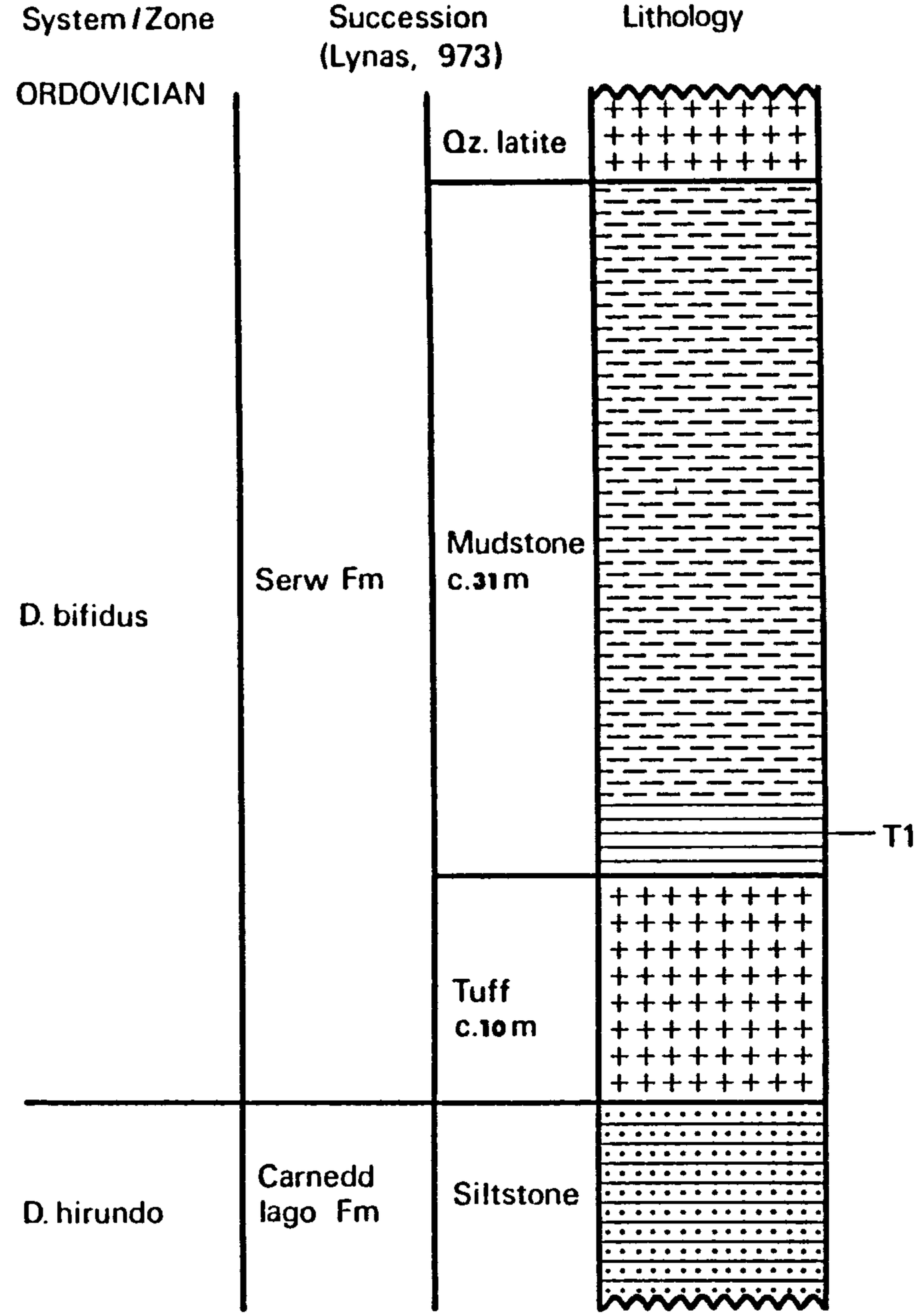
Sample	Location	N.G.R.	Lithology	Content	Preservation
N2	N.E. of Nant-ddu, 18m. E. of the beginning of the exposure.	80263848	Grey and dark grey striped mudstone	Frequent acritarchs, organic debris.	4/5 D/F c
N3	54.5m. as defined above.	80303848	..	Rare acritarchs, organic debris.	5 E c
N4	59.5m. as defined above.	80313848	Blue-grey siltstone, nodule horizon, iron stained.	Rare acritarchs, organic debris.	4/5 E d
N5	64.5m. as defined above.	80313848	Dark grey siltstone, iron stained	Rare acritarchs, organic debris.	4/5 E d
N7	74.5m. as defined above.	80323848	..	Rare acritarchs, organic debris.	4/5 E c/d
N9	84.5m. as defined above.	80333848	..	Rare acritarchs, organic debris.	4/5 E c/d
N11	94.5m. as defined above.	80343848	..	Rare acritarchs, organic debris.	4/5 E c/d
N13	98.0m. as defined above.	80353848	Pale grey-green mudstone concretion	Rare acritarchs, organic debris.	5 F c
T1	160m. N. of intersection of Nantrhos-ddu and B4391, E. bank of stream.	81183982	Dark grey slatey shale with graptolites	Rare chitinozoa and acritarchs, organic debris.	5 E/F d

Text-fig. 20 A-B SUCCESSIONS IN THE ARENIG AREA

A. Nant-ddu



B. Taihirion



Shropshire - Hope, Whitsburn, Lyde, Rorrington, Priestweston

The collection of samples in the Shelve district of Shropshire was based on the work of Whittard (1932, 1952, 1955-67). Reference was also made to a study by Jenkins (1965, MS.).

The stratigraphy of the Shropshire area was first elucidated by Lapworth and Watts (1894). Whittard (1931, 1952) subsequently studied the Arenig - Carodocian succession of the Shelve inlier in considerable detail and was able to calculate the thickness of some rock units. Owing to the limited exposure, folding and strike faulting, the figures given by Whittard are only approximate. In a personal communication to Jenkins (1965, MS.) Whittard provided additional information which has been used in the drafting of Text-fig. 24 in this study. The thickness of the Stiperstones Quartzite is that given by Dean, in Williams et al. (1972).

Ordovician sedimentation in the Shelve district, commenced with the deposition of quartzites interleaved with occasional conglomerates and shales. This latter formation, the Stiperstones Quartzite, in part represents the Zone of Didymograptus extensus, and rests unconformably upon flags and shales of Tremadocian age. The quartzites pass upwards into the Mytton Flags, a series of micaceous flags, grits and shales. Whittard (1931), recognised a fourfold subdivision of the Mytton Flags viz:

Mytton Flags	1	Tankerville Flags	D. hirundo
	2	Shelve Church Beds	
	3	Ladywell and Snailbeach Grits and Flags	D. extensus
	4	Lord's Hill Beds	

The Mytton Flags belong to a mixed facies and have yielded brachiopods trilobites, and graptolites which permit correlation partly with the Zone of D. extensus and partly with the Zone of D. hirundo. Dean, in Williams et al. (1972), separated the Tankerville Flags from the Mytton Flags and this modification is followed in Text-fig. 24 in this study.

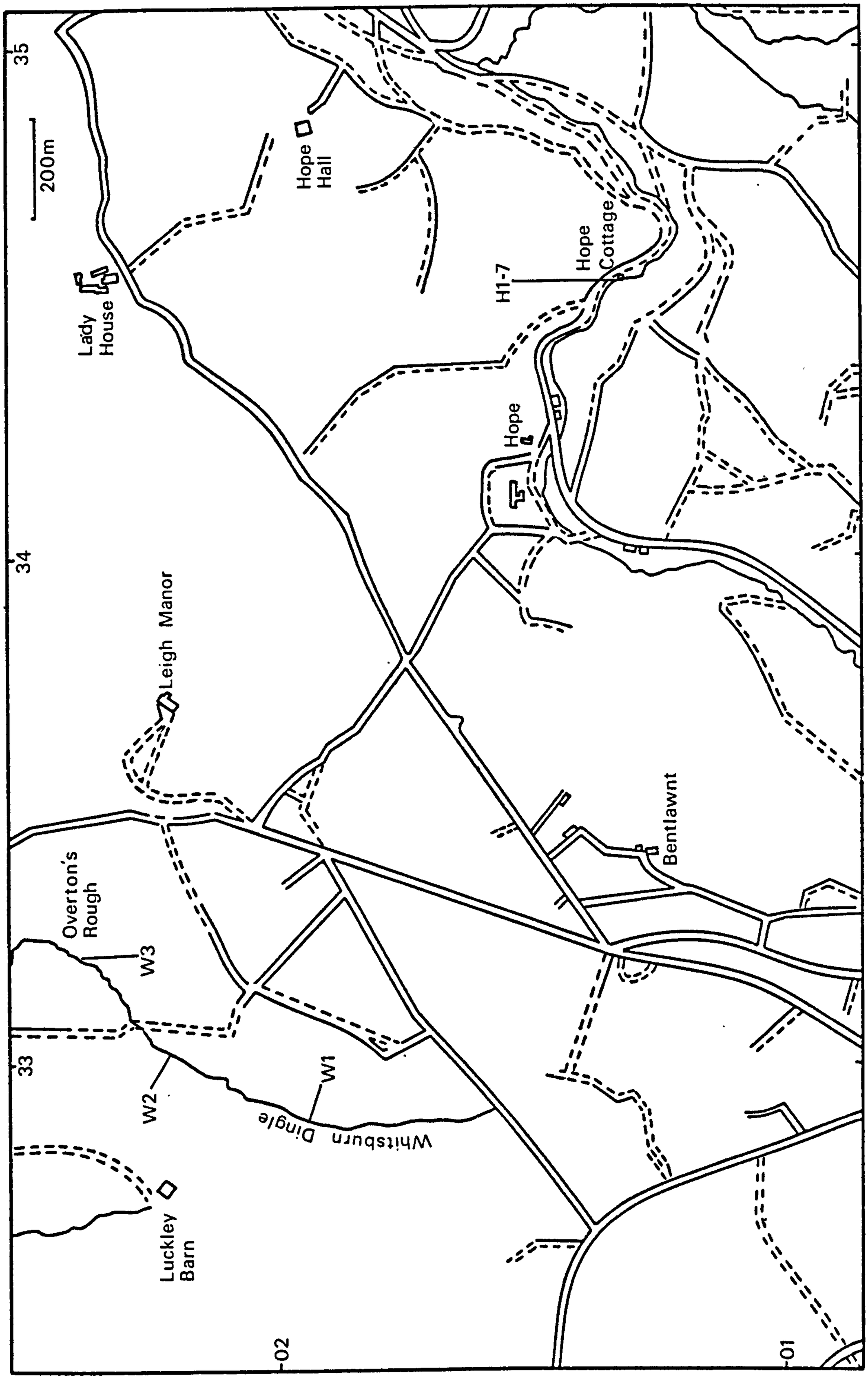
The succeeding Hope Shales incorporate a waterlain tuff horizon, the 'China-stone Ash', which although of restricted distribution has been used to subdivide the formation. The 'China-stone Ash' is unfossiliferous, but the Upper and Lower Hope Shales have yielded a mixed assemblage of fossils which include a characteristic Cyclopyge - Placoparia - Barrandia trilobite fauna which indicates the Zone of D. bifidus. The overlying Stapeley Volcanic Group is a variable sequence of ashes, tuffs and interbedded shales. Both the Stapeley Volcanic Group and succeeding Stapeley Shales have yielded a mixed fauna which correlates with the upper part of the Zone of D. bifidus.

The Weston Beds are in marked lithological contrast to the underlying shales, being composed of grits and flags. They have yielded a shelly fauna indicative of the Zone of D. murchisoni. The Weston Beds grade upwards into micaceous shales and flags which constitute the Betton Beds. The shales have yielded abundant D. murchisoni and D. murchisoni var. geminus thus indicating the Zone of D. murchisoni.

Detailed lists of the trilobite species characteristic of the above formations are given by Whittard (1955-67). The brachiopods have been similarly dealt with by Williams (1974).

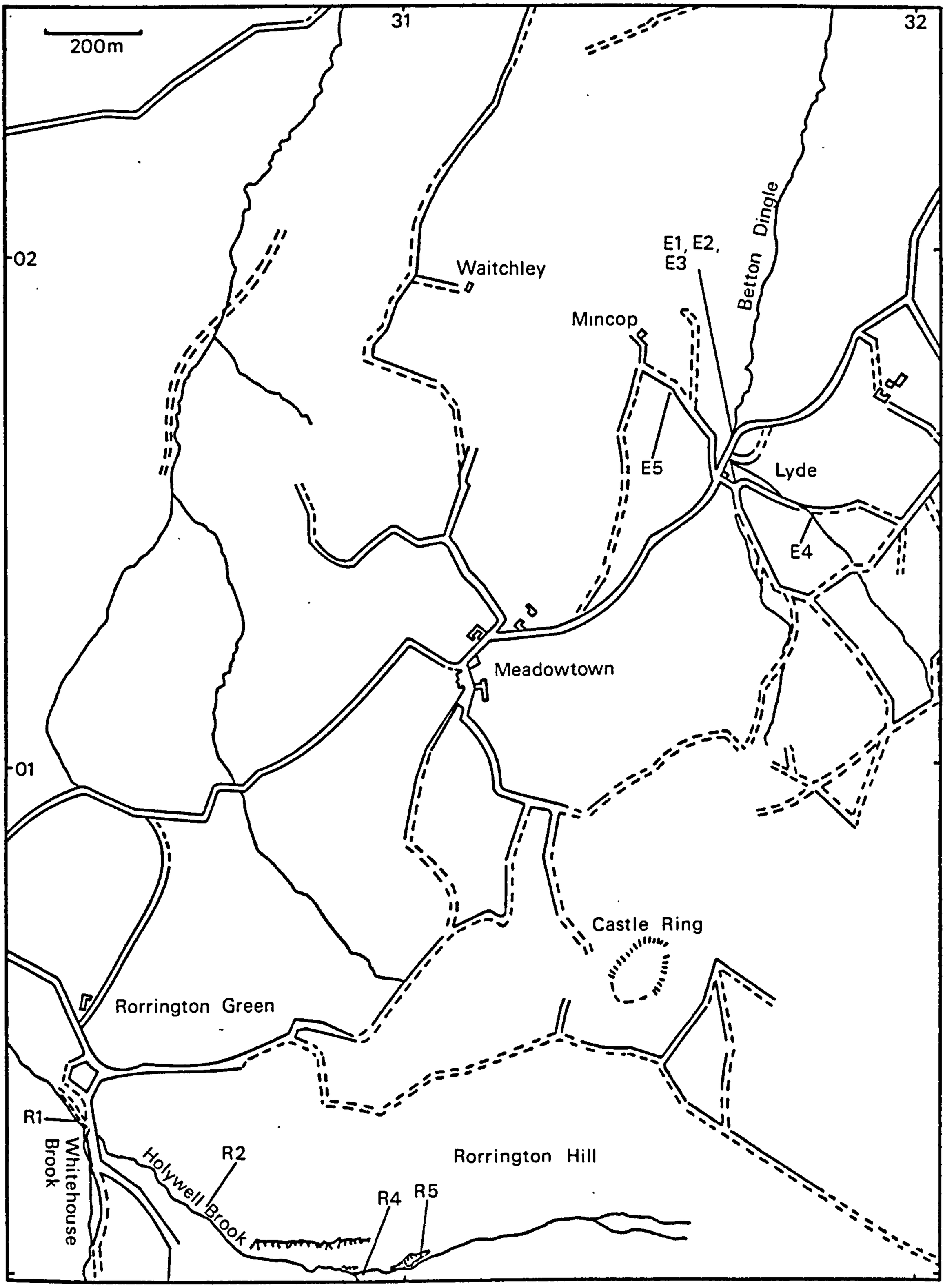
Twenty-four samples were processed from the Shelve district. The collection localities are given in Text-figs. 21-23. Grid references,

lithologies, micropalaeontological content and preservation, are summarised in Table 8. The samples are correlated to stratigraphic horizons in Text-fig. 24. The relative positions of samples within the Stapeley Shales, Weston Beds and Betton Beds are not known with certainty.



Text-fig. 21 SHROPSHIRE, HOPE and WHITSBURN

Text-fig. 22 SHROPSHIRE, LYDE and RORRINGTON



Text-fig. 23 SHROPSHIRE, PRIESTWESTON

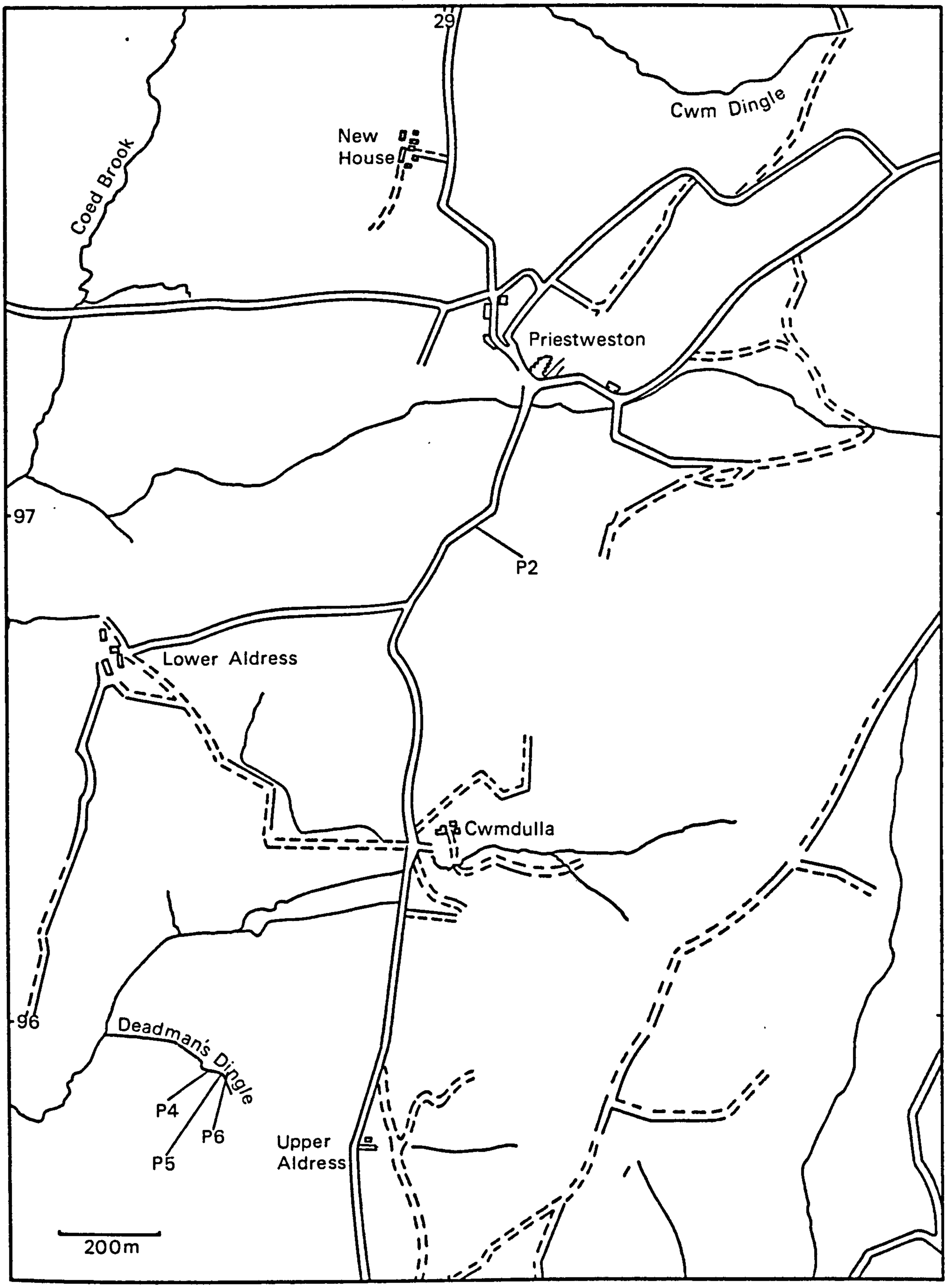


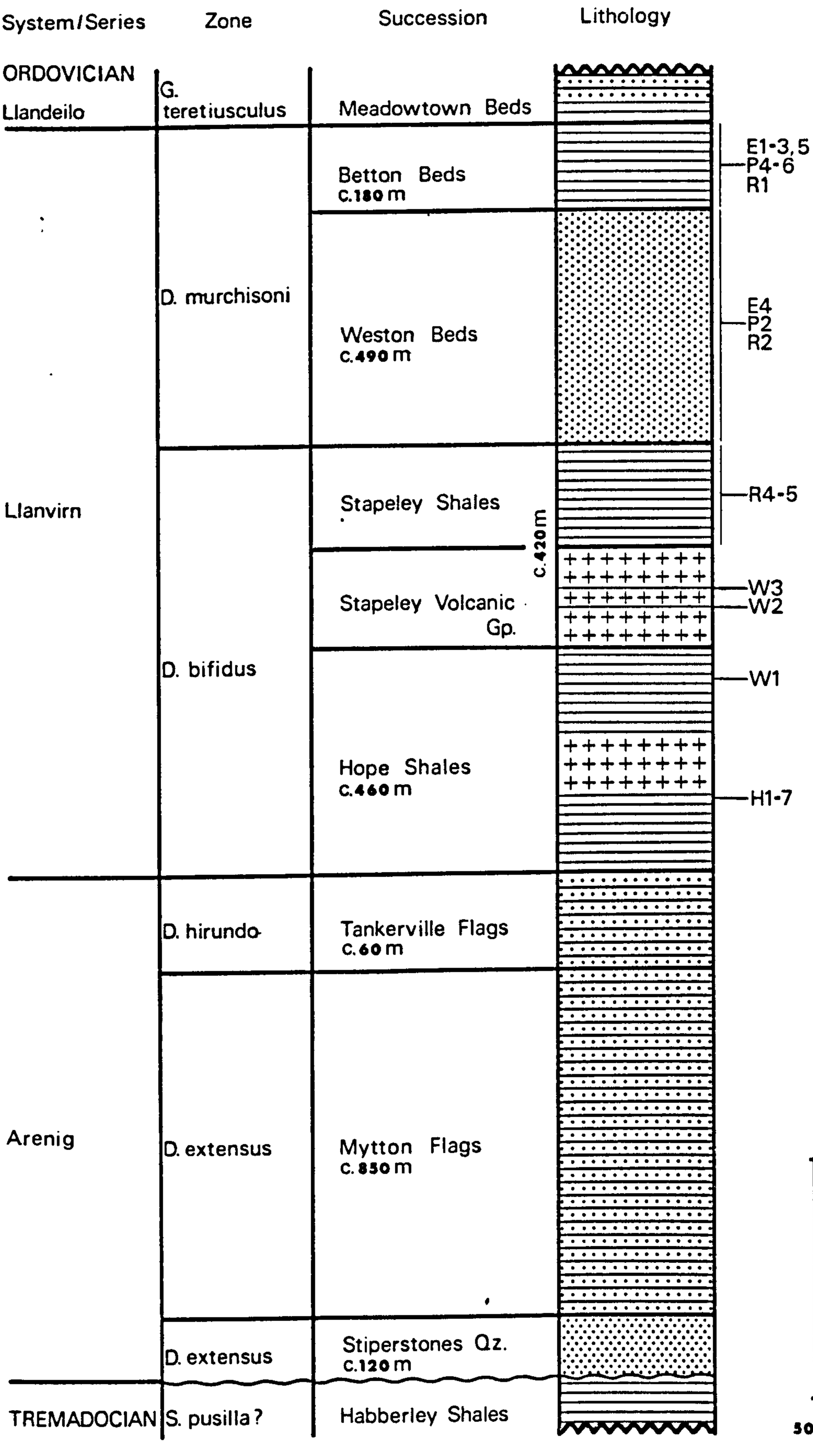
Table 8 Shropshire - Hope, Whitsburn, Lyde, Rorrington, Priestweston

Sample	Location	N.G.R.	Lithology	Content	Preservation
H1	Hope Cottage, stream bed 1.5m upstream from corner of water tank, almost beneath foot-bridge.	34540131	Dark grey shale, iron stained	Fragmentary chitinozoa, graptolites, occasional acritarchs; organic debris.	3/5 C/E c/d
H2	Hope Cottage, stream bed 3.4m. upstream from corner of water tank.	34540132	..	Fragmentary chitinozoa, occasional acritarchs, organic debris.	3/5 C/E c/d
H3	6.4m. as defined for H2.	34540132	..	Occasional chitinozoa, frequent acritarchs, organic debris.	3/5 C/E c/d
H4	8.8m. as defined for H2.	34540132	..	Occasional chitinozoa, frequent acritarchs, organic debris.	3/5 C/E c/d
H5	23.5m. as defined for H2.	34530133	Grey-black shale, iron stained	Chitinozoa and frequent acritarchs, organic debris.	3/5 C/E c/d
H6	29.0m. as defined for H2.	34530133	Dark grey shale, iron stained	Numerous chitinozoa and acritarchs, organic debris.	3/5 C/E c/d
H7	34.7m. as defined for H2.	34530134	..	Chitinozoa, acritarchs and organic debris.	3/5 C/E c/d
W1	Whitsburn Dingle, 460m. W. 19°N, of Luckley Barn, E.bank of stream, midway along Overton's Rough.	32890194	Grey-black shale, iron stained	Rare chitinozoa, frequent acritarchs, organic debris.	3/5 C/E c/d

W2	Whitsburn Dingle, directly E. of Luckley Barn, E. bank of stream.	33030221	Grey-black shale, iron stained.	Chitinozoa, frequent acritarchs, organic debris.	3/5	C/E	c/d
W3	Whitsburn Dingle, 300m. S. 26°W. of Luckley Barn, E. bank of stream.	33220238	Dark grey shale, iron stained.	Chitinozoa, frequent acritarchs, organic debris.	3/5	C/E	c/d
E1	Lyde, 3.4m. downstream from N.W. face of bridge, west bank of stream.	31640164	Dark grey mudstone	Rare chitinozoa, acritarchs, organic debris.	3/5	E/F	d
E2	Lyde, 5.2m. as defined for E1.	31640164	Dark grey micaceous shale	Rare chitinozoa, acritarchs, organic debris.	3/5	E/F	d
E3	Lyde, 7.4m. as defined for E1.	31640165	Dark grey micaceous shale	Rare chitinozoa, acritarchs, organic debris.	3/5	E/F	d
E4	Lyde, 200m. upstream from S.E. face of bridge, E. bank of stream.	31800148	Grey, fine-grained sandstone with brachiopods and trilobite fragments	Rare chitinozoa, acritarchs, organic debris.	3/5	E/F	d
E5	Lyde, on S. side of old track to Lyde, 155m. S. 25° E. of Mincop.	31530172	Grey siltstone	Rare chitinozoa, acritarchs, organic debris.	3/5	E/F	d
R1	Rorrington, about 35m. below junction of Holywell and Whitehouse Brooks.	30360030	Grey and dark grey siltstone.	Rare acritarchs, organic debris.	3/5	E	d

R2	Rorrington, at W. end of crags, just E. of foot-path, N. side of Holywell Brook.	30620013	Grey green fine-grained sandstone	Rare acritarchs, organic debris.	3/5	E	c/d
R4	Rorrington, W. flowing stream, N of Valley Knoll, approx. 20m. above junction with Holywell Brook.	30920000	Dark grey shale	Rare acritarchs, organic debris.	3/5	D/E	c/d
R5	Rorrington, 135m. as defined for R4.	31030004	Grey siltstone	Frequent acritarchs, organic debris.	3/5	D/E	c/d
P2	Priestweston, road exposure, 395m. S. 48°W. of the Miner's Arms.	29069697	Grey fine-grained sandstone with trilobites	Rare acritarchs, organic debris.	4/5	F	d
P4	Priestweston, Deadman's Dingle, 55m. below junction of W. flowing field stream, and that of Deadman's Dingle.	28539590	Dark grey siltstone with uneven shaly partings	Rare acritarchs, organic debris.	4/5	F	d
P5	Priestweston, Deadman's Dingle, 5m. below junction as defined for P4.	28569589	Dark grey shale with uneven parting	Rare acritarchs, organic debris.	3/5	E/F	d
P6	Priestweston, Deadman's Dingle, 5m above junction as defined for P4. N. bank of field stream.	28579589	Dark grey shale	Rare acritarchs, organic debris.	4/5	F	d

Text-fig. 24 SHELVE AREA SUCCESSION



CHAPTER 2 MICROFOSSIL EXTRACTION AND EXAMINATION

2.1. EXTRACTION

Collection of samples

In the field, samples were collected from freshly exposed surfaces of in situ outcrops. Closely spaced fissures, and growths of algae and lichens were avoided on account of their potential as a source of contamination. The localities sampled were selected after consulting the works of other authors. Evidence as to age was usually based on graptolites or trilobites.

General considerations and preparation of equipment

Organic walled microfossils were released from the rock matrix by chemically dissolving the surrounding mineral grains and cements. The organic fraction, was then separated from undissolved mineral particles by sieving and treatment with heavy liquids. Sieving was carried out as gently as possible to avoid damage to the microfossils by abrasion. Great care was also taken to prevent sample contamination. Each stage of the process carried a contamination risk, but by constant vigilance and careful attention to the cleaning of equipment, it is thought to have been reduced to a very low level.

All beakers, jars, sieves, covers and stirrers were first thoroughly washed with 'Teepol' and hot water. Glass and polythene ware was then sterilised by several chromic acid rinses. Copper sieves were rinsed with a high pressure stream of tap water; nylon gauzes and glass pipettes were renewed after each preparation.

Although the domestic water supply has been known to be a source of contamination in palynological preparation, in view of the large quantities of water required, the problem was not considered serious enough to force the use of distilled water. Diatoms were occasionally noted in mounted preparations which were presumed to have originated from the tap water.

Cleaning samples and testing for carbonates

The samples were first scrubbed with 'Teepol', dried, and then tested for carbonates by applying a few drops of concentrated hydrochloric acid. Non-calcareous samples requiring further cleansing were immersed in a solution of concentrated nitric and hydrochloric acids, in a 1 : 1 ratio, for a period of 5 to 30 minutes. Calcareous samples requiring further cleansing were immersed in concentrated nitric acid for a period of 5 to 40 minutes. After removal, the samples were thoroughly rinsed and allowed to dry.

Crushing and disaggregation

Each sample was crushed to fragments of about 2 - 5 mm. diameter using a steel pestle and mortar. Approximately 150 gms. were placed in a 250 ml. polypropylene screw-topped jar. Calcareous samples were treated with hydrochloric acid until all reaction ceased. The spent acid was then decanted and cautiously replaced with a 40% solution of hydrofluoric acid. The jar was then closed with a ventilated lid and placed in a water bath at 60°C for a period of 3 - 20 days. Non-calcareous samples were treated directly with a 40% solution of hydrofluoric acid. The jars were stirred daily and the spent acid replaced every third day. Several days of treatment produced a 'slurry' composed of organic matter and mineral grains.

Neutralisation and sieving

The acid was decanted from the organic/mineral residue and the jar refilled with water. After stirring the suspension was passed through a 250μ mesh copper sieve in order to remove any large particles which had resisted the chemical attack. The fraction passing through the sieve was collected in a 1000 ml. polypropylene beaker, then topped up with water, covered, and allowed to stand for 24 hours. The preparation was decanted at daily intervals until the overlying liquid was neutral to the blue litmus paper. The sample was then passed through a 53μ mesh copper sieve in order to remove the coarser organic and inorganic elements. The residue retained on the sieve gauze was transferred to a 100 ml. 'Pyrex' beaker, while the fraction which had passed through was in turn passed through a 20μ mesh nylon sieve. The residue retained by this sieve was also transferred to a 100 ml. 'Pyrex' beaker. Finally, the fraction passing through the 20μ nylon sieve was poured onto the sieve plate of a No. 2 'Pyrex' sinter-glass funnel (porosity 5 - 10μ). The residue retained by this sieve was likewise transferred to a 100 ml. 'Pyrex' beaker. The filtrate was discarded.

Removal of mineral matter

The separate residues were each then checked microscopically for the presence of mineral matter. Calcium fluorides were removed by boiling in concentrated hydrochloric acid for 2 - 5 minutes. Silicates were removed by heavy-liquid separation, the residue being first placed in a No. 2 'Pyrex' sinter-glass funnel (porosity 5 - 10μ), and acidified with hydrochloric acid. A solution of zinc bromide (S.G. 2.89) was added, and the residue, suspended in the zinc bromide solution, transferred to 100 ml. polypropylene centrifuge tubes. After 15 minutes at 2500 r.p.m.

the tubes were removed and the separated organic fraction carefully poured from the top of each tube into a 1000 ml. beaker of water, acidified with hydrochloric acid. The suspended organic material was passed through a suitable sieve (depending on the size fraction being dealt with) and washed several times with water. The residue from the sieve plate was transferred to a specimen tube and allowed to settle for 2 - 6 hours.

Oxidation

A small quantity of organic residue from each preparation was examined microscopically to determine whether or not oxidation should be attempted. Strongly carbonised specimens (Grades 5 - 6, see Table 14) did not respond favourably to oxidation, dilute or concentrated nitric acid having little effect, and 'Schultz' solutions causing fragmentation. On the other hand the transparency of moderately carbonised specimens (Grades 3 - 4) was usually improved by treatment with concentrated nitric acid for periods of 5 minutes to 4 hours. The time judged necessary was based on experience with previous samples. The progress of oxidation was checked at frequent intervals.

The oxidation was carried out in a No. 2 'Pyrex' sinter glass funnel (porosity 5 - 10μ) fitted to a Buchner flask with the side arm temporarily sealed to prevent the acid from flowing through. After the required oxidation period the residue was washed several times with water, and then resieved if necessary. The residue from the sieve plate was transferred to a specimen tube and allowed to settle for 2 - 6 hours.

Mounting

A small quantity of organic residue was transferred to a 2.5 ml. mixing tube, to which a few drops of 'Cellosize' solution were added. The suspended residue was then pipetted onto cover slips, and the excess liquid allowed to evaporate. The cover slips were mounted in Canada balsam.

2.2. EXAMINATION

Slide Examination

The slides were examined in an attempt to record all species present, and in order to obtain quantitative information about their occurrence. At least three slides per sample were fully examined at either x250, x400 or x1000 magnification.

The following broad categories of frequency occurrence were based on actual specimen counts of (where possible) at least 250 specimens per sample.

r	=	rare	= 1%
r/c	=	rare to common	= 1% - 3%
c	=	common	= 3% - 8%
c/a	=	common to abundant	= 8% - 20%
a	=	abundant	= 20%

These categories have been used in the compilation of Table 12 and are referred to in the text (Chapter 5.1).

The estimates of relative abundance must be treated with caution, as in some samples delicate species may have been destroyed by post depositional processes (see Chapter 7). In these circumstances, present microfloral composition cannot reflect the original composition. This must be taken into account when comparisons are made between well preserved and less well preserved assemblages.

Photography

Specimens were photographed on Kodak Panatomic-X or Kodak Plus-X film, using a Leitz Orthoplan microscope (No.746714) fitted with an Orthomat camera attachment. Prints were made on Kodak bromide paper of hardness 2 or 3, and developed in Kodak DPC 1 : 9.

CHAPTER 3 MORPHOGRAPHICAL TERMINOLOGY

Unfortunately, a comprehensive glossary of morphographical terms for the description of acritarchs is not available, although the lists given by Eisenack et al. (1973, 1976) form a useful guide. The need to establish adequate terminology was recognised at the Second International Conference on Palynology (Utrecht, 1966), where a resolution expressing this view was passed by the C.I.M.P. Subsequently, a report produced by Downie, Cramer, Evitt, Staplin, Jansonius and Pocock was presented to the Subcommission on Acritarcha (C.I.M.P.), but remained unpublished. However, the suggested terminology later formed the bases of glossaries published by Lister (1970) and Kjellström (1971a).

One of the difficulties associated with the production of a comprehensive glossary is that it should be found acceptable to all who attempt to use it. The morphographical diversity of acritarchs has necessitated the introduction of a large number of terms. Many are very specialised and hence of very limited application, but must be included in any glossary intending to be comprehensive. Translation from other languages can also be a difficulty, as it often proves impossible to translate the exact meaning of key descriptive words.

The following glossary is not comprehensive, but contains a selection of morphographical terms either used directly, or quoted in the descriptions of others, in this study. For additional information it is recommended that the works mentioned above should be consulted.

GLOSSARY

ACUMINATE: A process termination when pointed.

ALATE: See peteinate.

ANGULAR PROXIMAL CONTACT: A sharp juncture of the process stem with the central body.

APPENDAGE: See process.

ARBORESCENT: Tree-like, with reference to processes.

BASAL PLINTH: 'Basisfassung' of Burmann (1970). Cylindrical collar-like structure constricting the base of a process.

BRANCHED PROCESS: A process which divided repeatedly, resulting in a tree-like form. The branches may be referred to as being of the 1st, 2nd, 3rd, etc. orders.

CAPITATE PROCESS: A process with a swollen distal extremity.

CENTRAL BODY: The cyst without the processes.

CENTRAL BODY CAVITY: The space enclosed by the central body wall. It may or may not communicate with the process cavities.

CENTRAL BODY OUTLINE: The shape of the central body as seen in optical section. It may be described as triangular, rectangular rhomboidal, polygonal, subpolygonal, circular, subcircular, ovate, etc.

CLAVATE: Club-shaped.

CLOSED PROCESS: A process which is closed distally.

COMPRESSED: Flattened.

CONICAL PROCESS: A process of basically conical form; the stem diameter reducing progressively towards the distal extremity. (= tapering process).

CRYPTOSUTURE: A suture possessing no visible surface manifestation on the test, the position only becoming evident after dehiscence has commenced.

CURVED PROXIMAL CONTACT: A curved contact of process stem with central body. May be qualified by sharply, broadly, etc. (cf. angular contact).

CYLINDRICAL PROCESS: A process of basically cylindrical form, the stem diameter being more or less constant along the length.

ECTODERM: The outermost, (and often only) wall layer.

ENDODERM: The innermost layer of a two-layered wall.

EPITYCHE: A type of excystment opening in Veryhachium, which originated as an arched slit between two process bases.

EQUATOR: An intermediate line between two poles, separating a cyst into two more or less equal halves.

EVEXATE: A process termination when rounded (but not expanded).

EXCYSTMENT OPENING: An opening produced by the loss of an operculum or rupture of the cyst during dehiscence. (= excystment aperture).

EXPANDED PROCESS BASE: A process base which shows a marked increase in breadth proximally. (= flared process base).

FILIFORM: Erect and slender.

FLARED PROCESS BASE: See expanded process base.

FURCATE PROCESS: A process with distal division into two (bifurcate) three (trifurcate), or more (multifurcate), simple pinnae.

FUSIFORM: Spindle shaped.

GRANULOSE: A type of sculpture consisting of more or less closely spaced grains, which are essentially equidimensional and 0.25 - 1.0μ in height. (= granulate).

HEMIMORPHIC: See heteropolar.

HETEROMORPHIC: With reference to processes, used to indicate the presence of more than one type on the cyst.

HETEROPOLAR: Bipolar with poles dissimilar. (= hemimorphic).

HOLOMORPHIC: See homopolar.

HOMOMORPHIC: With reference to processes, used to indicate the presence of only one type on the cyst.

HOMOPOLAR: Bipolar with poles alike. (= holomorphic).

LAEVIGATE: See psilate.

LACINIATE: Fringed.

LANCEOLATE: Pointed, spear-like.

MEDIAN SPLIT: An excystment suture in an approximately equatorial position.

MICROGRANULOSE: Sculpture of granulose type where the elements generally do not exceed 0.25μ in height.

OMBRELLATE: Umbrella-like.

OPEN PROCESS: A process without distal closure. The process cavity is therefore in communication with the exterior.

OPERCULUM: Part of the cyst wall, which when detached reveals an excystment opening.

PALMATE: A process termination in which the process divides into several radially orientated pinnae which have a common origin.

PETALOID: See peteinate.

PETEINATE: Having veil-like membranes along the length of the process stems. (= alate, velate, petaloid).

PINNAE: The simple terminal elements of a furcate process. (= filaments, furcae).

PITTED: Marked by small irregular excavations.

PLUG: The thickened (and usually darker) area at the base of a process, which may partially or completely restrict communication between a process interior and the central body cavity.

PLURIFURCATE: Multifurcate.

POLE: In cysts having bilateral symmetry, each of two terminal areas along the symmetry axis. They may be referred to as apical and antapical.

POLYHEDRAL: Three dimensional, many sided.

PROCESS: A distinctive structure formed by an outward extension of the central body wall, often having a basically cylindrical or conical shape. (= appendage).

PROCESS CAVITY: The cavity of a hollow process stem, which may be continuous with the central body cavity or separated from it by a basal construction and/or plug of organic material. (= process interior).

PROXIMAL CONSTRICTION: A reduction in breadth around a process base.

PSILATE: Smooth, having no visible structure at x1000. (= laevigate).

PUNCTATE: Perforate.

PYLOME: Circular excystment opening.

PYRIFORM: Pear-shaped.

RECURVED: Curved through an angle greater than 90°.

RETICULATE: A surface network of intersecting lines or crests.

ROBUST PROCESS: A process with wide stem breadth relative to length.

RUGULATE: Sculpture of minute sub-parallel longitudinal folds etc., producing an irregular surface.

SHAFT: See stem.

SHAGRINATE: Sculpture of small folds and elevations similar to that on leather. (= chagrenate).

SIMPLE PROCESS: A process without terminal branches or swellings.

SLENDER PROCESS: A process of small breadth relative to length.

STEM: The process exclusive of any terminal complex or proximal structure. Synonym of shaft.

TAPERING PROCESS: See conical process.

TEST: The central body together with the processes.

TUBERCULATE: See verrucate.

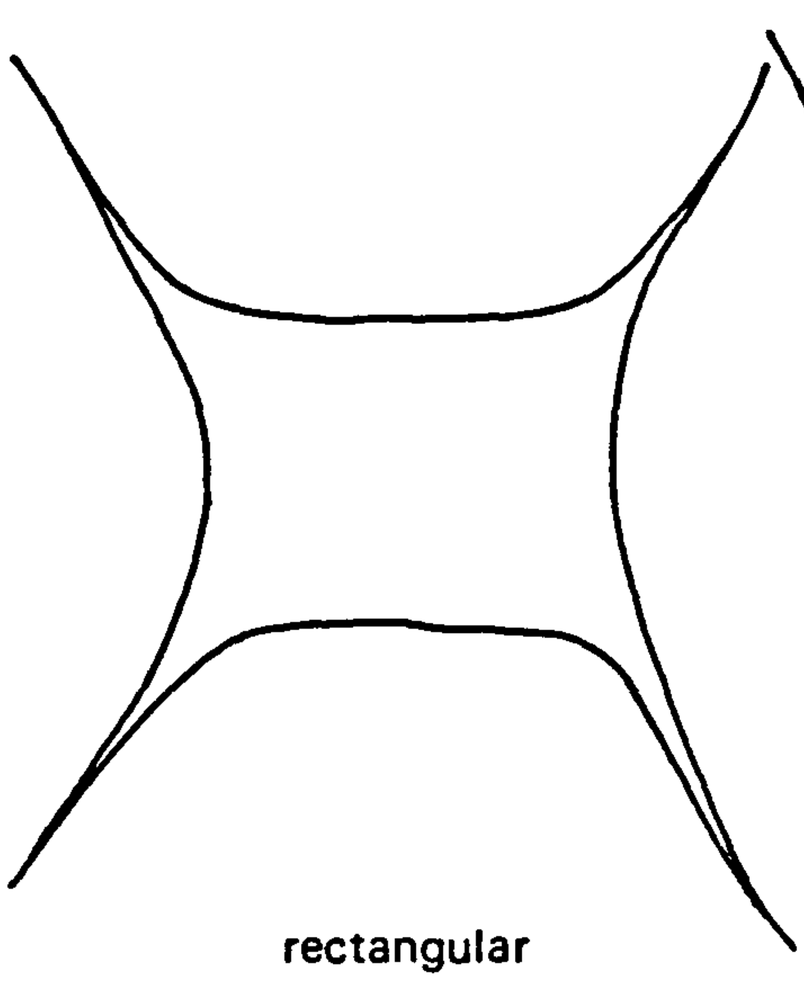
VELATE: See peteinate.

VERRUCATE: Sculpture of wart-like projections, generally greater = than 0.5μ in height. (= tuberculate).

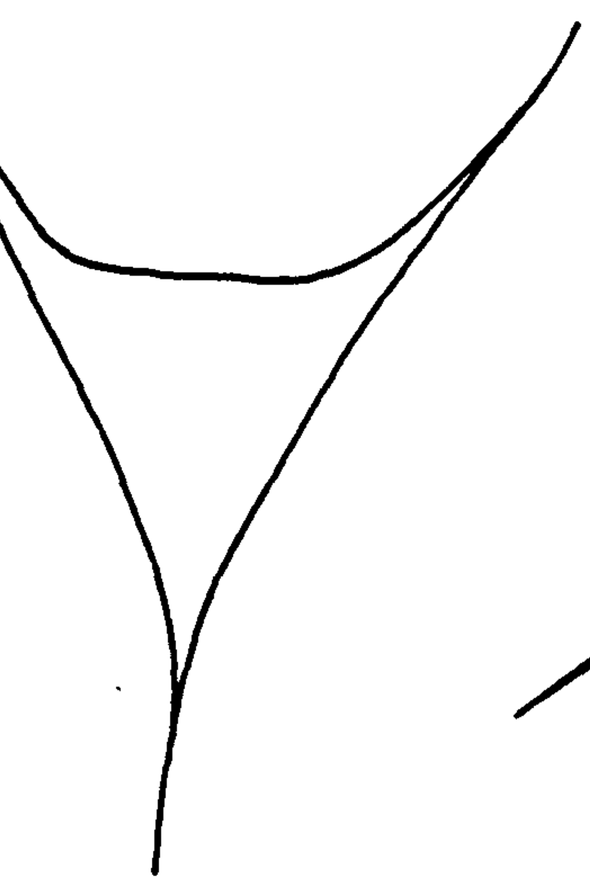
VESICLE: See central body.

WALL: The organic layer surrounding the central body and process cavities. It may be composed of one or more layers, and may be described as moderately thick, thin etc.

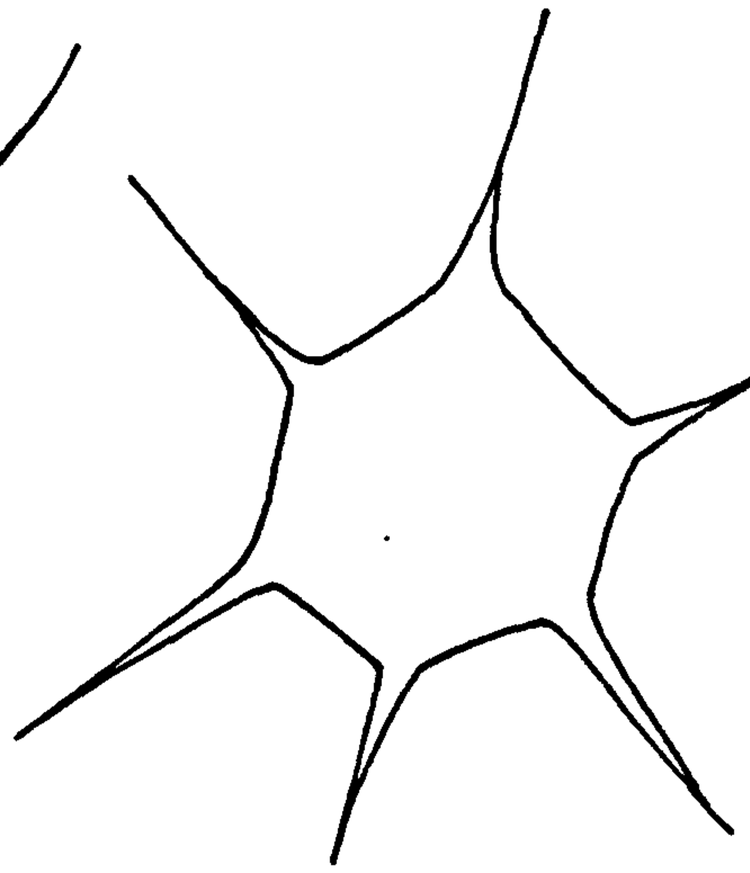
Text-fig. 25 Basic central-body types



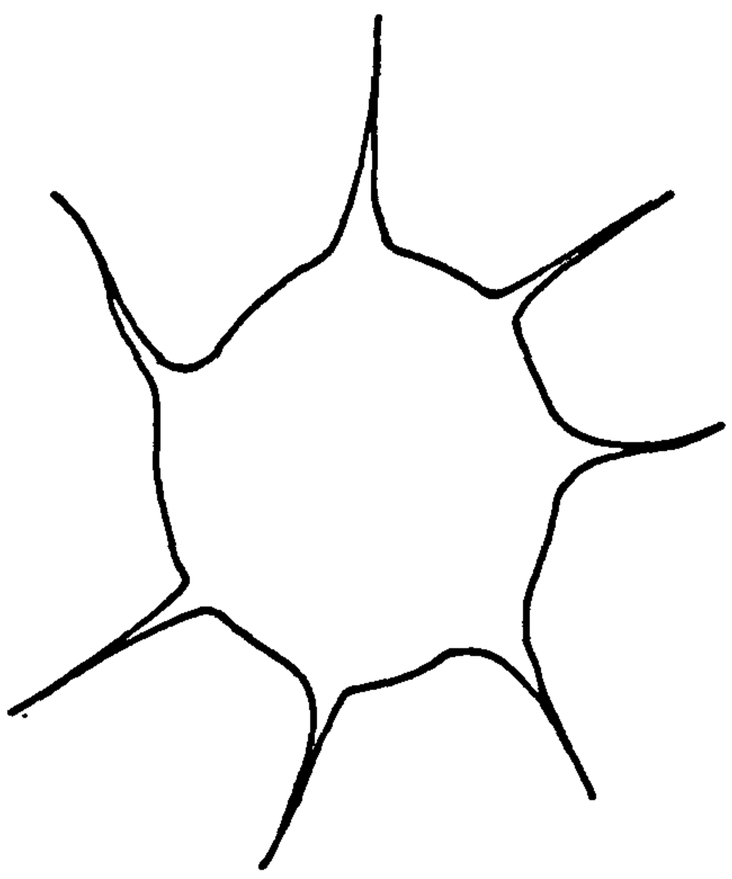
rectangular



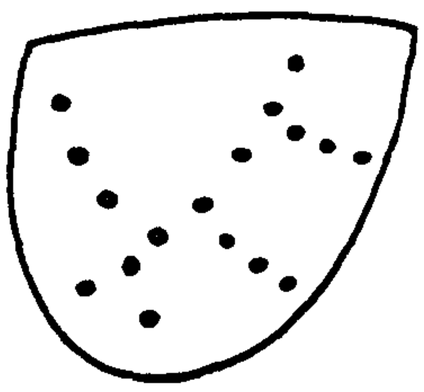
triangular



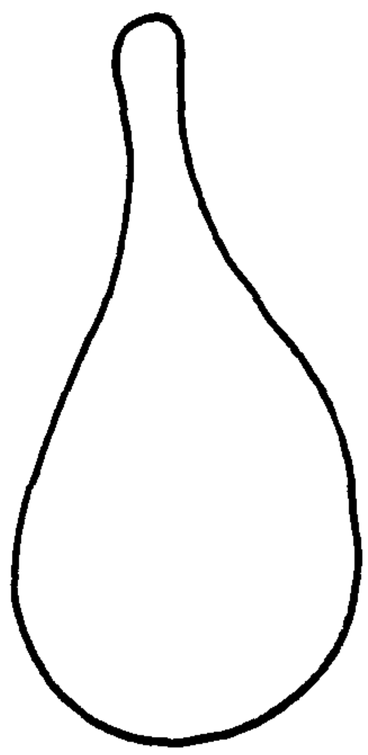
polygonal



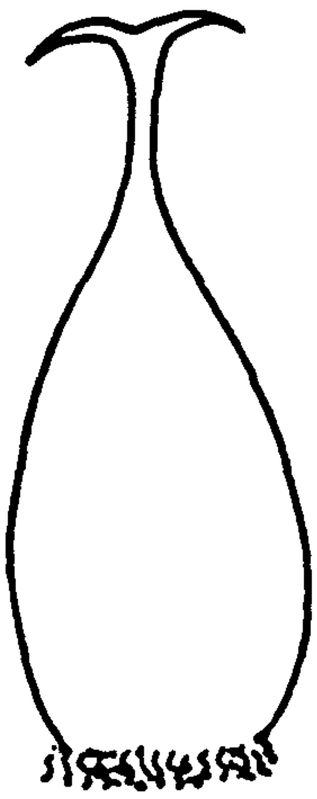
circular



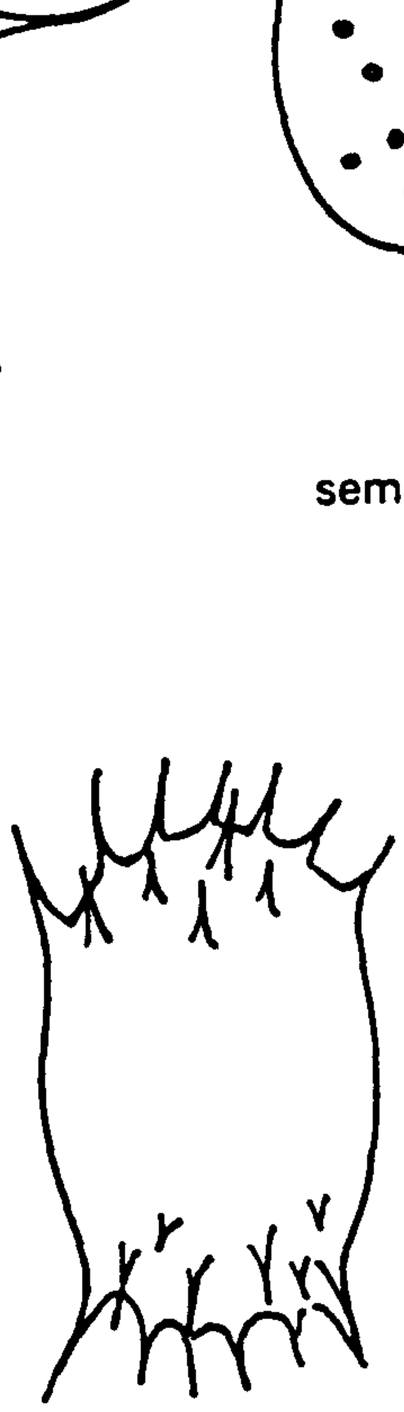
semi-circular



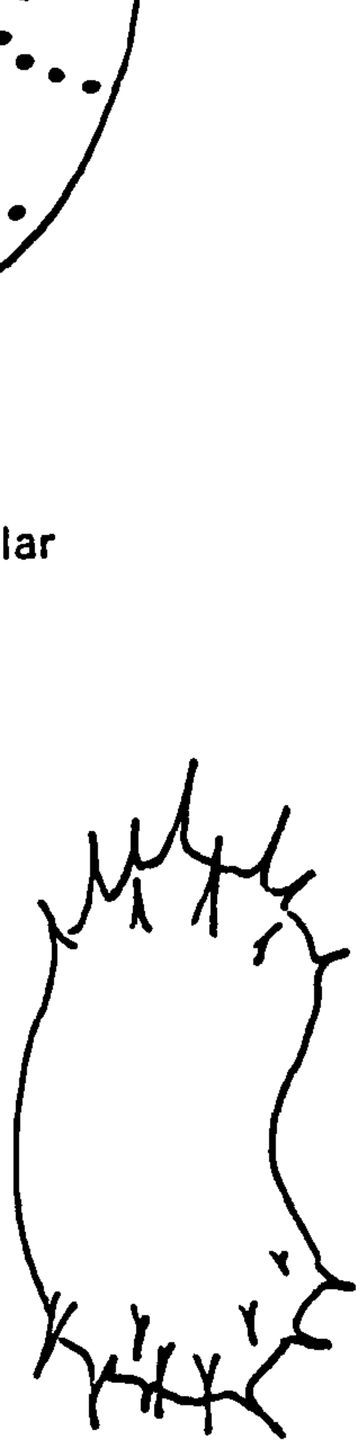
pyriform



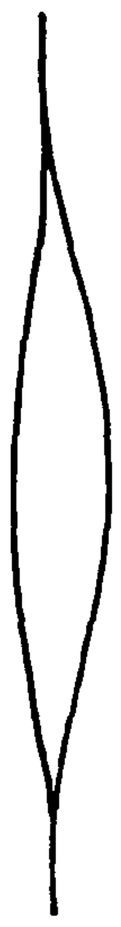
ovate heteropolar



ovate homopolar

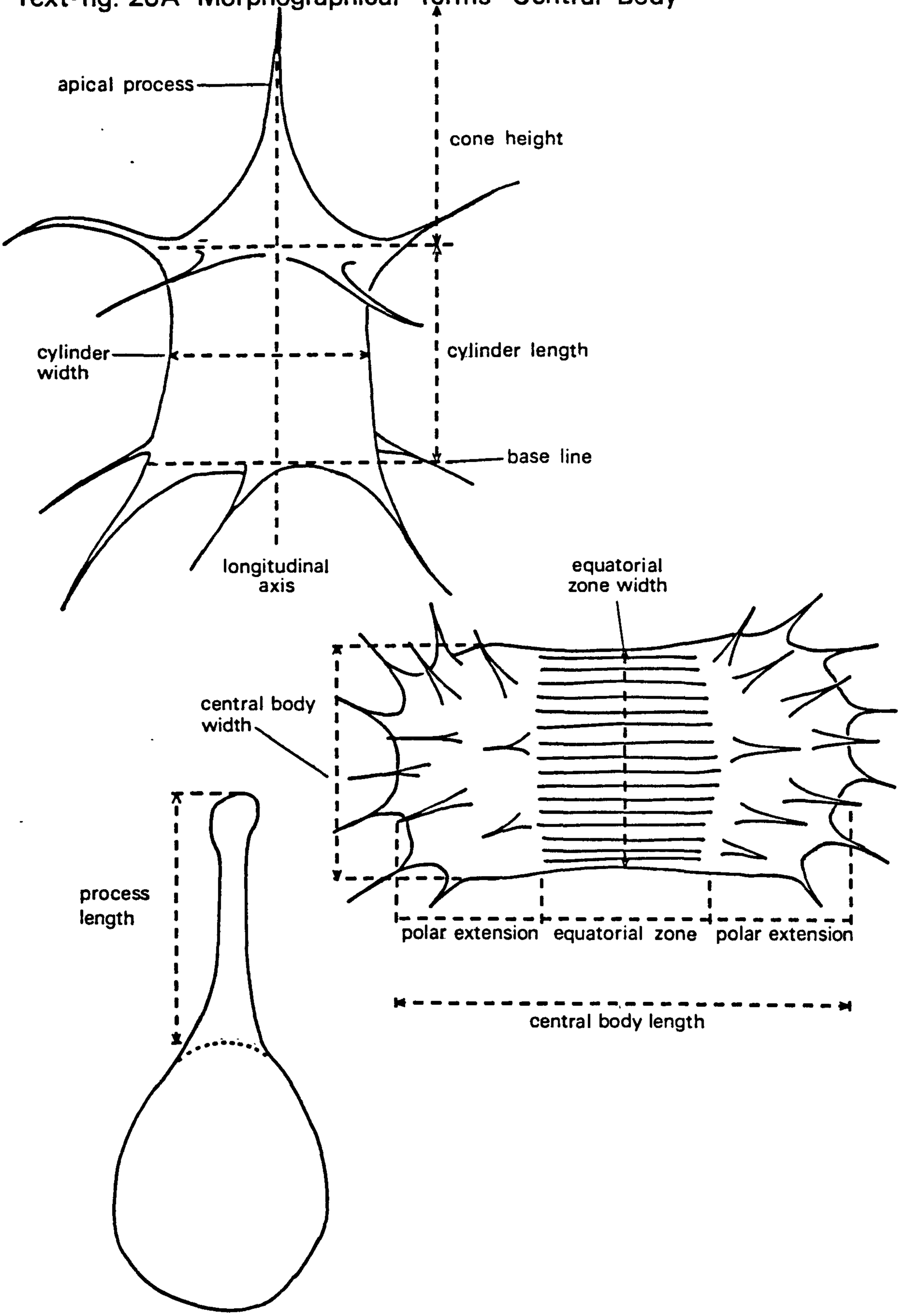


reniform

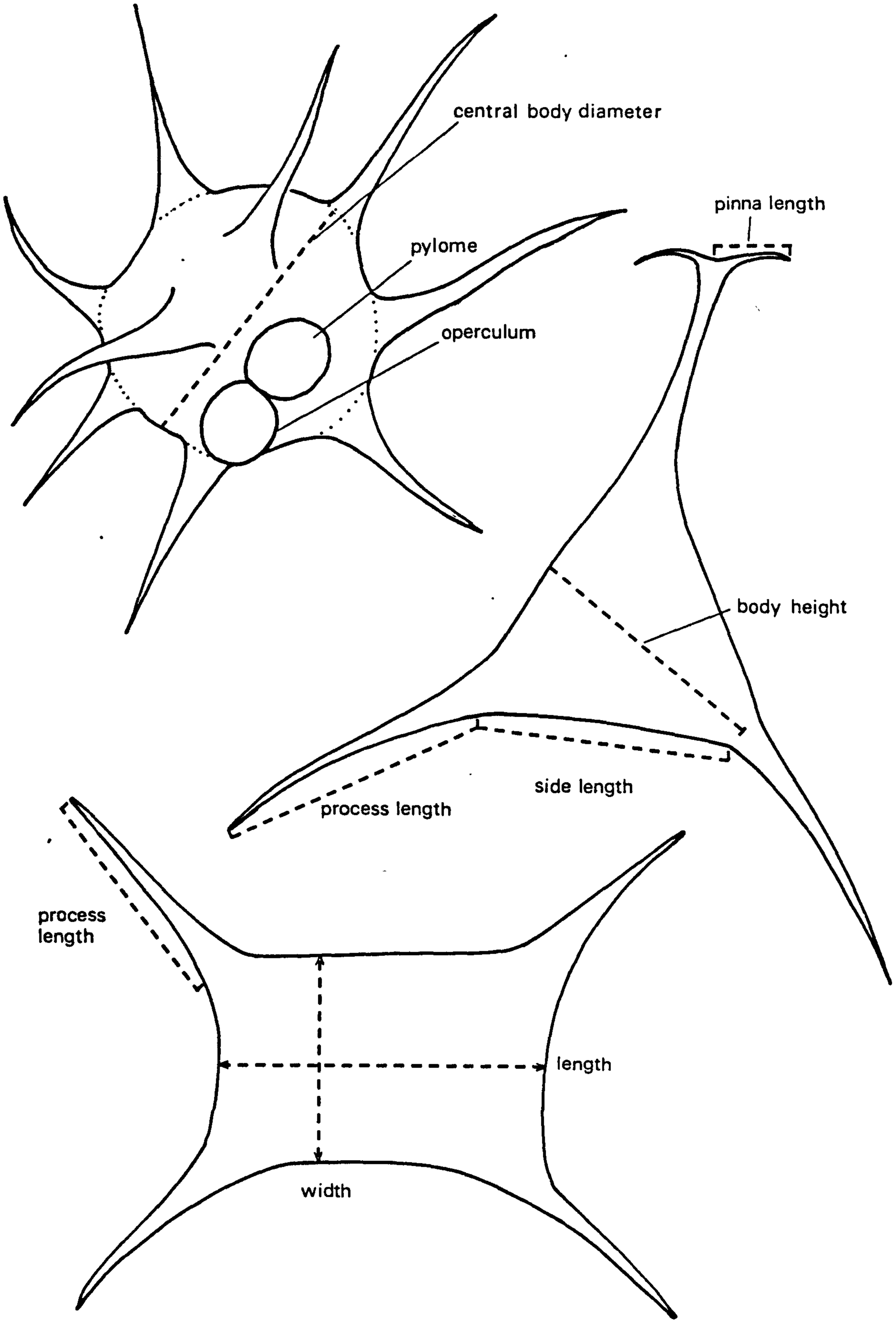


fusiform

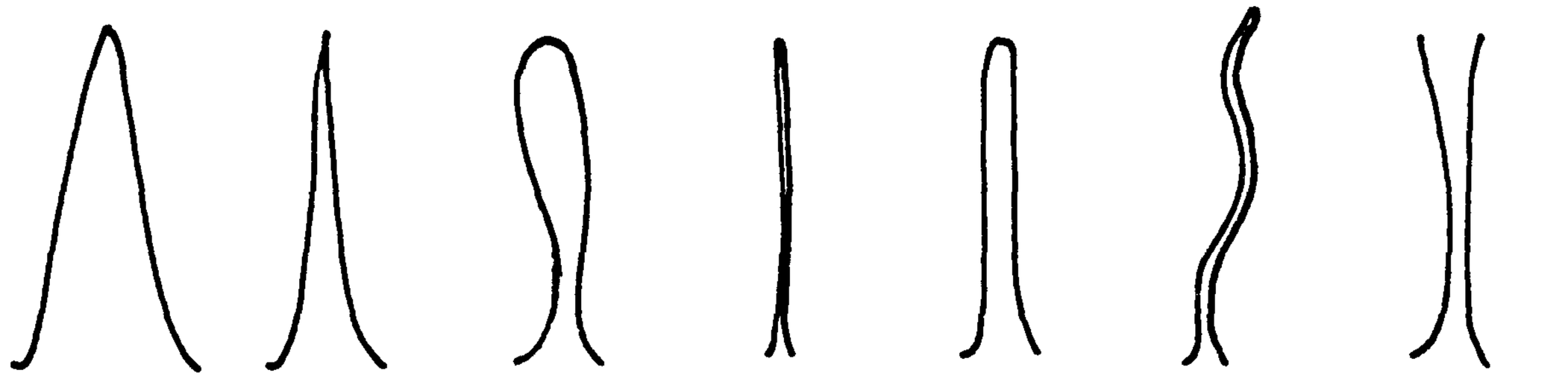
Text-fig. 26A Morphographical Terms - Central Body

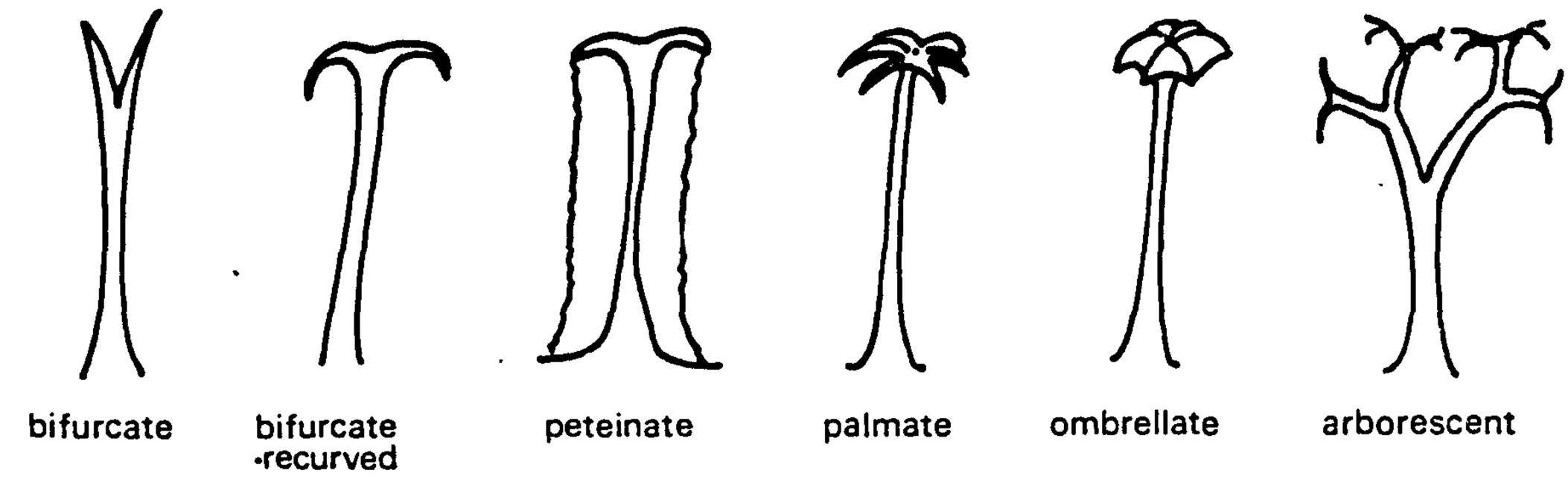


Text-fig. 26B Morphographical Terms-Central Body



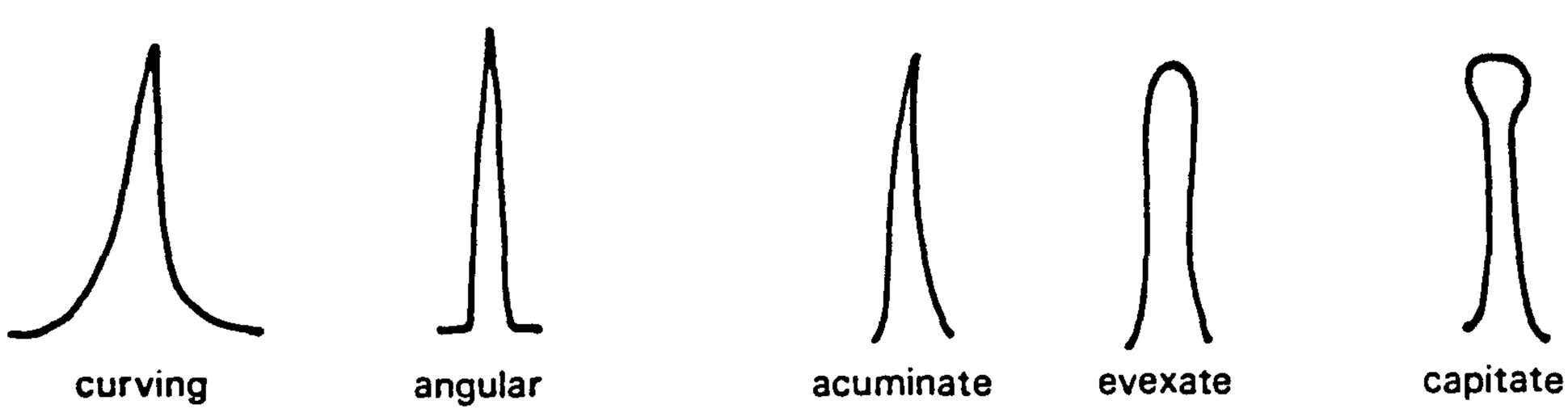
Text-fig. 27 Morphographical Terms – Processes

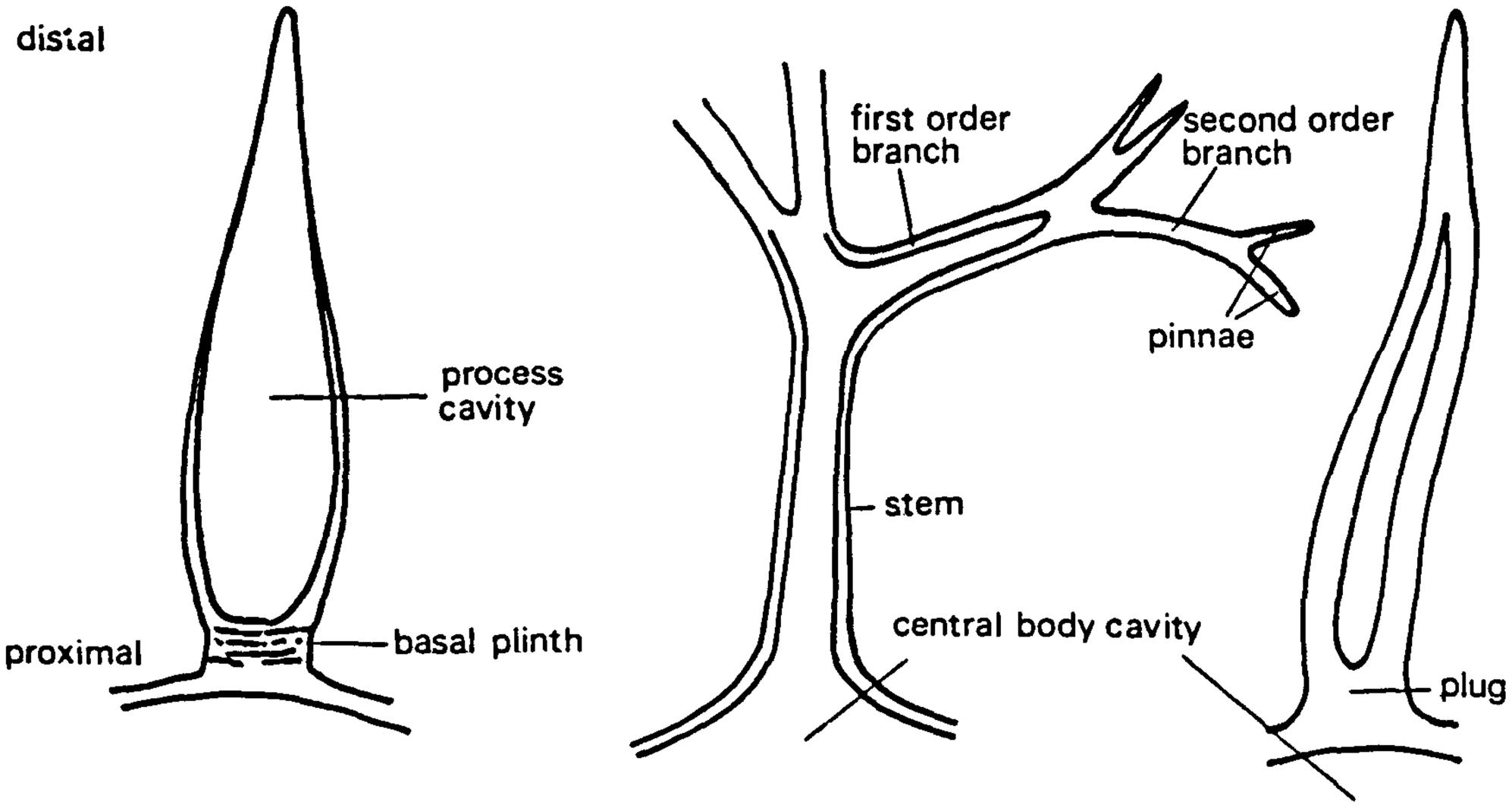




Proximal contacts

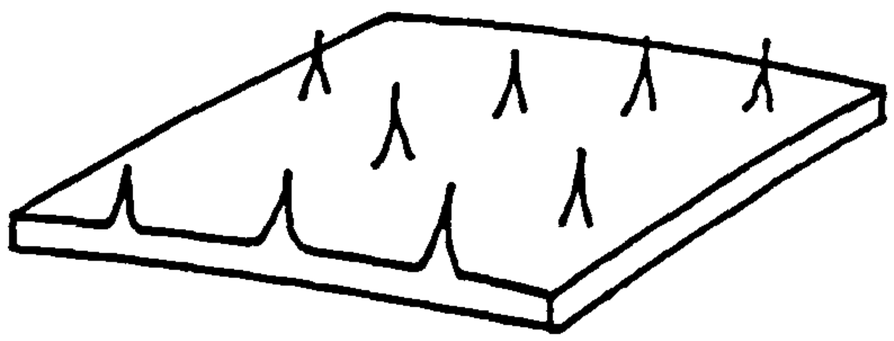
Simple terminations





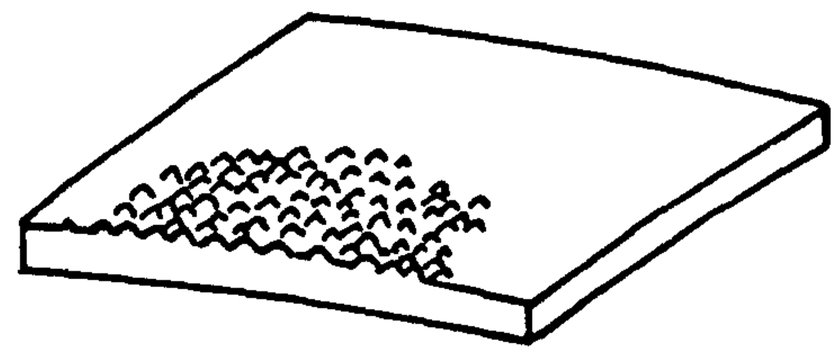
Text-fig. 28 Morphographical Terms-Ornament

a



echinate

b



granulose

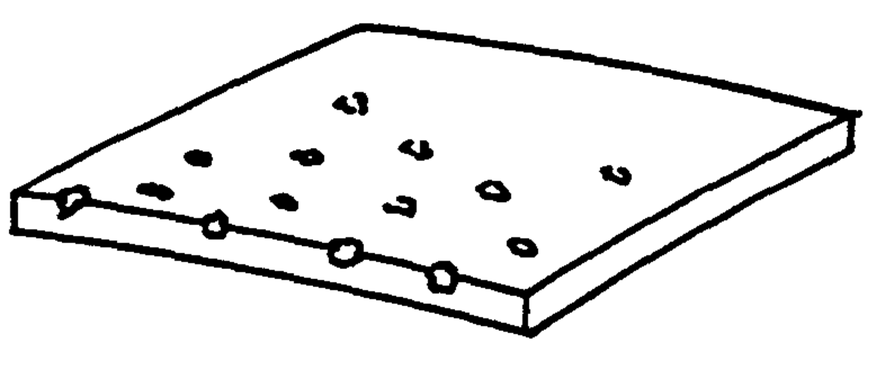
c

pitted

d

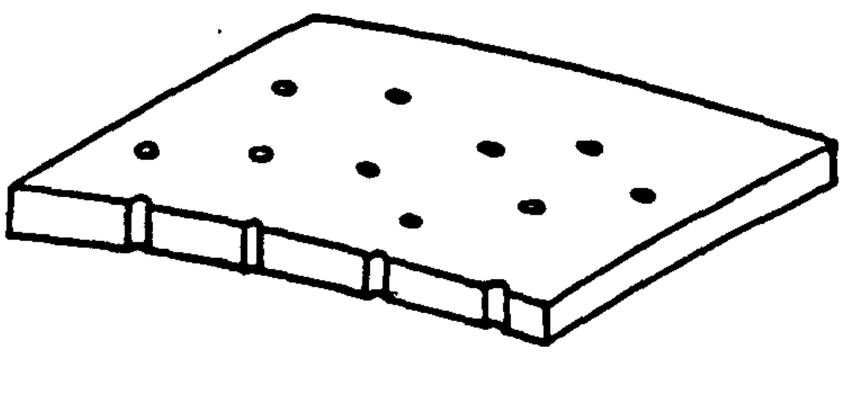
punctate

e



verrucate

f



shagrinate

CHAPTER 4 SYSTEMATICS

The genera have been arranged alphabetically within the scheme of subgroups proposed by Downie, Evitt and Sarjeant (1963). In addition the subgroup Corymorphitae, proposed by Vavrdova (1973) has been utilised for the genus Corphidium. Astropheos gen. nov., Culcitispina gen. nov., and Recavisentis gen. nov., are all placed within the subgroup Polygonomorphitae because of their basically polygonal outlines.

As there is no agreed scheme of useage for the term 'cf.', the use of the question mark, and inverted commas to qualify identifications, the way in which each has been employed in this study is outlined below.

cf. - indicates a specimen (or specimens) which, for reasons other than poor preservation, is definitely different from, but reminiscent of the species to which it is referred. It does not fall within the defined range of variability of the species. Example: Micrhystridium cf. cleae Martin.

? - doubtful attribution, usually where interpretation is difficult because of inadequate preservation. Examples: ?Acanthodiacrodium duplicatum Burmann - species doubtful. Elektoriskos? sp. A. - genus doubtful.

" " - genus or species used in a wider sense than diagnosed. It is recognised as an incorrect attribution, temporarily made due to the non-availability of a more suitable taxon. Example: "Baltisphaeridium" sp.

An index to the subgroups, genera and species referred to in this chapter is given on page 359, and the range of species (as determined in this study), and their frequency of occurrence are given in Tables 11, 12 and 13.

Incertae Sedis

Group ACRITARCHA Evitt, 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt and Sarjeant, 1963

Acritarchs having a spherical or ellipsoidal test, without an inner body and without crests. Processes isolate, simple or branching, solid or hollow, distributed arbitrarily or regularly. Without observed opening or with a simple circular pylome.

Genus BALTISPHAERA Burmann, 1970

Type Species: Baltisphaera ternata Burmann, 1970, p. 306, pl. 7, fig. 1; Aufschlusse A/19, Late Llanvirnian, G.D.R.

Original Diagnosis: The processes project from a spherical or ovate central body. They are usually long, and pass from the central body through a morphologically distinctive, basal plinth. The processes are hollow, unbranched and have a strong distal taper. The process length generally exceeds the diameter of the central body, often being a multiple of it. The process number is limited, generally being between 2 and 5, and seldom more than 8. A pylome was not observed, the central body separating into two halves through a smooth-edged opening. The long processes are usually slender, and the basal plinth extended. Processes and central body are either smooth or covered with small verrucae. (transl.)

Remarks: When deriving a name for this genus Burmann (1970) recognised certain morphological similarities with Baltisphaeridium Eisenack, 1958. Unfortunately detailed discussion of how the two genera can be distinguished is lacking.

Rauscher (1974), in an analysis of the genera Baltisphaera Burmann, 1970, Baltisphaeridium Eisenack, 1958 emend. Eisenack, 1969a, and Orthosphaeridium Eisenack, 1968a emend. Kjellström, 1971b, listed the characteristics which he considered definitive of each genus. He concluded that the genus Baltisphaera Burmann, although different from Orthosphaeridium Eisenack emend. Kjellström was indistinguishable from Baltisphaeridium Eisenack emend. Eisenack, and, therefore could not be upheld.

The generic diagnoses of Baltisphaeridium Eisenack emend. Eisenack, 1969a, Baltisphaera Burmann, 1970, and Orthosphaeridium Eisenack emend. Kjellström, 1971b, are summarised and compared in Text-fig. 29. It is clear from this comparison that three features which should be further considered if a separation of these genera is to be effected are:

a) proximal process structure

b) excystment mechanism

c) body outline

In general, only a minority of specimens show an excystment structure, and the feature is consequently an unsatisfactory one to use in the separation of these genera. Of greater importance are proximal process structure and body outline.

A rectangular outline is specified in the original and emended diagnoses of Orthosphaeridium Eisenack while in Baltisphaera Burmann the central body is described as spherical to ovate. All described species of Baltisphaera Burmann have distinctly rounded outlines, as do all specimens attributed to the genus in this study. Consequently the genera are here considered separable using the criterion of body outline,

Text-fig. 29. A comparison of the generic diagnoses of Baltisphaera Burmann, 1970, Baltisphaeridium Eisenack 1958, emend. Eisenack 1969a, and Orthosphaeridium Eisenack emend. Kjellström, 1971b.

Genus	Body outline	Process style	Process number	Process length	Ornament	Excystment
Baltisphaera	Spherical or ovate	Usually long and slender. Unbranched, hollow and tapering. Distinctive basal plinth.	2–5, rarely more than 8	Generally in excess of central body diameter	Smooth or with small verrucae	Rupture along a transverse suture
Baltisphaeridium	Spherical	Hollow, most unbranched. Process cavity not usually in communication with central body interior.	Numerous (4–20 in type species)	Not specified (usually not less than $\frac{1}{4}$ central body diameter	Not specified (smooth to granular in type species, smooth to verrucate in others)	Circular pylome (if present)
Orthosphaeridium	Rectangular (to ovate)	Hollow, simple or furcate. Process cavity not in communication with central body interior.	Not specified (4–8)	Not specified (but usually more than $\frac{1}{2}$ central body diameter)	Not specified (smooth, granular or with fine hairs)	Rupture along a transverse suture

Information in parentheses is additional to that given in the diagnoses.

although close similarity in other respects is recognised. This contradicts the view of Eisenack et al. (1976) who consider Baltisphaera Burmann to be a junior synonym of Orthosphaeridium Eisenack emend. Kjellström.

Burmann (1970) considered the presence of a basal plinth (Bassisfassung) in Baltisphaera Burmann to be of especial importance. The structure is a prominent feature in the type species, Baltisphaera ternata Burmann, 1970, and all other species attributed to the genus. It differs markedly from the proximal plug in, for example, the processes of the type species of Baltisphaeridium Eisenack, B. longispinosum (Eisenack) forma longispinosum, which in some cases, though not all, is also marked by a slight external proximal constriction.

In this study the view is held that proximal process structure provides a basis for separation of the two genera.

Several species at present attributed to the genus Baltisphaeridium Eisenack, (notably B. constrictum Kjellström, B. klabavense (Vavrdova), and B. latiradiatum (Eisenack)) appear from illustrations, to show a marked external proximal process constriction, but it is not certain from the descriptions whether the external constriction is developed into a basal plinth, morphographically similar to that in Baltisphaera Burmann, 1970.

Although there may be reason to contemplate re-allocation of the three aforementioned species from Baltisphaeridium Eisenack to Baltisphaeridium Burmann, it is considered that re-examination of type material would be necessary before a decision could be taken. Consequently the transfer of these species is not proposed in this study.

In addition to his rejection of the genus Baltisphaera Burmann 1970, Rauscher (1974) considers all species attributed to it to show such variation that they can only be regarded as divergent forms of a single species. Although occasional intermediate forms have also been encountered in the present work, most specimens can be attributed to one or other of the already described species without difficulty. Amalgamation under these circumstances seems inappropriate. It is necessary to stress, however, that much of the material examined was strongly carbonised and poorly preserved.

Because of poor preservation a number of specimens can only be attributed generically. They are nevertheless important as they indicate evolution of the genus Baltisphaera Burmann, early in the Arenigian.

Baltisphaera procera Burmann,1970

Pl. 26, fig. 3.

1970 Baltisphaera procera Burmann, p. 307, pl. 13, fig. 1.

1974 Baltisphaeridium ternatum (Burmann) Rauscher, p. 84 (pars.).

1976 Orthosphaeridium procerum (Burmann) Eisenack et al., p. 523-4.

Original Diagnosis: Central body oval in outline, clearly extended axially, with three similar long processes, which are orientated asymmetrically. The hollow, undivided, distally tapering processes, project from the central body through a rather narrow basal plinth. The axial extension of the central body is also reflected in the asymmetric process arrangement. In the extension direction of the central body is a single process - the apical process. The counterpole carries both the other two processes, whose basal separation is much reduced. Central body and processes are covered with verrucae. (transl.)

Description: (based on two specimens only) Compression has caused the body wall to fold, but the ovate outline had been maintained. The tests of both specimens are rather strongly carbonised, the central body being more opaque. The verrucate ornament, which is particularly well developed along the process stems, extends onto the central body in a somewhat reduced form. The development of a hemispherical split to the central body was not observed.

Dimensions:		
	Central body diameters:	65(70.5)76 x 49(55.5)60μ
	Length of processes:	not determined
	Basal plinth (width x height):	7-9 x 7μ
	Height of verrucae:	1μ

Remarks: The specimens differ from the holotype in being rather less elongate in outline, the maximum - minimum diameter ratio being 1.65 : 1 in the holotype, compared with 1.2 - 1.3 : 1 in the above specimens. Process length was not determinable because of breakage.

Comparison: This species may be distinguished from Baltisphaera ternata Burmann, 1970 by its ovate outline and asymmetric process arrangement.

Occurrence: Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Sample W3.

Previous Records: Aufschlusse B/26, G.D.R.; Late Llanvirnian (Burmann). (?) May-sur-Orne, France; Llanvirnian (Rauscher).

Baltisphaera ternata Burmann, 1970

Pl. 19, fig. 9; pl. 20, fig. 4; pl. 22, fig. 6; pl. 34, fig. 8.

?1965 Baltisphaeridium cf. eisenackiamum Deunff in Vavrdova, p. 352, pl. 1, fig. 1 (pars.).

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

1972 Baltisphaera ternata Burmann in Martin, p. 7, pl. 7, fig. 6.

1974 Baltisphaera ternatum (Burmann) Rauscher, p. 96, pl. 10, figs. 2-3, text-fig. 32 (pars.).

1976 Orthosphaeridium ternatum (Burmann) Eisenack et al., p. 529-30.

Original Diagnosis: Central body circular in outline with a triradiate array of long unbranched processes, which project from the central body through distinct, rather narrow, basal plinths. The processes are hollow, and distally tapering. They are normally orientated at an angle of about 120° to each other. Processes and central body may be smooth or covered with verrucae. A pylome is not present, the test separating into two halves by a smooth edged opening to the central body. (transl.)

Description: The specimens are carbonised and compressed and in some cases the body wall has developed a series of intersecting folds. More frequently, carbonisation has rendered the body wall totally opaque and all internal structural detail is consequently obscured. The basal plinth is always opaque irrespective of the extent to which carbonisation has affected the test.

With regard to size, the three process of each specimen are alike, but considerable disparity occurs between specimens. The ornament is variable, usually taking the form of blunt thorn or wart-like projections (verrucae), which are most prominent along the process stems, but also extend onto the central body. Scanning electron microscopy reveals a rugulate surface sculpture which is in addition to the verrucae. The zone of constriction at the base of each process is relatively free from surface ornament. Only occasional specimens show separation of the test into two halves.

Dimensions:	Central body diameter:	40(54.5)68μ
	Length of processes:	not possible to determine
	Maximum width of processes:	6(11.5)18μ
	Basal plinth (width x height):	7(8.5)10 x 4(6)8μ
	Height of verrucae:	0.5 - 1.5μ

Specimens measured: 7

recorded: 26

Remarks: The processes are often less opaque than the central body to which they are attached. This may indicate that the process walls are thin, relative to the central body. Similarly the constant opacity of the basal plinth may be taken as indicative of marked thickening at this point. Several specimens are deformed by the internal growth of pyrite.

Comparison: Baltisphaera procera Burmann has a more ovate central body outline and processes which are asymmetrically arranged. Other species of Baltisphaera Burmann differ in having more than three processes.

Occurrence: Menai, N. Wales, U.K.; Early Arenigian (doubtful record). Hope Shales, Shropshire, U.K.; Early Llanvirnian. Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Samples M3(?), H5, W1, SAL 2781.

Previous Records: (?) Bohdahlec Shales/Kraluv Dvur Shales, Central Bohemia; Late Caradocian - Early Ashgillian (Vavrdova). Montagne Noire (Monts de Cabrières), France; Arenigian, Llanvirnian (Martin). Aufschlusse A/M, G.D.R.; Late Llanvirnian (Burmann). (?) May-sur-Orne, France; Llanvirnian (Rauscher).

Baltisphaera div. spp.

Five specimens are considered here which because of their rarity and poor state of preservation cannot be specifically identified. They nevertheless possess features which allow generic attribution to Baltisphaera Burmann, 1970.

Two specimens resemble Baltisphaera transitoria Burmann, 1970, in having a single reduced process in addition to three or four major process. The central body (60 x 50μ) is somewhat smaller than that of the holotype. It has a slightly ovate outline and a granulose surface texture. The processes, on the other hand, carry an ornament of verrucae. Both specimens occur in a sample of Early Llanvirnian age (pl. 18, fig. 5 and pl. 19, fig. 8).

A large bodied form having at least seven processes is represented by a single poorly preserved specimen (pl. 16, fig. 2), recovered from material of Early Arenigian age. The central body of this specimen (60 x 55μ) is sub-ovate in outline. The processes are all of similar style, but vary in size. They are thin walled, much constricted proximally, and have a verrucate ornament, which also extends onto the central body. The characteristics of this specimen are undoubtedly those of the genus Baltisphaera Burmann, and its occurrence in this Early Arenigian sample is interesting.

Two fragmentary specimens of a species with a circular outline, which apparently once possessed four symmetrically arranged major processes have been recovered from a sample of Arenigian age. They may belong to the species Baltisphaera quadrinata Burmann, 1970, but their tests are so strongly carbonised, that evidence as to their specific identity is unreliable. (pl. 2, fig. 6).

Genus BALTISPHAERIDIUM Eisenack, 1958b emend. Eisenack 1969a.

Type Species: Holotype (lost): Baltisphaeridium (Ovum hispidum) longispinosum Eisenack, 1931, p. 110, pl. 5, fig. 10. Neotype: Baltisphaeridium longispinosum (Eisenack) forma longispinosum (al. filifera Eisenack, 1959), p. 194, pl. 15, fig. 1.

Emended Diagnosis: Shell round, without tabulation, with ± numerous radially extending, usually well separated processes, in general of similar type and appearing hollow; they are closed at the ends. The majority of the processes are not branched; nevertheless it is permitted for branched processes to occur in addition, on the same specimen. Only occasionally are all processes branched. The cavity of the process does not usually communicate with the central body. The processes are evenly (symetrically) distributed, even in the case of small numbers. The diameter of the body is, in general, more than 30µ (most about 40-60µ) and can be 70µ. The overall diameter can exceed 300µ. The (rare) pylomes are circular (normal pylome). (transl.)

Remarks: Prior to 1958, the genus Hystrichosphaeridium Deflandre, 1937, was distinguished from another collective genus, Micrhystridium Deflandre, 1937, on a size criterion. Forms less than 20µ were placed in Micrhystridium Deflandre, 1937, while those greater than 20µ were attributed to Hystrichosphaeridium Deflandre, 1937.

Eisenack (1958b), divided the genus Hystrichosphaeridium Deflandre, 1937, into two parts, separating forms having spherical to oval shells and closed appendages, from those having spherical to oval shells and open appendages. The former he placed in a new genus, Baltisphaeridium, while the latter he retained in an emended version of the genus Hystrichosphaeridium Deflandre, 1937. Eisenack omitted any reference to size either in his

emendation of Hystrichosphaeridium Deflandre, 1937, or in his diagnosis of Baltisphaeridium Eisenack, 1958b. Consequently, although the genus Baltisphaeridium Eisenack, 1958b, had been intended for larger forms, diagnostically, an overlap existed with Micrhystridium Deflandre, 1937.

Staplin (1961), in an attempt to resolve the problem, proposed abolition of the size limit applied to Micrhystridium Deflandre, 1937. The genus was thus made indistinguishable from Baltisphaeridium Eisenack, 1958b, and Staplin suggested that Micrhystridium Deflandre, 1937, as the senior synonym, should receive all simple spined species previous attributed to Baltisphaeridium Eisenack, 1958b. Staplin proposed a new genus, Multiplicisphaeridium Staplin, 1961, for forms having branched processes.

Baltisphaeridium Eisenack, 1958b was reinstated by Downie and Sarjeant (1963) who rejected the proposal of Staplin to abandon the 20μ size limit for Micrhystridium Deflandre, 1937. They presented statistical evidence which suggested that a natural size discontimuity between 'two foci of morphology' did occur at approximately 20μ. The diagnosis of Baltisphaeridium Eisenack, 1958b was emended by Downie and Sarjeant to include reference to a 20μ size minimum.

After examination of well preserved type material, Staplin et al. (1965), also proposed reinstatement of Baltisphaeridium Eisenack, 1958b. In a restricted diagnosis of the genus, emphasis was given to structural differences which they considered to occur between the body and process walls. The original concept of the genus was thus changed.

The restricted diagnosis of Staplin et al. (1965), was not accepted by Eisenack (1969) who stated: 'There are no distinctions in the structure of the membrane of the central body and the processes in

Baltisphaeridium spp.' (transl.)

In an emended diagnosis Eisenack referred to process variation, process intercommunication and size of the central body.

Kjellström (1971a), later found evidence to support the view of Staplin et al.(1965). In spite of his findings Kjellström preferred not to use the information 'as a basis for generic differentiation', and accepted the 1969 emended diagnosis of Baltisphaeridium by Eisenack.

Forms attributable to Baltisphaeridium Eisenack emend. Eisenack, 1969, recorded during this study are mostly in a very poor state of preservation. Only a few specimens show surface textural details, and the attribution of many specimens is in doubt. Under these circumstances it has not been possible to improve upon existing knowledge of the genus, and the 1969 emended diagnosis of Eisenack is accepted without further modification.

Baltisphaeridium constrictum Kjellström, 1971a

1971a Baltisphaeridium constrictum Kjellström, p. 22-3, pl. 1, figs. 5-6.

1973 Baltisphaeridium constrictum Kjellström in Eisenack et al., p.93-4.

Original Diagnosis: Baltisphaeridium sp. with thick, single walled, spherical, granulate vesicle. Excystment structure formed as a median split. Constricted proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Processes, about 8 in number, in length exceeding the vesicle diameter, psilate, broad above constricted proximal base area, homomorphic, simple with acuminate distal terminations.

Baltisphaeridium cf. constrictum Kjellström, 1971a

Pl. 19, fig. 1.

Description: (based on three specimens only). The central body is hollow, and although compressed, is more or less circular in outline. The wall is apparently composed of a single layer, and has a granulose or microgranulose surface texture. The processes are few in number (6-10?), relatively broad, tapering, distally acuminate, and constricted at the base, where they are also internally thickened. In length, they are usually equal to, or slightly exceed the diameter of the central body. Proximally the process stems have a microgranulate surface texture. Distally, a wart-like ornament is also present. No definite excystment structure is present.

Dimensions:		
	Central body diameter:	47(50)54μ
	Length of processes:	50-55μ
	Width of processes:	5.5μ (max)
	Width of basal constriction:	4.0μ
	Ratio of central body diameter to process length:	1.0 : 1.0 (approx.)

Remarks: The specimens are fragmentary and carbonised making identification and comparison with Baltisphaeridium constrictum Kjellström difficult. The above specimens differ most obviously from B. constrictum Kjellström in being much smaller in size (40-50% less). In addition they have micro-granulate, or only slightly granulate central bodies, and processes which may be tuberculate. These features contradict the diagnosis of B. constrictum Kjellström (central body granulate, processes psilate). A line drawing illustration of the species in Eisenack et al. (1973) does, however, show small tubercles on the processes. It is not clear whether this illustration was based on the holotype.

Comparison: Baltisphaeridium latiradiatum (Eisenack), is similar, but may be excluded from further consideration because of its broad conical processes and shagrinate central body.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian, Sample H5.

Baltisphaeridium diversum sp. nov.

Pl. 19, fig. 3; pl. 23, figs. 1, 2 (Hol.); pl. 25, figs. 1, 2.

?1969 Baltisphaeridium multipilosum (Eisenack) in Gorka, p. 28-9, pl. 2, fig. 11. (pars.)

Derivation of Name: Latin, diversus, different, diverse, referring to the variable processes.

Diagnosis: Central body with an ovate or sub-circular outline, and moderately thick wall. Processes numerous, approximately 50 in optical section, unequal in length, but mostly ranging between one tenth and one quarter of the body diameter. Processes tapering, simple or rarely dividing, with acuminate distal terminations, and angular or only slightly curving proximal contacts. Process stems decorated by thorn or hair-like lateral projections, which vary in development according to the specimen.

Holotype: Slide reference: W1 20 1 0.2 1077 329. Early Llanvirnian. Hope Shales, Whitsburn Dingle, Shropshire, U.K.

N.G.R. SJ 32890194

Dimensions: Central body diameter: 57(62)69 x 42(50.5)55µ

Length of processes: 6(10)15µ

	Width of processes proximally:	0.5 - 2.0μ
	Ratio of central body diameter to process length:	4.1 - 10.3 : 1
	Height of ornament:	< 1μ
Holotype:	Central body diameter	58.5 x 42μ
	Length of processes:	6 - 14μ
	Width of processes proximally:	1.0 - 1.5μ
	Ratio of central body diameter to process length:	4.1 - 9.8 : 1
	Height of ornament:	< 1μ

Specimens measured: 10

recorded: 25

Description: All the specimens are carbonised to some extent and their central bodies are not uniformly transparent. Three approximately concentric zones may be distinguished (an inner transparent, an intermediate opaque, and a peripheral transparent) which although not sharply defined, appear to be fairly consistent in their occurrence. The effect is apparently due to folding of the body wall. The internal structure of the process bases is not clear, but a slight thickening of the wall around the base of each shaft occurs in most cases. No excystment structure was observed.

Remarks: The specimens are generally similar in appearance to Baltisphaeridium multipilosum (Eisenack), and especially to the forms attributed to B. multipilosum (Eisenack) by Gorka (1969). It is clear that Gorka (1969) and other workers (notably Eisenack) consider B. multipilosum (Eisenack) to be a variable species with regard to process length, process number and body size. As far as can be ascertained from previous descriptions

however, B. multipilosum (Eisenack) seems always to have been regarded as having simple processes without decoration (see Eisenack, 1931, 1959; Kjellström, 1971a). This is certainly true of the holotype. The specimens described here are therefore referred to a new species.

It is interesting to note that Gorka (1969) remarks in discussion that B. multipilosum (Eisenack) differs from B. multipilosum s. sp. validum Sannemann, by having processes which are 'plus greles' (pitted?). Thus, it may be that Gorka (1969) indirectly indicates some form of process decoration for the specimens she encountered. The illustration of a specimen attributed to B. multipilosum (Eisenack) in Gorka (1969) (pl. 2, fig. 11) appears to show this, and it is therefore tentatively reattributed to B. diversum sp. nov.

Comparison: Baltisphaeridium diversum sp. nov. differs from B. multipilosum (Eisenack) by having ornamented processes.

Occurrence: Hope Shales and Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Samples H5, W1, W3.

Previous Records: (?) Sub-surface material, Poborowisko 1, 'Couches de Bialowiez', Poland. Late Arenigian (Gorka).

?Baltisphaeridium filosum Kjellström, 1971a

Pl. 18, fig. 7.

1971a Baltisphaeridium filosum Kjellström, p. 24, pl. 1, fig. 9.

1973 Baltisphaeridium filosum Kjellström in Eisenack et al., p. 113-4.

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.

Description: (based on three poorly preserved specimens). The central body is hollow and somewhat ovate in outline. The processes are numerous (approximately 40 in optical section), tapering, slender, distally acuminate, and have an angular or slightly curving contact with the central body. In length they are approximately equal to one third of the central body diameter. Both the processes and the body wall appear to have a slightly granulose texture. In addition, the processes occasionally possess a few fine lateral, hair-like projections. No definite encystment structure is present.

Dimensions:		
	Central body diameter:	54 x 47μ
	Length of processes:	16μ
	Width of processes proximally:	1.0 - 1.5μ
	Ratio of central body diameter to process length:	3.0 - 3.4 : 1

Specimens measured: 1

Remarks: A detailed comparison with Baltisphaeridium filosum Kjellström is impracticable because of the poor condition of the specimens. Similarities include an approximately equivalent body size (actually 20% smaller), similar process form, and process number. The specimens differ by occasional possession of fine process decoration. Surface textures cannot be satisfactorily compared due to strong carbonisation.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample H5.

Previous Record: Subsurface material, Grotlingbo No. 1, Gotland, Sweden; Middle Ordovician (Kjellström).

Baltisphaeridium granosum Kjellström, 1971a

Pl. 24, fig. 1; pl. 25, fig. 5.

1971a Baltisphaeridium granosum Kjellström, p. 25–26, pl. 1, fig. 11.

1973 Baltisphaeridium granosum Kjellström, in Eisenack et al., p. 121–2.

Original Diagnosis: Baltisphaeridium sp. with thick, single walled, spherical, granulate vesicle. Large excystment structure formed as a partial rupture. Curved proximal process contact with the vesicle. Separation of the interior of the process from the vesicle cavity. Processes, about 25 in number, in length about one third of the vesicle diameter, echinate, conical, homomorphic, simple with acuminate distal terminations.

Description: (based on two specimens only) Both specimens are poorly preserved, but they appear to correspond closely with the above diagnosis. The process bases are always thickened internally, but never constricted. The proximal contact is angular or slightly curved. The total process number exceeds 30 in both specimens. The body wall has a moderately granulose surface texture and is prominently ruptured.

Dimensions:		
	Central body diameter:	55(57)69μ
	Length of processes:	25+μ
	Width of processes proximally:	1–3μ

Remarks: The specimens differ from Kjellström's examples by being approximately 25% smaller in size and in possessing more processes.

Kjellström (1971a) proposes 25 as an approximate process number for this species. It is not clear, however, whether this number is to be taken as the total or the number seen in a particular plane of focus. The illustration of the holotype (Kjellström, 1971a, pl. 1, fig. 11) suggests more than 25, while the line drawing in Eisenack et al. (1973) has more than 40.

Occurrence: Hope Shales and Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Samples W1, W3.

Previous Record: Subsurface material, Grotlingbo 1, Gotland, Sweden; Lower Ordovician (Kjellström).

?Baltisphaeridium hirsutoides (Eisenack, 1951) Eisenack, 1958a

Pl. 4, fig. 2; pl. 5, fig. 5.

1931 Ovum hispidum cf. hirsutum Ehrenberg in Eisenack, p. 111, pl. 5, fig. 19.

1938 Hystrichosphaeridium cf. hirsutum (Ehrenberg) Eisenack, p. 13, pl. 1, fig. 11.

1951 Hystrichosphaeridium hirsutoides Eisenack, p. 189-90, pl. 3, fig. 8.

1955 Hystrichosphaeridium cf. hirsutoides Eisenack in Sannemann, p. 328-9, pl. 3, fig. 9; pl. 5, figs. 3-4; text-fig. 11.

1958a Baltisphaeridium hirsutoides (Eisenack), p. 400.

1958 Hystrichosphaeridium hirsutoides Eisenack in Downie, p. 335, pl. 16, fig. 11 (pars.)

1959 Baltisphaeridium hirsutoides (Eisenack) in Eisenack, p. 196

1962c Baltisphaeridium hirsutoides (Eisenack) in Eisenack, p. 359, pl. 44, figs. 4, 7 (pars.).

1963 Baltisphaeridium hirsutoides (Eisenack) in Downie and Sarjeant, p. 90.

1964 Baltisphaeridium hirsutoides Eisenack in Downie and Sarjeant, p. 91.

?1965a Baltisphaeridium cf. hirsutoides (Eisenack) in Eisenack, p. 259, pl. 22, fig. 11.

1965b Baltisphaeridium hirsutoides (Eisenack) in Eisenack, p. 135.

1967 Baltisphaeridium hirsutoides (Eisenack) in Schultz, p. 177, pl. 1, fig. 3.

non 1967 Baltisphaeridium hirsutoides (Eisenack) in Combaz, pl. 3, figs. 53-4.

1968b Baltisphaeridium hirsutoides (Eisenack) in Eisenack, pl. 2, fig. 4.

1969 Baltisphaeridium hirsutoides (Eisenack) in Gorka, p. 29-30, pl. 2, figs. 1-2, 5, 10.

1969 Baltisphaeridium hirsutoides (Eisenack) in Lister et al., p. 98.

1969 Baltisphaeridium hirsutoides (Eisenack) in Lister et al., p. 602.

1971a Baltisphaeridium hirsutoides (Eisenack) in Kjellström, p. 26-7, pl. 1, fig. 12.

1973 Baltisphaeridium hirsutoides (Eisenack) in Eisenack et al., p. 125-7.

1974 Baltisphaeridium hirsutoides (Eisenack) in Rauscher, p. 72, pl. 2, figs. 8-9.

Original Diagnosis: Central body spherical. Processes numerous, rather like H. longispinosum, yet shorter than in that species, approximately the length of the radius or less, mostly slender and bristle-like, passing to a point. In comparison with H. multipilosum the processes are greatly limited in number, and also usually longer. Furcate processes so far not observed. (transl.)

Description: The central body is hollow, with a smooth wall and distinctly rounded outline. The processes are slender and tapering, with acuminate distal terminations, and angular or sharply curving proximal contacts. They number approximately 15 in optical section, are unornamented and attain a length of one third to half of the central body diamter. No definite excystment structure is present.

Dimensions:		
	Central body diameter:	32(35)40μ
	Length of processes:	11(13)16μ
	Width of processes proximally:	1.5 - 2.0μ
	Ratio of central body diameter to process length:	2.5 - 3.5 : 1
	Number of processes in optical section:	14 approximately.
Specimens measured:		8
recorded:		6

Remarks: The specimens are strongly carbonised. Consequently, the internal structure of the processes and that of the process-central body proximal contact cannot be determined. Doubt also exists as to structure and thickness of the body wall. The specimens are therefore only tentatively attributed to this species.

There are some instances of central body rupture, but all cases are considered to have been due to compression during preservation, and not to excystment.

Comparison: Baltisphaeridium hirsutoides (Eisenack), differs from B. filosum Kjellström, in having fewer processes which are also more robust. In Baltisphaeridium sp. C. the processes are shorter and the central body smaller,

while in Baltisphaeridium sp. D. the central body is larger and distinctly ovate. Baltisphaeridium sp. E. has more numerous processes which are also shorter relative to the central body diameter.

Occurrence: Caernarvon, N. Wales, U.K.; Arenigian. Samples C4, C5.

Selected Previous Records: Baltic glacial erratics; Ordovician (Eisenack, 1931, 1938, 1959, 1962c, 1965b, 1968b). Estonia; Lower Ordovician (Eisenack, 1951). Subsurface material, Poland, Late Arenigian (Gorka, 1969). Subsurface material, Gotland, Middle Ordovician (Kjellström, 1971a).

Baltisphaeridium longispinosum (Eisenack, 1931)

Eisenack, 1959, forma longispinosum

Pl. 18, fig. 4; pl. 24, fig. 3.

1931 Ovum hispidum longispinosum Eisenack, p. 110, pl. 5, figs. 6–12. (pars.)

1938 Hystrichosphaeridium longispinosum Eisenack, p. 12, pl. 1, figs. 4, 6–7. (pars.)

1939 Hystrichosphaeridium longispinosum Eisenack in Eisenack, p. 146; text-figs. 9–11.

1940 Hystrichosphaeridium longispinosum Eisenack in Lewis, p. 33–4, pl. 3, figs. 3–7.

1951 Hystrichosphaeridium longispinosum Eisenack in Eisenack, p. 188, pl. 1, fig. 5.

?1953 Hystrichosphaeridium longispinosum Eisenack in Fisher, p. 16–7, figs. 12(?), 19.

non 1958 Hystrichosphaeridium longispinosum (Eisenack) in Downie, p. 116, figs. 5–7.

1959 Baltisphaeridium longispinosum forma filifera Eisenack, p. 195, pl. 15, fig. 1. (pars.)

1959 Baltisphaeridium longispinosum (Eisenack) in Timofeev, p. 51, pl. 4, fig. 1.

1959 Baltisphaeridium longispinosum (Eisenack) in Downie, p. 58, pl. 10, figs. 1-2, 6.

1962b Baltisphaeridium longispinosum (Eisenack) in Eisenack, p. 75.

1962c Baltisphaeridium longispinosum forma filifera Eisenack in Eisenack, p. 359.

non 1962 Baltisphaeridium longispinosum (Eisenack) in Timofeev, pl. 10, figs. 1, 1a, 1b.

1963 Baltisphaeridium longispinosum (Eisenack) forma filifera Eisenack in Downie and Sarjeant, p. 90.

1963a Baltisphaeridium longispinosum (Eisenack) in Eisenack, p. 208, pl. 19, fig. 1.

1964 Baltisphaeridium longispinosum (Eisenack) forma filifera Eisenack in Downie and Sarjeant, p. 92.

non 1964 Baltisphaeridium longispinosum (Eisenack) in Cramer, p. 297, text-fig. 19.7.

1965b Baltisphaeridium longispinosum (Eisenack) in Eisenack, p. 134, pl. 13, figs. 1, 2(?).

1965 Baltisphaeridium longispinosum (Eisenack) forma longispinosum in Staplin et al., p. 190, pl. 20, figs. 11, 15; text-fig. 11.

1965 Baltisphaeridium longispinosum (Eisenack) in Vavrdova, p. 351.

?1966 Baltisphaeridium cf. longispinosum (Eisenack) in Deflandre and Ters, p. 238, pl. 1, fig. 7.

?1966 Baltisphaeridium longispinosum (Eisenack) in Timofeev, pl. 42, fig. 6. (pars.)

1968b Baltisphaeridium longispinosum (Eisenack) forma filifera Eisenack in Eisenack, p. 6, pl. 1, fig. 8.

1968a Baltisphaeridium longispinosum (Eisenack) in Eisenack, p. 90, pl. 25, fig. 5.

?1969 Baltisphaeridium longispinosum (Eisenack) in Corré and Deunff, p. 46, fig. 13.

?1969a Baltisphaeridium longispinosum (Eisenack) in Eisenack, p. 250.

1969 Baltisphaeridium longispinosum (Eisenack) subsp. longispinosum Staplin et al. in Gorka, p. 34-5, pl. 6, fig. 2; pl. 7, figs. 1-5; text-fig. 9.

1971a Baltisphaeridium longispinosum (Eisenack) in Kjellström, p. 29-31, pl. 2, fig. 2.

1974 Baltisphaeridium longispinosum (Eisenack) in Rauscher, p. 96, pl. 5, fig. 4.

1974 Baltisphaeridium longispinosum (Eisenack) in Eisenack, p. 271, figs. 1-6.

non 1974 ?Baltisphaeridium cf. longispinosum (Eisenack) in Eisenack, p. 280, fig. 32.

?1974 Baltisphaeridium aff. longispinosum (Eisenack) in Eisenack, p. 280, fig. 34.

?1974 Baltisphaeridium longispinosum (Eisenack) Eisenack in Stockmans and Williere, p. 14.

Emended Diagnosis: (Eisenack, 1959) Shell spherical, with 4 and up to about 20 slender, terminally pointed, mostly undivided processes, also occasionally singly furcate or ramifying, their length, in general, exceeding the diameter. Pylomes rare. (transl.)

forma longispinosum (al. filifera) The shell is moderately proportioned, thin walled, consequently usually light yellow, and not always completely spherical, but ± polygonal. The processes are very long, and, even from the base, are slender in form. Only rarely is a process divided. (transl.)

Description: Although poorly preserved the specimens are in overall agreement with the above diagnosis. The central body is hollow, compressed, and slightly ovate in outline. The processes are hollow, slender, gradually tapering, variable in length though usually long and distally acuminate. A slight constriction may occur just above the process base, although it is more usual for the taper to be continuous. The process bases are internally thickened and the process interiors consequently do not communicate with the cavity of the central body. The proximal contact is angular or only slightly curved. Both body and processes have a rather granulose surface texture. No definite excystment structure is present.

Dimensions:	Central body diameter:	47(55)69 x 40(45)50µ
	Length of processes:	53µ (?)
	Width of processes proximally:	2.5 - 4.5µ
	Ratio of central body diameter to process length:	not known

Specimens measured: 6

recorded: 12(?)

Remarks: The reference in the description to variable process length is a deduction from their variable widths. Only one process was sufficiently well preserved to permit determination of its original length. The processes of some specimens apparently divide distally, but close examination shows this to be a preservational effect. Although difficult to assess due to carbonisation, the wall appears thin or of only moderate thickness.

In designating a neotype for the species longispinosum, Eisenack (1959), cited the same specimen as the type for the forma filifera. Staplin et al.(1965), noting this error, recommended that the name forma filifera should be changed to forma longispinosum in accordance with Articles 24 and 26 of the I.C.B.N.

Comparison: Baltisphaeridium longispinosum (Eisenack) forma longispinosum, differs from B. pachyacanthum Eisenack, 1965, by possession of a relatively thin body wall, and long slender processes.

Occurrence: Hope Shales and Stepeley Shales, Shropshire, U.K., Early Llanvirnian. Samples H5, W1.

Selected Previous Records: Baltic erratics; Ordovician. (Eisenack, 1931, 1938, 1951). Phosphate deposits, N. Wales; Late Caradocian (Lewis, 1940). Chasmops Limestone, Böda, Oland; Early Caradocian and Late Llanvirnian (Staplin et al., 1965). Subsurface material, Podborowisko 1, Zbrza 1, and Goldap 1, Poland; Late Arenigian and Caradocian (Gorka, 1969). Subsurface material Grotlingbo 1, Gotland Sweden; Middle and Upper Ordovician (Kjellström, 1971a).

Baltisphaeridium? sp. A

Pl. 5, fig. 1; Pl. 32, fig. 7.

Description: The central body is hollow, and more or less circular in outline. The body wall is either relatively thin or of only moderate thickness, smooth or microgranulose at the surface, and appears to be composed of a single layer. The processes are particularly variable in their dimensions, but rarely exceed half the central body diameter in length. They are numerous (approximately 50 in optical section), simple

or furcate, usually slender and tapering, distally acuminate, and have a slightly curving contact with the central body. In some cases the process stems are decorated by minute lateral hairs. In two specimens a definite circular pylome is present (approximately 12μ diameter).

Dimensions: Central body diameter: 37(42)46μ

Length of processes: 6(12)16μ

Width of processes proximally: 1–4μ

Ratio of central body diameter to process length: 3.5 : 1 (average)

Specimens measured: 3

recorded: 4

Remarks: The specimens are carbonised and have suffered damage to the walls. Details of process construction are therefore difficult to assess, and attribution to the genus Baltisphaeridium Eisenack is tentative. The features which serve to characterise this species are its process variability, high process number and possibly also, the occurrence of a pylome.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian. Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Samples C4, SAL 2778.

Comparison: The numerous variable length processes and the large circular opening distinguish Baltisphaeridium? sp. A from all previously described species.

Baltisphaeridium sp. B

Pl. 22, fig. 5.

Description: (based on 2 specimens) The central body is hollow and has a circular outline. The wall is moderately thick and appears to be

composed of a single layer. The processes (approximately 12) are hollow, simple, tapering, distally acuminate, and have a curving proximal contact with the central body. Just above the contact occurs a slight constriction accompanied by a marked internal thickening, which isolates the hollow process interior from the body cavity. Although alike in form, the processes vary in size. The smaller ones attain a length approximately equivalent to half the diameter of the central body, whilst the larger ones may exceed the central body diameter. Both body and processes carry an evenly distributed papillate ornament. No definite excystment structure occurs.

Dimensions:	Central body diameter:	57–75μ
	Length of processes:	35–46+μ
	Width of processes:	3–7μ
	Width of proximal construction:	2.5–6μ
	Ratio of central body diameter to process length:	1.0 – 2.0 : 1 (approx.)

Remarks: Neither specimen is intact, both are carbonised, and one has been partly deformed by the internal growth of pyrite. The main characteristics of this species are its relatively large body size, variable process length, moderate process number and papillate ornament.

Comparison: Baltisphaeridium sp. B is distinguished from B. longispinosum (Eisenack) forma longispinosum, and B. pachyacanthum (Eisenack), by possession of papillate ornament. B. verrucatum Kjellström, B. pustulatum Kjellström and B. calicispinae Górka differ by lacking proximally constricted processes. B. klabavense (Vavrdova) has more pronounced ornament and processes which are all of similar length.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Baltisphaeridium? sp. C

Pl. 2, fig. 4; pl. 5, fig. 7; pl. 13, fig. 6; pl. 15, fig. 12.

Description: The central body is hollow and has a circular or slightly ovate outline. The processes number approximately 30 in optical section, and attain a length one quarter to one half of the central body diameter. Their tapering form is variable, and both robust and slender styles may be present on the same specimen. Proximal contact with the central body is either slightly curving or angular, while distal terminations are acuminate. The wall surface of both body and processes appears smooth. Internal structure is obscured by strong carbonisation. No definite excystment structure is present.

Dimensions:		
	Central body diameter:	24(30)33μ
	Length of processes:	9-11μ approx.
	Width of process proximally:	1-3μ
	Ratio of central body diameter to process length:	3 : 1
	Number of processes in optical section:	30 approx.

Specimens measured: 12

recorded: 17

Remarks: The specimens cannot be positively assigned to the genus Baltisphaeridium Eisenack because of their uncertain internal structure.

Comparison: The specimens resemble Archaeohystrichosphaeridium acanthum Rasul (1971, MS.), but, the average size of the specimens exceeds the maximum quoted by Rasul for that species.

Occurrence: Bangor, Menai and Caernarvon, N. Wales, U.K.: Early and Late Arenigian. Samples M2(?), M3, C4, C6(?).

Baltisphaeridium? sp. D

Pl. 4, fig. 4.

Description: (based on two specimens only) The central body has an ovate outline. The processes attain a length equivalent to one third the maximum central body diameter and have an angular or slightly curving proximal contact with the central body. The processes have a simple tapering form with slender or robust stems. Distal terminations are acuminate. The surfaces of both body and processes are irregularly marked by small pits, but are otherwise smooth. Strong carbonisation prevents the determination of internal structural detail. No definite excystment structure is present.

Dimensions:		
	Central body diameter:	44(45)47 x 35(37)38μ
	Length of processes:	15μ approx.
	Width of processes proximally:	1.5 - 3.0μ
	Ratio of maximum central body diameter to process length:	3 : 1
	Number of processes in optical outline:	15 - 25

Remarks: The pitting of the test surface is presumed to be a preservational feature. The test is compressed. Generic attribution is tentative.

Comparison: Baltisphaeridium sp. D differs from Baltisphaeridium hirsutoides (Eisenack) in having an ovate outline and a larger central body.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian, Sample C5.

Baltisphaeridium? sp. E

Pl. 13, fig. 1; pl. 15, fig. 11.

Description: The central body is hollow with an ovate or sub-circular outline. The processes are numerous (approximately 40-50 in optical section), and have a simple tapering form with acuminate distal terminations. Proximal contact with the central body is most often angular, but in some instances is curved. In length, the processes are approximately equivalent to one quarter of the central body diameter. The processes are smooth except for the occasional development of small pits along their stems. The body wall also appears to be without definite ornament. Strong carbonisation has obscured all internal details. No excystment structure is present.

Dimensions:		
	Central body diameter:	31(34)44 x 28(30)36μ
	Length of processes:	6(7.5)8μ
	Width of processes proximally:	1-2μ
	Ratio of central body diameter to process length:	4.0 - 4.5 : 1

Specimens measured: 5

recorded: 7

Remarks: A few of the processes are sinuous in form but it is not clear whether this is a typical feature of the species. Splits and other irregular openings occur in some specimens, but these together with the occasional surface pitting of the processes, are considered preservational features. Attribution to the genus Baltisphaeridium Eisenack is not certain.

Comparison: Baltisphaeridium? sp. E differs from Baltisphaeridium sp. C in having more numerous processes, which are also shorter relative to the central body diameter.

Occurrence: Menai, N. Wales, U.K.; Early Arenigian, Samples M2, M3.

Baltisphaeridium div. spp.

Pl. 12, fig. 1; pl. 15, figs. 2, 4;

pl. 16, fig. 1; pl. 18, fig. 6; pl. 19, fig. 10; pl. 25, fig. 3.

The specimens described here are forms which, because of their poor state of preservation and rarity, cannot be attributed to known species. They can nevertheless be assigned to the genus Baltisphaeridium Eisenack with some degree of certainty.

A single specimen (pl. 25, fig. 3) recovered from sample W3 (Early Llanvirnian) has a large ovate central body (72 x 47μ) and numerous relatively short processes (15μ?). The processes are constricted and internally thickened at their bases, but have a curving contact with the central body. Additionally they are hollow, tapering, distally acuminate, and number approximately 30–40 in optical section. The body wall is moderately thick and strongly granulose at the surface. The granulation extends onto the processes where it takes the form of low verrucae about 0.5μ in height. The decoration and process form are reminiscent of Baltisphaeridium klabavense (Vavrdova) Cramer, 1970. In B. klabavense (Vavrdova), however, the processes are longer and less numerous.

Two specimens obtained from sample H5 are also of Early Llanvirnian age. One (pl. 18, fig. 6) has a strongly carbonised central body and a a subcircular outline (51 x 47μ). The processes number about 32 in optical section and are relatively short (14μ) simple, tapering and distally acuminate. They have a slightly curving or angular contact with the central body and are thickened internally at their bases. A few minute

verrucae decorate the processes which otherwise have a microgranulose texture. The surface texture of the central body is impossible to determine because of its opacity. No definite excystment structure is present.

The second, more fragmentary specimen from sample H5 (pl. 19, fig. 10) also has a carbonised central body of subcircular outline (50 x 45μ). The processes however, are not so numerous (perhaps 20 in optical section), are simple, tapering, acuminate (?) and attain a length exceeding half the central body diameter (32+μ). Proximally they are internally thickened and slightly constricted. The processes carry a verrucate ornament which may extend onto the central body. No definite excystment structure is present. Baltisphaeridium pauciverrucosum Kjellström, 1971a, is similar but considerably larger in size.

Four specimens occur in a sample of Early Arenigian age (M3). Two of them, both in a very fragmentary condition, carbonised and deformed by pyrite, have central body diameters of approximately 35μ. Their hollow processes taper to acuminate tips and are constricted and internally thickened at the base. They have a verrucate ornament and a length equivalent to at least half the central body diameter (pl. 15, fig. 2)..

A third specimen from sample M3 (pl. 15, fig. 4) has a central body in which the wall is thin and ruptured. The body outline is therefore somewhat irregular, though approximately ovate (60 x 45μ). The processes are numerous, hollow, tapering, distally acuminate and have a curving contact with the central body. Proximally they are internally thickened and sometimes slightly constricted. In length they do not appear to exceed the central body diameter. A semi-circular structure occurs, which may be the remains of a pylome. Both body and

processes are marked by strong verrucate ornament. A carbonised fragment from sample B2 (pl. 12, fig. 1) may also belong to this species.

Also recovered from sample M3 is a thin walled, hollow bodied specimen (pl. 16, fig. 1) with relatively short processes, and distinct ovate outline (50 x 39μ). Exact process length is difficult to determine, but most probably ranges between one quarter and one half of the central body diameter. They are numerous, apparently hollow, tapering, slender, distally acuminate (?), and have a curving proximal contact. A noticeable internal thickening occurs at each process base, but is only rarely accompanied by an external constriction. The body wall has a faintly granulose surface texture, while the processes are either microgranulose or psilate. No definite excystment structure is present. Baltisphaeridium brevifilicum Kjellström, 1971a, is similar, but has a large excystment opening and greater vesicle dimensions.

Two specimens from sample R1 (Late Llanvirnian) may also be attributable to Baltisphaeridium Eisenack (pl. 28, figs. 1-2). As a temporary measure six other specimens from this sample are referred to the genus, as a more suitable one is not yet available.

Genus ELEKTORISKOS Loeblich, 1970

Type Species: Elektoriskos aurora Loeblich, 1970, p. 717-8, figs. 12A-D. Middle Silurian, Maplewood Shale and Neahga Shale, Rochester, New York, U.S.A.

Original Diagnosis: Circular to sub-circular central body, wall apparently single layered, psilate chagrenate to granulate with numerous

slender, flexible but solid processes which do not communicate with the interior of the central body.

Remarks: As defined by Loeblich (1970) the genus is hardly distinguishable from Filisphaeridium Staplin et al., 1965. Loeblich (1970) remarks, however, that Elektoriskos differs in lacking distally differentiated processes. By implication, therefore, Loeblich (1970) emended the genus Filisphaeridium Staplin et al., to exclude forms having simple processes.

Comasphaeridium Staplin et al., 1965, differs in having densely arranged processes.

Elektoriskos? sp. A

Pl. 2, fig. 11; pl. 6, figs. 3-4; pl. 7, fig. 9;

Pl. 11, figs. 1, 7; pl. 13, fig. 10; pl. 16, fig. 9;

Pl. 19, fig. 4; pl. 30, figs. 11-12; pl.32, fig.6; pl.34, fig. 3.

Description: The central body is hollow, single layered, thin walled, and has an outline which is either circular or ovate. It is ornamented by numerous, slender, tapering, hair-like filaments, which, in general, do not exceed one eighth of the central body diameter in length. They appear to be solid, are often irregularly curved, have a fairly angular contact with the central body, and are acuminate or evexate at their tips. The body wall is smooth or slightly gramulose. No definite excystment opening is present.

Dimensions:	Central body diameter:	12(19)28μ
	Height of ornament:	1(3)5μ

Specimens measured: 15

recorded: 31

Remarks: Although carrying similar hair-like filaments (arbitrarily referred to above as 'ornament'), the specimens show considerable diversity of central body size.

The attribution of these specimens to the genus Elektoriskos Loeblich is provisional as it is not clear whether the hair-like filaments are solid or hollow.

Comparison: Of species previously attributed to Elektoriskos Loeblich, Elektoriskos? sp. A most resembles E. lasios Wicander, 1974, which differs in having longer processes. Micrhystridium breviciliatum Staplin, 1961, is also similar, but appears to have fewer processes.

Occurrence: Bangor, Menai and Caernarvon, N. Wales, U.K.; Hope Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K.; Early Arenigian - Late Llanvirnian. Samples B1, M2, M3, C1, C4, C6, H5, SAL 389, SAL 390, SAL 2781, SAL 2778(?).

Genus MICRHYSTRIDIUM Deflandre, 1937

Type Species: Micrhystridium inconspicuum Deflandre, 1937, p. 80, = Hystrichosphaera inconspicua Deflandre, 1935, p. 233, pl. 9, figs. 11-12; Upper Cretaceous, France; invalid I.C.Z.N. Art. 13(a) (i)

Original Diagnosis: The genus Micrhystridium includes globular organisms, ornamented with various appendages, and whose size, generally less than 20μ, can be as little as 8μ or 10μ. (transl.)

Remarks: In this study the genus Micrhystridium Deflandre is used to accommodate acanthomorphic acritarchs of small or moderate size, having a circular or subcircular outline, basically smooth, thin wall, and simple hollow

processes, drawn out from the central body, and closed at the tip. The arbitrary 20μ upper size limit is not strictly adhered to.

Usage is therefore in a sense similar to Staplin, Jansonius and Pocock (1965), and Wicander (1974). As the diagnosis of Staplin et al. (1965) was not a formally expressed emendation it is doubtful whether it can be considered valid.

The forms attributable to Micrhystridium Deflandre encountered in this study do not throw further light on the problems of the genus. In view of this it was not considered appropriate to attempt emendation of the diagnosis.

Micrhystridium Deflandre was one of the earliest microphytoplankton genera to be introduced, and was diagnosed on the basis of specimens recovered from Upper Cretaceous flints. At the same time, Deflandre (1937) introduced the genus Hystrichosphaeridium for forms with central bodies in excess of 20μ. Much of the controversy concerning Micrhystridium which has existed since, has centred on two problems:

1. the 20μ upper size limit
2. the relationship of Mesozoic to Palaeozoic forms

Each is considered separately below:

1. Deflandre returned to the issue of size when he reviewed the genus (1947, p. 17), and made it clear that the limit of 20μ was entirely arbitrary. Nevertheless, he added that he would not be surprised if future studies objectively demonstrated the presence of a size discontinuity at about 20μ. Downie (1958) subsequently demonstrated a natural size discontinuity to occur at approximately 17μ in acritarchs of Tremadocian age.

If, therefore, one takes into account the restricted knowledge during this early phase of investigation, the 20μ limit was probably a useful guide for the separation of relatively simple forms into the genera Micrhystridium Deflandre and Hystrichosphaeridium Deflandre.

Eisenack (1958b) suggested that the genus Hystrichosphaeridium should be restricted to forms having open tipped processes. Micrhystridium Deflandre, may be considered to have been emended by implication, species being restricted to those of central body size < 20μ, having processes with closed tips. For forms having a central body size > 20μ and close-tipped processes, Eisenack (1958b), proposed the genus Baltisphaeridium. Thus, two genera were available at this time for relatively simple, round bodied forms, with close-tipped, simple or branching processes, allocation depending principally on central body size.

Staplin (1961) removed the upper size limit from Micrhystridium Deflandre and restricted it to forms having simple spines. Micrhystridium Deflandre emend. Staplin was thus indistinguishable from Baltisphaeridium Eisenack, 1958b, which Staplin therefore proposed to treat as a junior synonym. Forms having branching processes were removed to a new genus Multiplicisphaeridium Staplin, 1961.

The action taken by Staplin (1961), was subsequently much criticised. Eisenack (1962a), considered the original concept of Micrhystridium to have been unacceptably altered, and defended the 20μ size limit as being of practical usage. Downie and Sarjeant (1963) further demonstrated the likely existence of two natural size groupings by analysis of central body size in a large number of Palaeozoic acanthomorph acritarch species. Staplin's proposal to remove the size limit was consequently rejected, but Downie and Sarjeant (1963) did accept that Micrhystridium Deflandre should be restricted

to forms having closed processes. The diagnosis was emended accordingly. The emendation of Downie and Sarjeant (1963) was approved by the 1963 meeting of Group 9 (Acritarcha) of the Commission Internationale du Microflore du Paléozoique.

A further emendation by G. and M. Deflandre (1965) took into account observations regarding the method of excystment. They retained the 20μ size restriction. In the same year Staplin, Jansonius and Pocock used a modified version of the Staplin 1961 emendation, in which the central body size was described as 'small to moderate'. Sarjeant (1967) and Lister (1970b) also published emendations which incorporated details of excystment and wall structure. Both described the central body as 'generally less than 20μ'.

Loeblich (1969) was less convinced of the practicality of the 20μ size restriction. He commented: 'the size limit of 20μ for Micrhystridium is of little use biologically, and has probably resulted in the lumping of various morphologically dissimilar species that probably represent unrelated genera'.

The publication by Eisenack (1969) of an emendation to the diagnosis of Baltisphaeridium may be considered to have removed at least some of the usefulness of the 20μ limit, as the rediagnosed Baltisphaeridium was made distinguishable from Micrhystridium Deflandre by criteria other than size. There remained, however, a large number of forms attributable to Baltisphaeridium sensu Eisenack, 1958b, but not transferrable to Baltisphaeridium sensu Eisenack, 1969, from which Micrhystridium Deflandre might be distinguishable only by retention of the 20μ limit.

It is clear from the opinions briefly reviewed above that thought

has been divided on this issue. The present author considers that while the 20μ size limit once performed a useful function it can no longer be applied. Forms having a central body diameter exceeding 20μ are considered admissible providing that they also satisfy other criteria outlined earlier in this section.

2. In his review, Deflandre (1947) noted that as Micrhystridium had an entirely morphological definition the Palaeozoic and Mesozoic species might be unrelated, and might be separable at a later date. Very little evidence has accumulated to support this idea, but the work of Sarjeant (1967) may be of relevance and is certainly worthy of note. Sarjeant comments: 'Examination of large numbers of specimens of Micrhystridium of various species from Jurassic and Cretaceous horizons has demonstrated that the shell is in all cases two-layered: that the cavity of the spines, when present links directly with the shell interior: and that in general, the spines are formed from the outer shell layer only'. Sarjeant added that this appeared to be the case consistently in M. inconspicuum (the type species), M. fragile, and M. recurvatum.

The evidence did not agree with the redefinition of Micrhystridium by Staplin, Jansonius and Pocock (1965), in which it was stated that there occurred 'no differentiation in wall structure between spines and vesicle'. A two-layered wall has not been recorded by other workers in either Palaeozoic or Mesozoic forms of Micrhystridium. Authors have rarely commented on wall structure or thickness although Staplin (1961) and Wicander (1974) both describe thin-walled species of Micrhystridium from the Devonian.

Until, therefore, the work of Sarjeant is substantiated, and more account is taken of wall structure in general, this issue is unlikely to be resolved. Palaeozoic and Mesozoic forms must at the the present time be considered congeneric.

Comparison: Polygonium Vavrdova, 1966, emend. may be distinguished from Micrhystridium Deflandre by its polygonal outline. The genera Crassisphaeridium Wicander,1974, and Guttatisphaeridium, Wicander, 1974, differ in having a granulose wall to the central body. Ecthymabrachion Wicander, 1974, differs in having granulate processes. The genus Ephelopalla Wicander, 1974, is distinguishable by secondary infilling of the processes. Exilisphaeridium Wicander, 1974, is said by Wicander to differ in possessing a low number of processes distinct from the vesicle. Ecmelostoiba Wicander, 1974, is very similar to Micrhystridium Deflandre, and it is unfortunate that Wicander does not state how it may be distinguished from Micrhystridium. Both the described species of Ecmelostoiba Wicander (E. asymmetrica Wicander, and E. leptoderma Wicander), have a low number of processes and the intended distinction may be based on this.

Micrhystridium aremoricanum Paris and Deunff, 1970, comb. nov.

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(?).

1970 Micrhystridium inconspicuum var. aremoricanum Paris and Deunff, p. 31, pl. 2, fig. 20.

Original Diagnosis: Acritarch with a spherical central body, exhibiting conical spines, the length of which measure approximately one third the diameter of the vesicle. The appendages are numerous and robust. (transl.)

Description: The central body is hollow, generally with a circular or subcircular outline. The body wall and walls of the process stems have a

texturally similar microgranulose appearance, and are moderately thin and single layered. The processes are numerous, hollow stemmed, conical and acuminate, with a widely or sharply curved proximal contact. They are evenly distributed and often slightly curved or distorted in a way that suggests flexibility. The body cavity and process interiors appear to be in free communication. No excystment structures were observed.

Dimensions:	Central body diameter:	13(18)25 x 12(16)24μ
	Process length:	4(6)8μ
	Process width proximally:	1.5 - 2μ
	Ratio of central body diameter to process length:	3 : 1 (approx.)
	Number of processes in optical section:	20 - 30

Specimens measured: 46

recorded: 96

Remarks: The diameter of the central body, process length and process number are rather variable. The central body is often less transparent than the processes. Occasional specimens display irregular 'V' shaped clefts or have part of the central body wall missing. It is not clear whether these features are associated with excystment or whether they result from mechanical damage.

The species occurs commonly in material of Arenigian age and apparently ranges into the Llanvirnian. Through variations in form (process length, body diameter, etc.) it may prove possible to divide better preserved assemblages into several subspecies.

Micrhystridium aremoricanum Paris and Deunff comb. nov. does not appear to be closely related to Micrhystridium inconspicuum Deflandre. It appears to differ from the latter in size, process style and number,

and in surface texture. It is here considered sufficiently distinctive for elevation to the rank of species.

Comparison: Micrhystridium sp. B differs in being smaller in size. Micrhystridium sp. C may be distinguished by its short conical processes.

Occurrence: Menai, Bangor and Caernarvon, N. Wales, U.K.; (?) Hope Shales, Shropshire, U.K.; (?) Skiddaw Slates, Lake District, U.K.; Arenigian and (?) Llanvirnian. Samples B1, B2, M2, M3, C1, C4, C6, H5(?), SAL 390(?), SAL 278(?).

Previous Record: La Roche-au-Merle, Ille-et-Vilaine, France; Llanvirnian (Paris and Deunff).

Micrhystridium cleae Martin, 1972

Pl. 16, fig. 10.

1972 Micrhystridium cleae Martin, p. 10-1, pl. 1, figs. 5, 9; pl. 5, figs. 10, 14, 27.

Original Diagnosis:

- Central body: circular outline of diameter 7-14μ
- Appendages: five to seventeen in number. Length 3 to 8μ. Conical form tapering to a simple sharp distal extremity. Internal cavity in communication with that of the central body.
- Opening: generally present; more or less circular to polygonal and 3 to 6μ diameter.
- Ornamentation: five to eleven fine spines, length 1μ, are arranged around the edge of the opening. (transl.)

Description: (based on a single specimen). The outline of the central body is polygonal, with a 'V' shaped cleft running from the periphery towards the centre. Short conical processes are developed at the angles of the central body, and four or five short spines fringe the margin of the opening.

Dimensions:	Central body diameter:	13.5 x 13.5μ
	Length of processes:	3 - 6μ
	Width of processes proximally:	< 1μ
	Length of spines:	1μ

Remarks: The specimen has a distinctly polygonal outline and thus differs from the diagnosis. However, most specimens illustrated by Martin (1972), including the holotype, do have central bodies which are sub-polygonal in appearance.

Comparison: The short conical processes, evenly distributed and few in number, together with body outline, size, and the small spines surrounding the opening, distinguish Micrhystridium cleae Martin from all previously described forms.

Occurrence: Menai, N. Wales, U.K.; Early Arenigian. Sample M3.

Previous Record: Montagne Noire, Herault, France; Tremadocian (Martin).

Micrhystridium cf. cleae Martin, 1972

Pl. 2, fig. 12(?); pl. 14, figs.14-16; pl. 16, figs.11-12.

Description: The central body is hollow with a polygonal to sub-circular outline. The wall appears to be single layered and is psilate

at x1000. Processes are few in number (5 to 7 in optical section), short, conical or occasionally tapering, and acuminate at their tips. They are hollow and communicate freely with the cavity of the central body. The processes are homomorphic, although some diversity in form exists between specimens. The junction between process stem and central body varies between curved and angular.

Dimensions:	Central body diameter:	9(12)16 x 8.5(11)13μ
	Length of processes:	1(2.5)4μ
	Width of processes proximally:	0.5(1.0)1.5μ

Specimens measured: 18

recorded: 22

Remarks: Although similar to Micrhystridium cleae Martin, the specimens do not appear to possess excystment openings with attendant marginal spines As this feature is a diagnostic characteristic of M. cleae Martin, and is stated by Martin (1972) to be 'generally present', it is considered that the above specimens cannot definitely be assigned to the species.

Comparison: The species differs from Micrhystridium cleae by lacking an opening surrounded by short spines.

Occurrence: Menai and Caernarvon, N. Wales, U.K.; Early Arenigian. Samples M2, M3, C6.

Micrhystridium crispum sp. nov.

Pl. 4, fig. 17; pl. 6, figs. 9 (Hol.), 10.

Derivation of Name: Latin, crispus, curly, referring to the processes.

Diagnosis: Central body hollow, ovate in outline, wall usually firm, psilate, and of moderate thickness. Processes numbering 6 to 10, similar

in length to the central body diameter, sinuous, tapering, with acuminate tips. Proximal contact with the central body fairly angular.

Holotype: Slide reference: C4 <20 1 0 1014 461. Late Arenigian. Caernarvon, North Wales, U.K.; N.G.R. SH 47956196

Dimensions: Central body diameter: 9(11)12 x 11(13.5)15.5µ
Length of processes: 6.5(9)14µ
Width of processes proximally: 1 - 1.5µ (approx.)

Holotype: Central body diameter: 9 x 12µ
Length of processes: 10µ
Width of processes proximally: 1 - 1.5µ

Specimens measured: 9
recorded: 12

Description: As diagnosis.

Remarks: Although the specimens are moderately carbonised and compressed, the body wall has resisted rupture and severe distortion, and the central body outline is regularly ovate. From this it is presumed that the wall is of moderate thickness. Excystment openings were not observed.

Comparison: Of previously recorded species, Micrhystridium recurvatum forma reductum Valensi, is somewhat similar in appearance, but may be distinguished from M. crispum sp. nov. by possession of more numerous processes, less simuous in style.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian. Sample C4.

Micrhystridium henryi Paris and Deunff, 1970

Pl. 12, figs. 3-4, 8; pl. 13, fig.11.

1970 Micrhystridium henryi Paris and Deunff, p. 31-2, pl. 2, figs. 2, 10, 14-5, 18; pl. 3, fig. 7.

1974 Micrhystridium henryi Paris and Deunff in Rauscher, p. 97-8, pl. 5, figs. 9-10.

Original Diagnosis: This species possesses short spines, conical in form, with simple extremities, thinning rapidly. The spines, of lengths varying between 2 and 4μ merge at their bases. The spherical shell has a diameter varying between 17 and 24μ. The number of spines is greater than 120. (transl.)

Description: The central body is hollow with an ovate to sub-circular outline. The wall is apparently single layered and psilate at x1000. The processes are also without surface ornament, conical in form with a straight or slightly curving axis, and distally acuminate, with a wide or sharply curved proximal contact. Process interiors and the vesicle cavity appear to be in communication. No definite excystment structures were observed.

Dimensions:		
	Central body diameter:	20(22.5)24 x 16.5(17)20μ
	Length of processes:	1.5(2.5)4μ
	Process width proximally:	1 - 1.5μ

Specimens measured: 6

recorded: 12?

Remarks: The specimens have a more ovate outline than those figured by Paris and Deunff (1970). Process number is difficult to assess due to carbonisation and breakage, but it appears likely that in some specimens the number specified in the diagnosis (120) is not attained.

Comparison: This species differs from Micrhystridium aremoricanum Paris and Deunff comb. nov. in possessing fewer, shorter processes of generally more slender appearance.

Occurrence: Menai and Bangor (?), N. Wales, U.K.; Early Arenigian. Samples M2, B2(?).

Previous Record: La Roche-au-Merle, (Ille-et-Vilaine), France Llanvirnian (Paris and Deunff).

?Micrhystridium nannacanthum Deflandre, 1942 ex Deflandre, 1945

Pl. 4, fig. 20; pl. 6, fig. 12; pl. 11, fig. 5; pl. 14, fig. 8; pl. 30, fig. 8.

1942 Micrhystridium nannacanthum Deflandre, p. 476, fig. 13. (nom. nud.)

1945 Micrhystridium nannacanthum Deflandre, p. 66, pl. 3, figs. 5-7.

1947 Micrhystridium nannacanthum Deflandre in Deflandre, text-fig. 3.13.

1951 Micrhystridium nannacanthum Deflandre in Deunff, p. 322, figs. 1-2.

1959 Micrhystridium nannacanthum Deflandre in Deunff, p. 32, pl. 10, fig. 97.

1963 Micrhystridium nannacanthum Deflandre in Downie, p. 645.

1963 Micrhystridium nannacanthum Deflandre in Stockmans and Williere, p. 463, pl. 3, fig. 20.

1966b Micrhystridium nannacanthum Deflandre in Martin, p. 430.

1966a Micrhystridium nannacanthum Deflandre in Martin, p. 364.

1967 Micrhystridium nannacanthum Deflandre in Martin, p. 315.

1969 Micrhystridium nannacanthum Deflandre in Martin, p. 73-4, pl. 7, fig. 315.

1969 Micrhystridium nannacanthum Deflandre in Konzalová - Mazancová, p. 82, pl. 15, figs. 4?. 5.

1970 Micrhystridium nannacanthum Deflandre in Lister, p. 80, pl. 10, fig. 11.

1974 Micrhystridium nannacanthum Deflandre in Rauscher, p. 98, pl. 5, fig. 11.

1974 Micrhystridium nannacanthum Deflandre in Stockmans and Willière, p. 27-8, pl. 3, fig. 29.

Original Diagnosis: (Deflandre, 1945). Their globular shell, slightly ellipsoidal, was perhaps originally spherical. The specific character which easily allows recognition of Micrhystridium nannacanthum resides in the ornamentation of the shell surface: this is covered with very short spines which do not exceed 1μ in length. (transl.)

Description: The central body is hollow and has an ovate or subcircular outline. The wall is smooth, firm, but moderately thin, and appears to be composed of a single layer. It is ornamented by numerous short, evenly distributed conical spines which terminate either bluntly or in a sharp point. No definite excystment opening is present.

Dimensions:	Central body diameter:	10(13)17.5 x 8(11)13μ
	Height of ornament:	0.25 - 2μ

Specimens measured: 10
recorded: 16

Remarks: The specimens are rather poorly preserved and either lightly or moderately carbonised. The conical spines are presumed hollow, but may be solid.

Some of the specimens described above have spines which exceed the limit. In addition there is considerable variation in central body

size. They are therefore only tentatively assigned to Micrhystridium nannacanthum Deflandre ex Deflandre.

Comparison: Micrhystridium parinconspicuum Deflandre ex Deflandre, differs in having a relatively small number of longer spines. M. bacilliferum Deflandre may be distinguished by its ornament of short, slender, rod-like projections.

Occurrence: Bangor, Menai and Caernarvon, N. Wales, U.K.; (?) Stapeley Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K. Arenigian - Early Llanvirnian. Samples B1, M2, C4, C5, W3(?), SAL 389, SAL 390.

Selected Previous Records: Silurian limestones, Roquemaillère, Montagne Noire, France; Wenlockian (Deflandre, 1942, 1945). Sub-surface samples, Belgium; Arenigian - Ludlovian; (Martin, 1969). Wenlock Shales, Lower Bringewood Beds (Millichope), and Middle Elton to Whitcliffe Beds (Ludlow area), Shropshire, U.K.; Wenlockian - Ludlovian; (Lister). Schists with Calymene, May-sur-Orne, Normandy, France; Llanvirnian (Rauscher).

Micrhystridium robustum Downie, 1958

Pl. 4, fig. 19; pl. 8, fig. 11.

1958 Micrhystridium robustum Downie, p. 344, pl. 17, fig. 5; text-figs. 3a-b.

1969 Micrhystridium robustum Downie in Martin, p. 71-8, pl. 1, figs. 40, 47-8; pl. 6, fig. 278; text-figs. 25-6.

1970 Micrhystridium robustum Downie, in Lister and Holliday, p. 453, pl. 19, fig. 7.

1972 Micrhystridium robustum Downie, in Martin, p. 11, pl. 1, fig. 6.

1974 Micrhystridium robustum Downie in Rauscher, p. 73, pl. 2, fig. 15.

Original Diagnosis: Test spherical or slightly ellipsoidal, diameter 10 - 12μ, test walls about 1μ thick, composed of greenish highly refracting organic matter, surface granular; processes simple, cylindrical, tapering more or less sharply at the tip, becoming hair-like, rising abruptly from the test surface; length 40 - 150% of test diameter; number in optical section 6 - 15.

Description: The central body is hollow, with a firm wall and has an approximately ovate outline. It bears a rather low number of slender tapering processes (6 - 10 in optical section), with acuminate tips, which, in length, are approximately equivalent to the central body diameter. The contact between process stem and central body is angular or slightly curving, and the process stems appear hollow and without external ornament. In contrast, the body wall is decorated with granules or short stiff hairs. No definite excystment structure is present.

Dimensions:

Central body diameter:	5(8)11 x 7(11)15.5μ
Length of processes:	4(7.5)11μ
Height of body ornament:	0.25 - 2.0μ

Specimens measured: 3

recorded: 5

Remarks: The specimens differ from those originally recorded by Downie (1958) in being more variable in size and in sometimes exhibiting a bristle-like body ornament. Martin (1969), noted similar variations.

Comparison: The Jurassic species, Micrhystridium fragile Deflandre, is superficially similar, but differs in lacking prominent ornamentation

of the body wall.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian - Early Llanvirnian. Samples C1, C4, C5.

Previous Records: Shineton Shales, Shropshire, U.K.; Tremadocian; (Downie). Massif du Brabant, Crete du Condroz, Belgium; Tremadocian - Llanvirnian; (Martin, 1969). Greenschists, Sainte-Cécile, Montagne Noire (Monts de Cabrières), France; Lower Ordovician; (Martin, 1972). Montagne Noire; Arenigian (Rauscher).

Micrhystridium subtile sp. nov.

Pl. 2, figs. 13-4; pl. 4, fig. 16; pl. 6, fig. 16; pl. 8, fig. 12; pl. 14, figs. 12 (Hol.), 13; pl.16, fig.3.

Derivation of name: Latin, subtilis, delicate, referring to the delicate diminutive form.

Diagnosis: Central body hollow, small, generally within the range 9μ to 15μ in diameter, outline subcircular to ovate, wall particularly thin, smooth at x1000. Processes few in number (often 8 - 12 in optical section), usually slender tapering, occasionally more conical and robust, with acuminate tips and a curving or angular contact with the central body. Processes attaining a length approximately equivalent to one third of the central body diameter.

Holotype: Slide reference: M2<20 1 09 1046343, Early Arenigian, Bangor, Menai, North Wales. N.G.R. SH 54987128

Dimensions:

Central body diameter:	7(12)16.5μ
Length of processes:	3(4.5)6μ
Ratio of central body diameter to process length:	2.7 : 1 (av.)

Holotype:	Central body diameter;	13.5 x 12μ
	Length of processes:	4(4.5)5μ
	Width of processes proximally:	< 0.5μ
	Ratio of central body diameter to process length:	2.8 : 1 (av.)
	Number of processes in optical section:	10

Specimens measured: 50

recorded: over 100 - fragmentary specimens are particularly common in the < 20μ preparation of M2.

Description: All specimens agree with the above diagnosis.

Remarks: It is possible that two or three forms may be distinguishable through variation in body outline, body size and process number, but such a subdivision does not appear reliable enough to be stratigraphically useful.

Some specimens have been deformed by the internal growth of pyrite. No definite excystment opening was observed.

Comparison: Certain specimens from the Jurassic and Cretaceous attributed to Micrhystridium inconspicuum Deflandre (for example, Deflandre (1937), p. 80, pl. 12, fig. 13; Sarjeant (1959), p. 340, text-fig. 7b; and (1960), p. 398, text-fig. 1f, g; (1961), p. 105, text-fig. 8f; (1970), p. 279-82, pl. 1, fig. 3, text-fig. 1a-d) bear superficial resemblance to M. subtile sp. nov. However, they appear to differ from M. subtile sp. nov. in possessing a thicker wall and relatively long, robust processes.

Occurrence: Menai and Caernarvon, N. Wales, U.K.; Arenigian and Early Llanvirnian (?). Samples C1(?), C4, C5, C6, M2, M3.

Micrhystridium sp. A

Pl. 4, fig. 18; pl. 6, fig. 11; pl. 27, figs. 11-12.

Description: The central body is hollow, compressed, usually ovate in outline and has a smooth, firm, moderately thick wall. The processes are few in number (6-10 in optical section), tapering, often curved, and have hollow stems with closed acuminate tips. In length they are rather variable, generally ranging between one quarter and three quarters of the central body diameter. The contact between central body and stem base is curved. No definite excystment opening is present.

Dimensions: Central body diameter: 12(15.5)18 x 9(12.5)4μ

Length of processes: 3(5.5)7μ

Specimens measured: 6

recorded: 8

Remarks: The specimens are reasonably well preserved though moderately carbonised. The body wall displays folds in some cases, although a uniform outline is maintained.

Comparison: Micrhystridium parinconspicuum Deflandre, 1942, ex Deflandre, 1945, is similar, but has a more circular outline, and more numerous processes.

Occurrence: Caernarvon, N. Wales, U.K.; Stapeley Shales, Shropshire, U.K.: Late Arenigian - Early Llanvirnian. Samples C4, C5, W3.

Micrhystridium sp. B

Pl. 6, fig. 8; pl. 14, fig. 11; pl. 16, fig. 15; pl. 30, fig. 15.

Description: The central body is hollow, apparently single layered, and sub-ovate or irregular in outline. The processes are conical, acuminate,

hollow stemmed, variable in length, and have a microgranulate surface texture. The cavity of the central body and the process interiors are probably in communication.

Dimensions:	Central body diameter:	10(11)12 x 8(9)10μ
	Length of processes:	4(5)5.5μ
	Width of processes proximally:	0.5 - 2.0μ
	Ratio of central body diameter to process length:	1.8 - 2.2 : 1

Specimens measured: 3

recorded: 4

Remarks: In general appearance Micrhystridium sp. B resembles M. aremoricanum Paris and Deunff comb. nov., but is distinguished by its smaller size. The specimens are rather poorly preserved.

Occurrence: Menai and Caernarvon, N. Wales, U.K.; Skiddaw Slates, Lake District, U.K.; Arenigian - Early Llanvirnian. Samples C4, M2, M3, SAL 389.

Micrhystridium sp. C

Pl. 14, fig. 10; pl. 16, fig. 4; pl. 34, fig. 12.

Description: The central body is hollow with an ovate or circular outline, and a covering of short conical processes. The processes are numerous, evenly distributed, and sharp tipped. The stems are hollow, and in communication with the central body cavity. The proximal contact with the central body is curved. The body wall is apparently single layered, and has a psilate to microgranulose surface texture. A small circular opening is present in two of the specimens.

Dimensions:	Central body diameter:	12(4.5)16.5 x 9(12)15μ
	Length of processes:	2(3)4μ
	Width of processes proximally:	1 - 1.5μ
	Ratio of central body diameter to process length:	2.7 - 4.1 : 1

Specimens measured: 8

recorded: 8

Remarks: Due to carbonisation of the wall it is not clear whether the observed circular opening is an excystment structure or not. Other specimens in the same assemblage are frequently pitted by the growth of pyrite. When removed during preparation the resultant cavities may assume the appearance of excystment apertures.

Comparison: Micrhystridium aremoricanum Paris and Deunff comb. nov. differs in having longer processes. Micrhystridium sp. B may be distinguished by the longer processes and smaller size.

Occurrence: Menai, N. Wales, U.K.; Skiddaw Slates, Lake District, U.K.; Early Arenigian and Late Llanvirnian. Samples M2, M3, SAL 2781.

Micrhystridium div. spp.

Two reasonably well preserved specimens recovered from sediments of Early Llanvirnian age, have been recorded in the assemblages from Caernarvon and the Lake District. (Pl. 8, fig. 7, and pl. 30, fig. 14). Although their occurrence is considered worthy of note, owing to their rarity, they have not been described in detail, nor included in the range charts.

Genus MULTIPLICISPHAERIDIUM Staplin, 1961

emend. Lister, 1970b.

Type Species: Multiplicisphaeridium ramispinosum Staplin, 1961, p. 411, pl. 48, fig. 24; text-fig. 9g-h; Woodhead Fm., Upper Devonian, Alberta, Canada.

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: Originally proposed by Staplin (1961) the genus was restricted by Staplin, Jansonius and Pocock (1965) to include only those forms having free communication between process interiors and the central body cavity. Both Eisenack (1969a) and Lister (1970b) later proposed emendations, though neither is significantly different from the restricted diagnosis of Staplin et al. (1965).

Eisenack et al. (1973) follow a diagnosis which is basically a combination of the Staplin et al. (1965) and Eisenack (1969a) versions, although it is not presented as a formal emendation.

Lister (1970b) discusses the genus in detail and the present author agrees with the opinions expressed by him. The emendation of Lister (1970b) is the diagnosis accepted here. It differs from the restricted diagnosis of Staplin et al. (1965) only in that the mode of excystment is specified.

Multiplicisphaeridium maroquense Cramer et al., 1974a

Pl. 4, fig. 5; pl. 5, fig. 12(?); pl. 15, fig. 9(?); pl. 21, fig. 4; pl. 24, fig. 5(?), pl. 33, figs. 1-2; pl. 35, fig. 9(?)

1974a Multiplicisphaeridium maroquense Cramer et al., p. 185, pl. 27, figs. 3-5, 7-9.

Original Diagnosis: Central body tumidly polygonal; form determined by number and width of the bases of the processes. Although the processes are broadly based, they are clearly differentiated from the central body. Four to seven, most commonly five or six, processes present. They are plump, columnar, broad-based and distally branched. No branching occurs below the distal portion. The branches consist of regular groups of two to three pinnae (generally two) of the second order sprouting from regular groups of commonly four first order pinnae. The branching is very regular and the second order pinnae bend back towards the processes in a characteristic manner.

The splitting angle of the first and second order pinnae is approximately sixty degrees. Process and first order pinnae are hollow; second order pinnae are distally solid and have a narrow cavity at the base. The surface of both processes and central body is psilate; there is no differentiation between body and processes in either sculpture or construction. The vesicle wall is approximately 1.5 microns thick. Mode of opening is not known; no endodermal structures observed.

Description: In form, size, and branching style the specimens correspond to the above diagnosis.

Dimensions:

Central body diameter:	20(27.5)40μ
Length of processes:	10(15)20μ
Width of processes proximally:	2 - 6μ
Ratio of central body diameter to process length:	1.8 : 1

Specimens measured: 6

recorded: 9(?)

Remarks: The specimens range in body form from tetragonal to ovate and although this variation could be attributed to compression during preservation the illustrations of Cramer et al.(1974) also suggest that the species have a variable central body shape. This was confirmed by the author's own examination of well preserved Ordovician material from a Moroccan borehole.

Some of the specimens have a triangular outline and resemble Vogtlandia ramificata Burmann. Other specimens have an elongate body and more numerous processes and resemble Vogtlandia multiradialis Burmann. Cramer however, (pers. comm.) claims that Vogtlandia ramificata Burmann and Multisplicisphaeridium maroquense Cramer et al. are different species. The distinction may rest upon the style of the terminal branching, which, according to Burmann, in V. ramificata Burmann takes the form of a relatively compact crown. The task of discriminating between V. multiradialis Burmann and Multiplicisphaeridium maroquense Cramer et al. is even more difficult and re-examination of the type material may be necessary before the issue can be satisfactorily resolved. The fragmentary specimens described above certainly do not offer a solution. The question of synonymy between these species, is, therefore, at present undecided.

Comparison: According to Cramer et al. (1976) the characteristic manner of recurvate branching distinguishes this taxon from forms of similar construction.

Occurrence: Menai, Bangor and Caernarvon, N. Wales, U.K.; Skiddaw Slates, Lake District, U.K.; Hope Shales, Shropshire, U.K.: Arenigian-

Llanvirnian. Samples M3(?), C4(?), C5, SAL 2778, SAL 2781(?).

Previous Records: Subsurface material, Tadla Basin, Morocco, Late Arenigian - Early Llanvirnian. North-central Saudi Arabia, late Lower Ordovician; Libya and Tunisia, late Lower Ordovician (Cramer et al.).

Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b
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.

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

1964b Baltisphaeridium raspa Cramer, p. 301, pl. 4, figs. 1-2. 3?, 4?, 5?, 6?, 11?.

1965 Micrhystridium raspa (Cramer) Deflandre and Deflandre-Rigaud, Index cards 2488-9 (not effectively published?)

1965 Micrhystridium raspa Cramer in Rauscher et al., p. 312, pl. 4, figs. 8-9, 11.

1966b Micrhystridium raspa (Cramer) in Martin, p. 429; text-fig. 5.

1967 Micrhystridium raspa (Cramer) in Martin, p. 315, 327.

1969 Micrhystridium raspa (Cramer) Deflandre and Deflandre-Rigaud in Martin, p. 77, pl. 3, figs. 145-6, 157; pl. 5, figs. 241-2; pl. 8, figs. 377, 384.

non 1969 Micrhystridium raspa (Cramer) in Konzalová-Mazancová, p. 82, pl. 15, figs. 4-5.

1970b Multiplicisphaeridium raspa (Cramer) Lister, p. 84.

1973 Multiplicisphaeridium raspa (Cramer) in Eisenack et al., p. 767-8.

1974 Multiplicisphaeridium raspa (Cramer) Lister, in Rauscher, p. 85-6; text-fig. 29.

1974 Multiplicisphaeridium raspa (Cramer) in Martin, p. 11, pl. 4, figs. 117-8.

1974 Micrhystridium raspa (Cramer) Stockmans and Williere, p. 30.

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 1200x magnification.

The processes are simply bifurcated at the tips with branches of the second to third order. Number of processes 10 - 35 in optical section. Processes 25% or more of Øi. The number and length of the processes are rather variable.

Description: Although partially opaque the specimens can be seen to be in close agreement with the above diagnosis. The central body has a sub-circular or sub-ovate outline and the processes display considerable heterogeneity. Simple tapering processes may occur alongside others which have second or even third order branching. The processes also differ in their widths and lengths, some appearing slender and others robust. No excystment opening is present.

Dimensions:

Central body diameter:	12(16.5)20 x 10(13)16µ
Length of processes:	2.0(3.5)5.0µ
Width of processes proximally:	0.5 - 2.0µ
Ratio of central body diameter to process length:	3.7 - 4.7 : 1

Specimens measured: 14

recorded: 41

Remarks: The specimens here attributed to Multiplicisphaeridium raspum (Cramer) all have a relatively small body and heteromorphic processes, and closely resemble the holotype. The line-drawing illustration in Eisenack et al.(1973) is not like the holotype.

Comparison: Multiplicisphaeridium lobeznum (Cramer) Eisenack et al. differs in having processes of characteristic arborescent form. M. picorricum (Cramer) Lister is distinguished by generally slender processes which rarely bifurcate simply.

Occurrence: Bangor, Menai and Caernarvon, N. Wales, U.K.; Hope Shales and Stapeley Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K.; Arenigian and Llanvirnian. Samples B1, C4, C5, C6, M3, H5, W1, W1, W3, SAL 389.

Previous Records: La Vid Shales, Leon, N.W. Spain; Siegenian to Emsian; (Cramer). Cotentin, France; Siegenian (Rauscher et al.). Belgium; Ordovician - Silurian; (Martin, 1966, 1967, 1969). Montagne Noire, France; Ashgillian (Rauscher). Lichtervelde and Deerlijk, Belgium; Upper Ordovician - Lower Silurian (Martin).

Multiplicisphaeridium sp. A

Pl. 5, fig. 3.

Description: (based on a single damaged specimen) The body is hollow, compressed, and has an approximately quadrate outline generated by the expanded bases of four processes. The process stems are broad, hollow and communicate freely with the central body cavity. The processes attain a length approximately equivalent to quadrangular dimensions of

the central body. Distally the processes branch repeatedly (up to and possible exceeding 4th order) to form a compact hemispherical crown of recurved pinnae. Proximally, the stems are faintly granulose, in common with the central body wall, but otherwise lack any form of ornament. No excystment structure is present.

Dimensions:	Central body diameter:	24 x 22μ
	Length of processes:	18 - 25μ
	Width of processes:	4 - 8μ
	Width of terminal branching complex:	15μ

Remarks: Slight crumpling of the specimen, and its relative translucency in an assemblage where thick walled forms are quite opaque, suggest a moderately thin wall.

The specimen apparently possessed four processes, three of which remain attached, while the fourth is disconnected and appears to be folded beneath the central body. It is possible, however, that a fifth centrally located process may have been present.

Comparison: In form and branching style the processes are reminiscent of Vogtlandia ramificata Burmann. However, this latter species has a triangular outline.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian. Sample C4.

Multiplicisphaeridium sp. B

Pl. 24, fig. 6.

Description: (based on a single specimen) The central body is approximately rhomboidal in outline and from each corner emerge two or three processes which divide several times distally. The cylindrical

or tapering process stems are variable in width and are hollow. They communicate directly with the cavity of the central body. The main stems and the branches of the second or third order are usually long, slender and tapering. Proximal contact with the central body is gradual and curving. Both process stems and the body wall are thin and unornamented. No excystment structure is present.

Dimensions:	Central body diameter:	28 x 26μ
	Length of process stems:	10 - 14μ
	Width of process stems:	2 - 4μ
	Length of first order branches:	8μ (approx.)

Remarks: The specimen is reasonably preserved and does not appear to be greatly compressed or distorted.

Comparison: Process style and arrangement distinguish this species from other forms of superficially similar appearance.

Occurrence: Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Multiplicisphaeridium? sp. C

Pl. 1, fig. 9.

Description: The central body is hollow and has an ovate outline. The wall is of moderate thickness and apparently psilate. Approximately twenty processes arise abruptly from the central body, dividing distally into 3, 4, or 5 radiating pinnae. The process stems are hollow, and cylindrical or slightly tapering. Proximally they appear to be internally thickened and free communication with the cavity of the central body is doubtful.

In length they are approximately equivalent to half the maximum central body diameter. No definite excystment structure is present.

Dimensions: Central body diameter: 34 x 28.5μ

Length of processes: 12.5μ (approx.)

Width of processes: 2μ

Specimens measured: 1

recorded: 5

Remarks: The specimens are carbonised and have lost much of their original translucency. It is therefore difficult to determine the internal structure of proximal process contacts, and attribution to the genus Multiplicisphaeridium (Staplin) Lister is provisional.

The specimens bear some resemblance to Multiplicisphaeridium loriferum (Deunff) Eisenack and Cramer, but are smaller and have rather more processes.

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian. Sample C6.

Multiplicisphaeridium sp. D

Pl. 9, figs. 9–10; pl. 12, fig. 2(?)

Description: The central body is thin walled, hollow and has an indefinite, polygonal outline. The process stems are cylindrical, hollow, communicate directly with the central body cavity and are usually no more than one third the central body diameter in length. Proximally they expand and make a widely curving contact with the central body. The stems may also show slight distal expansion before dividing into two to four first order branches, which subsequently divide once or twice more to form

slender pinnae with acuminate tips. Process wall structure is similar to that of the central body and appears to be single layered and psilate. No definite excystment structure is present.

Dimensions:	Central body diameter:	25(38)50μ
	Length of process stems:	8(10)12μ
	Length of 1st order branches:	2.5(3.5)4μ
	Ratio of central body diameter to process length:	3.8 : 1
Specimens measured:	8	
recorded:	12	

Remarks: All specimens are fragmentary and the average process number could not be accurately determined. The number estimated from a consideration of the spacing of the process bases is 10 to 15.

Comparison: Potter (1974, MS.), records a superficially similar form, Multiplicisphaeridium hollybushensis Potter, (1974, MS.) from the Lower - Middle Cambrian, which differs in having relatively long tapering stems and in being smaller in overall size.

Other forms of similar appearance include M. maroquense Cramer et al., which is distinguished by having fewer, relatively long processes, M. anastomosis Wicander, which has a smaller central body, relatively long processes and more elaborate distal ramifications, and M. verrucarum Wicander, which has a lightly granulate wall.

Occurrence: Bangor, N. Wales, U.K.; Early Arenigian. Sample B1.

Multiplicisphaeridium? sp. E

Pl. 8, fig. 9; pl. 11, fig. 11.

Description: The central body is ovate in outline, hollow and thin walled. The processes are hollow, slightly tapering or cylindrical,

number approximately 20 in optical section and have an angular contact with the central body. They vary in length but usually range between one quarter and one fifth of the maximum central body diameter. Average stem width is 0.5μ, but varies proportionally with the length. Distally the processes divide into 2, 3 or 4 slender pinnae which may arise from, or be reduced to, a minute terminal swelling. The central body wall and process stems are psilate. No definite excystment structure is present.

Dimensions:	Central body diameter:	19(22)25 x 15(15.5)16μ
	Length of processes:	3(4)5μ
	Width of processes:	< 1μ
	Length of terminal pinnae:	< 1μ
	Ratio of central body diameter to process length:	3.9 - 5.5 : 1 (approx.)

Specimens measured: 4

recorded: 10

Remarks: The test is marked by linear thickenings of the body wall which appear to intersect at random. They are probably infolds of the wall. Unfortunately the specimens are not well preserved and interpretation is difficult. One specimen has been affected by the internal growth of pyrite. Because of the interpretive problems generic attribution is tentative.

Comparison: This species resembles Micrhystridium? triangulum Potter, (1974, MS.) but differs in that the process terminations usually divide into slender pinnae. In M.? triangulum Potter (MS.) the processes are only rarely pinnate (up to three processes per specimen), and may, in fact, have funnel shaped terminations.

Occurrence: Bangor and Caernarvon, N. Wales, U.K.; Early Arenigian and Late Llanvernian. Samples B1, C1.

Multiplicisphaeridium div. spp.

The specimens described here have not been considered in detail because of their generally poor state of preservation and rarity.

Eight specimens (pl. 2, fig. 7; pl. 18, fig. 1; pl. 22, fig. 4) have hollow central bodies (30 - 45μ) with subcircular outlines and processes which are approximately equivalent in length to one quarter to two thirds the central body diameter. The specimens are united by characteristic distal process ramifications (up to 4th order?). The process stems are hollow, gradually tapering and have a fairly angular contact with the central body. Some of the stems appear to possess a dark central strand. The specimens have suffered moderate to strong carbonisation, are much corroded and often deformed by pyrite. Textural and additional structural details are masked by their poor state of preservation and carbonisation. The specimens were recovered from samples C6 (Early Arenigian), H5, W1 and W3 (Early Llanvirnian). They are reminiscent of the arborescent Silurian species Multiplicisphaeridium ramusculosum Cramer and Diez, and M. frondis (Cramer and Diez).

A small carbonised specimen (pl. 30, fig. 9) recovered from sample SAL 389 (Early Llanvirnian) has a circular - polygonal outline (15 x 16μ) and a low number (9 in optical section) of short ramusculose processes (approximately one quarter of the central body diameter in length). Stem width and the degree of distal ramification are variable. Branching is to 1st, 2nd or 3rd order, individual branches not exceeding the process stem length. Proximal contact with the central body is curved and the body wall is psilate at x1000. There is no definite excystment structure. Multiplicisphaeridium borracherosum (Cramer) Lister is similar in form.

Two small specimens from samples C1(pl. 7, fig. 10) and C4 (Early Llanvirnian and Late Arenigian respectively) have central bodies (approximately 15 x 10μ) with an ovate-polygonal outline and numerous processes (about one quarter to one half the central body diameter in length). Their ramusculose terminations may include branches of up to the 4th order. Process stems are hollow, tapering, and variable in width (1-3μ proximally). The specimens are similar to certain forms attributed to Multiplicisphaeridium raspum (Cramer) Lister, by Cramer (1964b) (pl. 4, figs. 4, 5, 6, 11). They are not here attributed to M. raspum (Cramer) Lister as they do not closely correspond with the holotype, nor are they linked to it by the presence of intermediate forms.

Sample H5 (Early Llanvirnian) yielded five specimens with approximately circular or ovate outlines and broad cylindrical processes. The following brief description is based upon the two best preserved of these specimens. The central body is semi-inflated, approximately ovate in outline (32 x 25μ) and carries four (originally six?) cylindrical, thin walled processes, which communicate freely with the central body cavity. Distally the processes have a serrated edge, the individual serrations recurving through at least 180°. The processes may be open ended. They are generally similar in proportion and size, although one specimen does display a much reduced process. Proximal process contact is curved. At x1000 both body wall and processes appear to be psilate. No definite excystment structure is present (pl. 18, fig. 2). These specimens are only tentatively attributed to the genus Multiplicisphaeridium Staplin emend. Lister, 1970b.

A single specimen (pl. 19, fig. 2) recovered from sample H5 (Early Llanvirnian) has a hollow central body of circular outline (45μ) and numerous short branching processes (< one quarter of the central

body diameter in length. In addition to terminal elements each process stem may carry one or more side branches. The branches are sometimes recurved and have evexate or acuminate tips. Other structural and textural details are obscured by carbonisation.

A small fragmentary specimen (pl. 2, fig. 15), sample C6 (Early Arenigian) may belong to Multiplicisphaeridium saharicum Lister. An originally circular outline is presumed (16μ). The processes are short (3μ), homomorphic, and show a double bifurcation.

Two further specimens are also tentatively referred to this genus (pl. 3, fig. 4; pl. 4, fig. 6).

Genus ORTHOSPHAERIDIUM Eisenack, 1968a,
— emend Kjellström, 1971b

Type Species: Orthosphaeridium rectangulare (Eisenack) Eisenack, 1968a, p. 92, pl. 25, fig. 1 = Baltisphaeridium rectangulare Eisenack, 1963, p. 211, pl. 20, fig. 1.

Emended Diagnosis: Unicellular, organic walled microplankton with rectangular vesicles. Excystment structure always produced along a transverse suture line, median split, dividing the vesicle into two almost equal halves. Separation of the interior of the process from the vesicle cavity. Processes simple or furcate.

Remarks: The diagnosis was emended by Kjellström (1971b) to include reference to furcate processes.

Orthosphaeridium? sp. A.

Pl. 27, figs. 8–10

Description: (based on three specimens) The central body is approximately rectangular, thin walled and pillow-like. Each corner bears a single thin walled process, lying in the same plane as the central body. In length they are more or less equivalent to the central body width. The process stems are hollow, and taper gradually to acuminate tips. At the curving proximal contact there is a prominent internal thickening which appears to isolate the process interior from the body cavity. The body wall is psilate at x1000. No definite excystment structure is present.

Remarks: In two specimens the central body is ruptured. It is not clear whether this is due to excystment or whether the openings are the result of damage during, or prior to, fossilisation.

The specimens correspond with the generic diagnosis of Orthosphaeridium Eisenack emend. Kjellström, except possibly, in the important feature of excystment by transverse suture. Their attribution to Orthosphaeridium Eisenack emend. Kjellström must consequently be regarded as provisional.

The possible occurrence of this genus in the Llanvirnian is interesting as all previous records of Orthosphaeridium Eisenack emend. Kjellström are younger.

Dimensions:	Central body:	9(11)14 x 6(8)11μ
	Length of processes:	5(6.5)8μ
	Width of processes proximally:	1.0 – 1.5μ
	Ratio of central body length to process length:	1.2 – 1.7 : 1

Occurrence: Stapeley Shales, Shropshire, U.K.; Early Llanvirnian.

Sample W3.

Genus PETEINOSPHAERIDIUM Staplin, Jansonius and Pocock, 1965

emend. Eisenack, 1969a

Type Species: Peteinosphaeridium bergstromii Staplin et al., 1965, p. 194, pl. 20, fig. 13.

Emended Diagnosis: Shell spherical, rather firm, always with numerous, long, radial, solid or hollow, similar, evenly distributed processes, which are closed at the ends, and are divided into 2, 3 or more ± irregularly formed spines which curve gradually outwards until directed almost tangentially. Secondary spines of smaller size can also develop. Spines, as with the process stems, can be provided with ± broad membranes, which on the stems run downwards. The membranes may be reduced to nothing, or conversly, be strongly developed so as to increase the branching. Pylomes (normal or raised) common. (transl.)

Remarks: Spherical forms having furcate processes without peteinos were originally excluded from the genus by Staplin et al. (1965).

The type species of the genus, Peteinosphaeridium bergstromii Staplin et al., 1965, was listed by Eisenack et al. (1973) as a junior synonym of P. trifurcatum forma typicum (Eisenack) Eisenack et al., 1973.

P. trifurcatum forma typicum (Eisenack) Eisenack et al., is however, an illegitimate name. The species (sensu Eisenack et al., 1973) was originally described as Ovum hispidium trifurcatum by Eisenack (1931). It was validly redescribed as Hystrichosphaeridium trifurcatum by Eisenack in 1938, when the holotype was re-illustrated together with other specimens attributed to the same species. In discussion, Eisenack described his choice of holotype as 'unfortunate', and referred to a second specimen (pl. 2, fig. 5) which he considered more representative. In 1959 the species was transferred by Eisenack to Baltisphaeridium Eisenack, 1959, and at the same time he proposed

subdivision of the species into three forms and two sub-species viz:

Baltisphaeridium trifurcatum forma typica

Baltisphaeridium trifurcatum forma longiradiata

Baltisphaeridium trifurcatum forma breviradiata

Baltisphaeridium trifurcatum sub sp. nudum

Baltisphaeridium trifurcatum sub sp. paucifurcatum

A neotype was then designated to replace the lost holotype (pl. 17, fig. 3). This specimen was unlike the holotype. Nor, apparently, did Eisenack intend it to be similar, for while the neotype was referred to the forma typica, the lost holotype was referred to the forma breviradiata. Clearly, the neotype was incorrectly appointed and must be rejected because of misinterpretation (I.C.B.N. Art.8).

The name Baltisphaeridium trifurcatum (Eisenack) forma typica Eisenack is therefore incorrect as it purports to contain the nomenclatural type of the species (which it does not). The name must therefore be rejected (I.C.B.N., Art 24).

The name Baltisphaeridium trifurcatum (Eisenack) forma breviradiata Eisenack is also incorrect as it contains the nomenclatural type of the species, yet the specific epithet is not repeated. The name must therefore be changed to Baltisphaeridium trifurcatum (Eisenack) forma trifurcatum (I.C.B.N., Art 26). This correction may initially create some confusion as other authors appear to have overlooked the fact that Baltisphaeridium trifurcatum Eisenack forma typica Eisenack does not contain the nomenclatural type, and have used a 'corrected' version of the name first published by Staplin et al. (1965) viz:

Baltisphaeridium trifurcatum (Eisenack) forma trifurcatum.

Consequently, Baltisphaeridium trifurcatum (Eisenack) forma trifurcatum is a name which should be applied to the sub-species breviradiata, but has been applied to the sub-species typica.

If the I.C.B.N. is to be followed, Baltisphaeridium trifurcatum (Eisenack) trifurcatum (al. typica or typicum = Peteinosphaeridium trifurcatum (Eisenack) Staplin et al., 1965; = P. trifurcatum (Eisenack) forma typicum in Eisenack et al., 1973) must be given a new name. However, in this study the taxon is considered to be the same species as Peteinosphaeridium bergstromii Staplin et al., which, being a correct name, is accorded priority in synonymy. The following records are, therefore considered to belong to P. bergstromii Staplin et al.

1938 Hystrichosphaeridium trifurcatum Eisenack, p. 16, 18-9, pl. 2, figs. 8-11; pl. 3, fig. 1a-b (pars)

1951 Hystrichosphaeridium trifurcatum Eisenack in Eisenack, p. 188-9, pl. 2, figs. 2, 7 (pars)

1954 Hystrichosphaeridium trifurcatum Eisenack in Eisenack, p. 81, 85, pl. 12, figs. 1-2.

1959 Baltisphaeridium trifurcatum forma typica Eisenack, p. 202, pl. 17, figs. 1(?), 3, 11(?), 12(?) (pars)

1963b Baltisphaeridium trifurcatum Eisenack in Eisenack, p. 122, pl. 1, fig. 3.

?1969 Baltisphaeridium bergstromii (Staplin et al.) Martin, p. 44, pl. 5, fig. 215; pl. 6, fig. 299.

1969 Peteinosphaeridium trifurcatum (Eis.) Staplin et al. in Gorka p. 51-3, pl. 14, fig. 3 (pars)

?1969 Baltisphaeridium trifurcatum (Eis.) subsp. typicum Eisenack in Gorka, p. 23-5, pl. 1, fig. 3 (pars)

?1971a Peteinosphaeridium trifurcatum (Eisenack) in Kjellström, p. 57-8, pl. 4, fig. 7.

1974 Peteinosphaeridium trifurcatum (Eisenack) Staplin et al. in Rauscher, p. 74, pl. 2, fig. 18.

?1974 Peteinosphaeridium trifurcatum (Eisenack) in Martin, p. 16-7, pl. 1, figs. 36, 38.

1973 Peteinosphaeridium trifurcatum typicum (Eisenack) in Eisenack et al., p. 929-30.

Again, if the I.C.B.N. is to be followed then all previous references to Baltisphaeridium trifurcatum (Eisenack) forma breviradiata Eisenack (and to Peteinosphaeridium breviradiata (Eisenaek) as it subsequently became known) must be reattributed to Baltisphaeridium trifurcatum (Eisenack) forma trifurcatum, which is the correct name for the taxon.

B. trifurcatum (Eisenack) forma breviradiata Eisenack was elevated to the rank of species and transferred to the genus Peteinosphaeridium Staplin et al. by Eisenack (1969a). The author is in agreement with the transfer to Peteinosphaeridium Staplin et al., but the taxon cannot be elevated to species rank as it contains the nomenclatural type. It may, however,revert to its original binomial status if all existing sub-species are elevated to the rank of species. As the author recommends that the taxa Peteinosphaeridium trifurcatum cylindroferum (Eisenack), and P. trifurcatum longiradiatum (Eisenack) be elevated to species rank, the taxon P. trifurcatum (Eisenack) trifurcatum may be designated P. trifurcatum Eisenack. To avoid confusion,the species is referred to elsewhere in this text as P. trifurcatum (Eisenack) (al. breviradiata Eisenack). Previous records, which are considered by the author to belong to the species, are listed in the synonymy (p. 159-160).

Peteinosphaeridium aequifurcatum Kjellström, 1971a

Pl. 20, fig. 7.

1971a Peteinosphaeridium aequifurcatum Kjellström, p. 51-52, pl. 3, fig. 12.

Original Diagnosis: Peteinosphaeridium sp. with thin, single walled, spherical to sub-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. Processes, about 10 in number, in length not exceeding the vesical diameter, psilate, no peteinos, cylindrical, broader in the middle part of the stem, homomorphic, bifurcate with acuminate furca-tips.

Description: (based on two specimens) The specimens are carbonised and have an ovate outline. In both cases the central body is ruptured, but this may be due to compression. The processes are approximately equivalent in length to half the central body diameter. The body wall is possibly of moderate thickness. In other respects the specimens are in close agreement with the above diagnosis.

Dimensions:		
	Central body diameter:	52 x 41µ
	Length of processes:	18 - 21µ
	Length of individual furcae:	8 - 12µ
	Width of processes proximally:	4µ
	Width of process stems (max.):	5.5µ

Remarks: In overall size the specimens are smaller than those of Kjellström (1971a). Because of poor preservation, wall thickness and total process number are difficult to determine.

Comparison: P. majorfurcatum Kjellström differs by having more processes, which are relatively shorter in length.

Occurrence: Hope Shales, Shropshire, U.K., Early Llanvirnian. Sample W1.

Previous Record: Grotlingbo 1, Gotland, Sweden; Middle Ordovician.

Peteinosphaeridium heteromorphicum Kjellström, 1971a

Pl. 21, fig. 1.

1971a Peteinosphaeridium heteromorphicum Kjellström, p. 53, pl. 4, fig. 2.

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 25 in number, in length about one third of the vesicle diameter, psilate, conical, heteromorphic, simple, always with bulbous distal terminations and bifurcate with acuminate furca-tips.

Description: (based on a single specimen) The central body is ovate in outline. There are at least 24 processes. They are variable in length and divide 2, 3 or 4 times distally. The furcae are sometimes strongly recurved. Other details of body and process construction correspond to the diagnosis.

Dimensions:

Central body diameter:	61.5 x 50.5μ(?)
Length of the processes:	7(13.5)16.5μ
Width of processes proximally:	2 - 4μ
Ratio of central body diameter to process length:	5.0 - 8.0 : 1 approx.

Remarks: The body outline may not have been originally ovate, as the specimen has been compressed and ruptured. Because of this distortion original dimensions are difficult to assess. Certainly, however, the

specimen is smaller than the holotype (perhaps 20% less). There also appears to be greater variation in process structure and length.

Comparison: According to Kjellström (1971a) the possession of heteromorphic processes distinguishes this species from all others.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Previous Record: Grotlingbo 1, Gotland, Sweden; Middle Ordovician.

Peteinosphaeridium hymenoferum

(Eisenack, 1938) Eisenack, 1969.

Pl. 15, fig. 8.

1938 Hystrichosphaeridium hymenoferum Eisenack, p. 19, pl. 3, figs. 2-5.

1958a Baltisphaeridium hymenoferum (Eisenack) Eisenack, p. 400.

1959 Baltisphaeridium hymenoferum (Eisenack) in Eisenack, p. 204.

1963 Baltisphaeridium hymenoferum (Eisenack) Eisenack in Downie and Sarjeant, p. 90.

1964 Baltisphaeridium hymenoferum (Eisenack) Eisenack in Downie and Sarjeant, p. 91.

1969 Peteinosphaeridium hymenoferum (Eisenack) Eisenack, p. 254.

1973 Peteinosphaeridium hymenoferum (Eisenack) in Eisenack et al, p. 903-4.

1974 Peteinosphaeridium hymenoferum (Eisenack) in Eisenack, p. 272, fig.48.

Original Diagnosis: The spherical body carries numerous radial processes which thin distally and consist of one, two, or even three stiff spine-like reinforcements which support membranes. The reinforcing spines form

either the midrib or are symmetrically placed, with the membrane stretching between them. Also, three long ribs often occur running down the edge of the membrane. At their ends the membranes are either lanceolate, with recurved hook-like spines, or, when there are two ribs, inwardly curving. In addition, irregularly arranged lateral spines occur. (transl.)

Description: (based on 2 specimens) The body outline is sub-circular, and the majority of the processes have a more or less conical or fusiform appearance with one or several central supporting ribs. Broad membranes extend laterally from these central supports and may or may not be strengthened at their edges by additional ribs. The specimens are strongly carbonised and compressed. No definite excystment structure is present.

Dimensions:

Central body diameter:	38 - 44μ
Length of processes:	8(13)15μ
Ratio of central body diameter to process length:	3.0 - 3.5 : 1

Remarks: Because of the strong carbonisation it is impossible to ascertain whether or not the supporting ribs are solid or hollow. Nor is it possible to describe their contact with the central body. Irregular openings occur in the body wall, but they are presumed due to damage during preservation.

Comparison: P. hymenoferum (Eisenack) Eisenack may be distinguished from P. bergstromii Staplin et al., by its distinctive conical or fusiform processes.

Occurrence: Menai, N. Wales, U.K.; Early Arenigian. Sample M3.

Previous Record: Baltic erratics: Ordovician (Eisenack).

Peteinosphaeridium lepton sp. nov.

Pl. 4, fig. 3; pl. 5, fig. 2; pl. 9,

figs. 7-8; pl. 13, fig. 7; pl. 15, fig. 7 (Hol.)

?1968 Baltisphaeridium trifurcatum Eisenack, pl. 24, fig. 12 (pars.)

Derivation of name: Greek, leptos, thin, small, slender, referring to the processes.

Diagnosis: Central body with an ovate or sub-circular outline. Processes moderate in number, having a slender (possibly solid) stem, and dividing distally into two or three furcae. The furcae are never strongly recurved, and usually support delicate membranes which form narrow flanges down the process stems. The membranes often have a denticulate edge. Processes are approximately one quarter of the body diameter in length. A large excystment opening (one-quarter to one-half central body diameter) may be present.

Holotype: Slide reference: M3 20 1 3 1054 395 Early Arenigian, Menai, Bangor, North Wales, U.K. N.G.R. SH 54987127

Dimensions:	Central body diameter:	44(51)63 x 34(40)46µ
	Length of processes:	5(7)9µ
	Length of furcae:	2(4)5µ
	Ratio of central body diameter to process length:	5.7 - 7.3 : 1
Holotype:	Central body diameter:	48.5 x 45µ
	Length of processes;	6(7.5)9µ
	Lenth of furcae:	4µ approx.
	Ratio of central body diameter to process length:	6.0 - 6.7 : 1

Description: The body outline is usually ovate and the wall, whilst firm, is apparently not thick. The process stems have a curving proximal contact with the central body and the area surrounding the junction may

be slightly thickened. Although masked by carbonisation, the wall appears to be either microgranulose or psilate. The delicate flange structures are often absent.

Remarks: The process shape is distinctive and even very fragmentary specimens may be identified with reasonable certainty. Eisenack (1968a) illustrates a specimen under the name Baltisphaeridium trifurcatum (Eisenack which may be the same species.

Comparison: Peteinosphaeridium nanofurcatum Kjellström differs from P. lepton sp. nov. in having lambda shaped processes with bulbous furca-tips. P. trifurcatum Eisenack (al. breviradiata) may be distinguished by its relatively robust processes.

Occurrence: Bangor, Menai and Caernarvon, N.Wales, U.K.; Arenigian. Samples B1, M2, M3, C4, C5?.

Peteinosphaeridium paucifurcatum (Eisenack, 1959) Eisenack, Cramer and Diez, 1973.

1959 Baltisphaeridium trifurcatum subsp. paucifurcatum Eisenack, p. 203, pl. 17, figs. 8–10; text-fig. 10.

1973 Peteinosphaeridium paucifurcatum (Eisenack) Eisenack et al., p. 919 –20.

Original Diagnosis: Vesicle spherical, thin walled, with ± numerous processes, which have simple, or complex terminations with short branches. The processes do not possess winged borders, and are less than half the

diameter. Pylomes are frequent, diameter about 30% of the vesicle diameter. (transl.)

Peteinosphaeridium cf. paucifurcatum (Eisenack, 1959)
Eisenack, Cramer and Diez, 1973.
Pl. 1, figs. 10–11; pl. 4, fig. 10; pl. 5, figs. 13–14.

Description: The central body is hollow, with a firm wall, and has a sub-ovate outline. The processes are few in number and have an angular or slightly curving contact with the central body. They terminate distally in two or three short recurving, acuminate, or evexate filaments. The process stems are without peteinate structures and are hollow. They may or may not communicate with the central body cavity. The processes usually attain a length between one-quarter and one-half the central body diameter. A large approximately circular opening may be present.

Dimensions:
Central body diameter: 27(29)34 x 21(23.5)26μ
Length of processes: 5(7)10μ
Ratio of central body diameter to process length: 3.3 - 4.1 : 1

Specimens measured: 5
recorded: 5

Remarks: The specimens cannot be definitely assigned to Peteinosphaeridium paucifurcatum (Eisenack) as they are considerably smaller than previous attributions to that species.

Occurrence: Caernarvon, N. Wales, U.K.; Early and Late Arenigian. Samples C4, C5, C6.

Peteinosphaeridium trifurcatum (Eisenack, 1938)

(al. breviradiata Eisenack, 1959)

Pl. 1, figs. 5–6; pl. 4, fig. 7; pl. 13, fig. 5.

1931 Ovum hispidum trifurcatum Eisenack, p. 112, pl. 4, fig. 21 (pars)

1938 Hystrichosphaeridium trifurcatum Eisenack, p. 8, pl. 2, fig. 2 (pars.)

1959 Baltisphaeridium trifurcatum forma breviradiata Eisenack, p. 202, pl. 17, fig. 7.

1963 Baltisphaeridium trifurcatum (Eisenack) forma breviradiata Eisenack in Downie and Sarjeant, p. 90.

1964 Baltisphaeridium trifurcatum (Eisenack) forma breviradiata Eisenack in Downie and Sarjeant, p. 97.

1965b Baltisphaeridium trifurcatum subsp. breviradiata Eisenack in Eisenack, p. 138, pl. 11, fig. 8; pl. 12, fig. 15.

1968b Baltisphaeridium trifurcatum (Eisenack) subsp. breviradiata Eisenack in Eisenack, p. 7, pl. 1, fig. 9; pl. 2, fig. 3.

1969 Baltisphaeridium trifurcatum (Eisenack) subsp. breviradiatum Eisenack in Gorka, p. 25–6, pl. 6, figs. 13–15.

1969a Peteinosphaeridium breviradiatum (Eisenack) in Eisenack, p. 255.

1970b Baltisphaeridium trifurcatum breviradiatum Eisenack in Lister, p. 31.

1971b Peteinosphaeridium breviradiatum (Eisenack) Eisenack in Kjellström, p. 32–4, fig. 22.

1971 Peteinosphaeridium breviradiatum (Eisenack) in Rauscher, pl. 1, fig. 3 (pars.)

1973 Peteinosphaeridium breviradiatum (Eisenack) in Eisenack et al., p. 895–6.

?1974 Peteinosphaeridium breviradiatum (Eisenack) in Martin, p. 16, pl. 1, figs. 5, 10; pl. 2, fig. 53; pl. 4, figs. 137, 144–5.

1974 Peteinosphaeridium breviradiatum (Eisenack) in Rauscher, p. 74, pl. 2, figs. 19–20; pl. 5, fig. 14(?).

Original Diagnosis: These cysts of 0.05 - 0.06 mm. shell diameter, have numerous processes of half the length of the shell radius. The processes are very regularly formed at their terminations into three short spines, which either stand vertically from the stem or make an angle of 120°. (transl.)

Description: (based on two specimens) Both specimens are compressed, strongly carbonised, and corroded. They have a sub-ovate body outline, and numerous processes (about 30–40 in optical section) which are approximately equivalent in length to one-tenth of the maximum central body diameter. Proximally the processes have an angular or slightly curving contact with the central body. Distally the processes divide into 2 or 3 short furcae. The style of this division is variable. No definite excystment structure is present.

Dimensions:		
	Central body diameter:	50(51)51.5 x 40.5(42)44µ
	Length of processes:	3.5(4.5)5.5µ
	Ratio of central body diameter to process length:	9.3 – 11.3 : 1

Remarks: Although the two specimens have many features in common (e.g. overall size and form, process length) they are not identical, one having a greater range of process styles than the other. Considering their generally poor condition, it is possible that this variation may be due, wholly or in part, to corrosion and distortion. Remnant peteinos may be present in a few cases, but most processes are certainly without these structures.

Peteinosphaeridium palmatum var. strictum Combaz and Peniguel, 1972, (nom. illegit) is similar in concept and may overlap with this species.

Peteinosphaeridium trifurcatum (Eisenack) is a new name for forms previcusly attributed to P. breviradiatum (Eisenack) Eisenack. The necessity for this change was discussed earlier (p.148-51).

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian. Sample C6, M2.

Previous Records: Baltic erratics; Ordovician (Eisenack, 1931, 1938, 1959, 1965b, 1968b, 1969a). Podborowisko 1, Poland; Late Arenigian (Gorka). ?Grotlingbo 1, Gotland, Sweden; Middle Ordovician (Kjellström)

Peteinosphaeridium velatum Kjellström, 1971a

Pl. 21, fig. 2; pl. 23, fig. 5; pl. 25, fig. 6; pl. 27, fig. 2.

1971a Peteinosphaeridium velatum Kjellstrom, p. 58, pl. 4, fig. 8.

Original Diagnosis: Peteinosphaeridium sp. with thin, single walled, ellipsoidal, shagrinate vesicle. No excystment structure recorded. Angular proximal process stem contact with the vesicle. Separation of the interior of the process stem from the vesicle cavity, Processes, about 17 in number, in length about one-third to one-quarter of vesicle diameter, psilate, peteinos ornament along the entire process stem, each velate process containing three stems, filiforme, homomorphic, trifurcate.

Description: The central body has an ovate or circular outline. The body wall appears to be firm, but only thin or moderate in thickness. The total number of processes may exceed 17. They range in length from one-sixth to one-third of the central body diameter, but are usually of fairly

constant length in individual specimens. Otherwise, the processes are more or less as described in the diagnosis. Wall textures are obscured by strong carbonisation.

Dimensions:	Central body diameter:	42(46.5)54 x 34(37)46μ
	Length of processes:	7(9)11μ
	Width of processes (maximum)	4 - 8μ approx.
	Ratio of central body diameter to process length:	4.1 - 5.2 : 1

Specimens measured: 7

recorded: 10

Remarks: The specimens are in a relatively poor state of preservation. They are carbonised, have broken processes, and have in some cases suffered deformation through an internal growth of pyrite. Details of process construction are difficult to determine. A terminal division into four filaments occurs in some cases. One specimen has a circular opening of 10μ diameter.

Comparison: Peteinosphaeridium velatum Kjellström differs from P. bergstromii Staplin et al., in having shorter processes.

Occurrence: Hope Shales and Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Samples W1, W3.

Previous Record: Grotlingbo 1; Gotland, Sweden; Lower Ordovician (Kjellström)

Peteinosphaeridium sp. A.

Pl. 1, fig. 3.

1971 Peteinosphaeridium trifurcatum (Eisenack) in Jux, p. 119-20, pl. 42, figs. 13-19; text-fig. 4.

Description: (based on a single specimen) The specimen is highly carbonised and incomplete. It has a sub-ovate outline and numerous short processes (approx. 40 in optical section). The processes are variable but usually bifurcate distally. Proximal contact with the central body is angular or slightly curving. The apparently hollow process stems are decorated by lateral thorn-like projections. The terminal furcae are recurved and in some cases appear to support delicate peteinos. No definite excystment structure is present.

Dimensions:		
	Central body diameter:	4.6 x 37.5μ
	Length of processes:	3.0 - 6.5μ(?)
	Width of processes:	1 - 2μ

Remarks: The species is distinguished from other forms by the style of its processes, and is very similar to the specimen (text-fig. 4) illustrated by Jux (1971).

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian. Sample C6.

Peteinosphaeridium sp. B.

Pl. 1, figs. 7-8.

Description: (based on two specimens). The specimens are strongly carbonised, compressed and fragmentary. The body outline is approximately ovate and the processes moderate in number (perhaps 20-30 in optical section). They have a slightly curving proximal contact, and a large distal bifurcation. The furcae recurve strongly, each furca being approximately equivalent in length to the process stem which supports it. Peteinos are absent, but the furcae and process stems are ornamented by short spines or tubercles. No definite excystment structure is present.

Dimensions:	Central body diameter:	46μ?
	Length of processes:	12 - 20μ
	Length of furcae:	12 - 15μ
	Width of process stems:	2 - 3μ

Remarks: A third specimen (sample B2, Early Arenigian) is similar in form, but lacks the prominent process ornament which distinguishes this species from previously recorded forms.

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian. Sample C6.

Peteinosphaeridium sp. C

Pl. 1, fig. 4; pl. 4, fig. 8; pl. 5, fig. 4; pl. 15, fig. 6.

Description: The central body is hollow, thick walled, and usually ovate in outline. The processes are moderate in number (perhaps 20–40 in optical section), short (one-quarter of the central body diameter or less), thick-set, and have a curving proximal contact with the central body. Distally, they divide into three or four short acuminate filaments. An ovate or circular opening is often present, approximately equivalent in diameter to one-third the central body diameter. Internal process structure and surface texture are obscured by strong carbonisation.

Dimensions:	Central body diameter:	30(40.5)4.5 x 29.5(33.5)38.5μ
	Length of processes:	4(6)8μ
	Width of processes:	2 - 2.5μ
	Length of furcae:	1.5 - 2.5μ
	Ratio of central body diameter to process length:	5.6 - 6.8 : 1

Specimens measured: 11

recorded: 19

Remarks: The specimens are similar to Peteinosphaeridium trifurcatum (Eisenack)(al.breviradiata), but differ in that their processes are usually quadrifurcate distally.

Because of poor preservation it is sometimes difficult to determine the exact number of terminal filaments developed. The specimens attributed to Peteinosphaeridium sp. C are forms in which either the majority or all sufficiently complete process terminations are quadrifurcate.

Occurrence: Bangor, Menai and Caernarvon, N. Wales, U.K.; Early and Late Arenigian. Samples M3, C4, C5, C6.

Peteinosphaeridium? sp. D

Pl. 30, figs. 2-5.

Description: The central body is hollow with an ovate or circular outline and an apparently firm smooth wall of moderate thickness. The processes are short with cylindrical stems, and a curving proximal contact. Distally, they are slightly swollen and divide into 2 or 4 slender curving pinnae orientated approximately at right angles to the stem axis. In optical section they number 15–25, and generally fall into a size range between one-fifth and one-tenth that of the central body diameter. Some specimens have processes which appear to support alae. A circular opening is sometimes present.

Dimensions:		
	Central body:	11(13)14 x 9(11)12μ
	Length of processes:	1(2)3μ
	Length of pinnae:	< 0.5μ
	Diameter of opening (when present):	2 - 5μ

Specimens measured: 8

recorded: 15

Remarks: Carbonisation has masked details of process distribution and although apparently random in some specimens, in others it is possibly linear.

Despite their small size the specimens generally show features which suggest that they should be attributed to the genus Peteinosphaeridium Staplin et al. emend Eisenack, 1969. This, however, must be considered a temporary expedient pending the examination of better preserved specimens.

Comparison: Peteinosphaeridium? sp. D differs from all previously described species of Peteinosphaeridium Staplin et al., in being much smaller in size.

Occurrence: Skiddaw Slates, Lake District, U.K.; Early Llanvirnian. Sample SAL 390.

Peteinosphaeridium div. sp.

A strongly carbonised and highly corroded specimen from sample R1 (Late Llanvirnian) is also tentatively referred to the genus on account of its outline and process construction (pl. 28, fig. 3).

Genus RECAVISENTIS gen. nov.

Derivation of Name: Latin, recavus, hollowed or arched inward, concave, referring to the concave facets of the body surface, and sentis, thorn, briar, bramble, referring to the briar-like processes. Gender masculine.

Diagnosis: Central body hollow, body outline sub-polygonal, with the development of concave facets between adjacent, widely curving, process bases. Wall single layered, smooth or micro-granulose, and either thin or of only moderate thickness. Processes, simple, tapering, acuminate, hollow, communicating freely with the body cavity, and ornamented with lateral, thorn-like projections.

Type Species: Recavisentis uncinatus Downie comb. nov. = Baltisphaeridium uncinatum (Downie) Martin, 1966a, p. 425, text-fig. 1. = Hystrichosphaeridium longispinosum var. uncinatum Downie, 1958, p. 337, text-fig. 2a, Tremadoc, Shropshire.

Remarks: The genus Uncinisphaera Wicander, 1974, differs in that the body outline is much more rounded, and the proximal process contacts less curving. Polygonium Vavrdova, 1966 emend differs in lacking prominent process decoration. The genus Tectitheca Burmann, 1968, may be distinguished by elongation of the body along the longitudinal axis.

Recavisentis uncinatus Downie, 1958 comb. nov.

Pl. 4, fig. 9; pl. 5, fig. 6(?), 8; pl. 23, fig. 8(?);
Pl. 26, fig. 8; pl. 31, fig. 4; pl. 33, fig. 3; pl. 35, fig. 3.

?1951 Hystrichosphaeridium sp., ex aff. longispinosum Eisenack, p. 191, pl. 3, fig. 7, text-fig. 1.

1958 Hystrichosphaeridium longispinosum var. uncinatum Downie, p. 337, text-fig. 2a.

1964 Baltisphaeridium longispinosum (Eisenack) var. uncinatum (Downie) Downie and Sarjeant, p. 92.

1966b Baltisphaeridium uncinatum (Downie) Martin, p. 425-6, text-fig. 1.

non 1967 ?Baltisphaeridium aff. uncinatum (Downie) in Martin, p. 310-11, pl. 1, fig. 5.

1969 Baltisphaeridium uncinatum (Downie) in Martin, p. 66-7, pl. 2, fig. 70, text-fig. 19. (pars.)

?1969 Baltisphaeridium cf. longispinosum var. uncinatum Downie in Henry, p. 77, pl. 1, fig. 8. (pars.)

1970 Micrhystridium uncinatum (Downie) Cramer, p. 108-8, text-fig. 29d. (pars.)

non 1971b Goniosphaeridium uncinatum (Martin) Kjellström, p. 27-8, fig. 18.

1974 Goniosphaeridium uncinatum (Downie) Kjellström in Rauscher, p. 97, pl. 5, figs. 5, 6.

Original Diagnosis: Test rather polygonal, thin walled; processes with numerous small lateral branches, 1 - 1.5μ in length, normal to the main process and giving it a barbed appearance.

Description: The specimens are in close agreement with the above diagnosis. Although strongly carbonised the body outline is distinctive. The processes number approximately 14 in optical section, and attain a length which, on average, is equivalent to half the central body diameter. The ornament is apparently restricted to the process stems, and consists of thorn-like elements, which may be prolonged distally into fine threads. No definite excystment structures are present.

Dimensions:		
	Central body diameter:	22(30.5)37.5μ
	Length of processes:	10(14.5)22μ
	Width of processes proximally:	1.5(2.5)3.5μ
	Height of ornament:	0.5(1.0)3.0μ
	Ratio of central body diameter to process length:	2.1 : 1

Specimens measured: 15

recorded: 20

Remarks: Most specimens are poorly preserved. Consequently surface textures are difficult to determine, and delicate ornament has survived in relatively few cases. The body wall is often pitted, and the tests of some specimens are ruptured, but both features are considered preservational in origin.

Only one of the specimens illustrated by Martin (1969), under the name Baltisphaeridium uncinatum (Downie), is considered attributable to Recavisentis uncinatus (Downie) comb. nov. The rest are here thought more likely to belong to either Uncinisphaera Wicander, 1974, or to Astropheos gen. nov. The forms attributed by Cramer (1970) to Micrhystridium uncinatum (Downie) are (except for text-fig. 29d) unlike the holotype and are considered in part attributable to Uncinisphaera Wicander, 1974.

Goniosphaeridium uncinatum (Martin) Kjellström, 1971b, has a large central body and numerous robust processes with echinate ornament. It is not here considered to be the same species as Recavisentis uncinatus (Downie) comb. nov.

Rasul (1971, MS.) considered the holotype of Recavisentis uncinatus (Downie) comb. nov. (Hystrichosphaeridium longispinosum var. uncinatum Downie, 1958, p. 337, text-fig. 2a) to be a species of the genus Tectitheca Burmann, 1968. However, after re-examination, the author considers the holotype to lack the necessary characteristics for attribution to Tectitheca Burmann, 1968. The author nevertheless agrees that the specimens illustrated by Rasul may belong to the genus Tectitheca Burmann, 1968.

The forms illustrated by Martin (1969) and described as Baltisphaeridium uncinatum (Downie) Martin are thought by Rasul (1971, MS.) to be the same as Tremadocian specimens which he attributes to Polygonium uncus Rasul (MS.). In this study only one of Martin's illustrated specimens (pl. 1, fig. 17) is regarded as a specimen of P. uncus Rasul (MS.). P. uncus Rasul (MS.) and P. elongatum Rasul (MS.) are here considered to be species of Recavisentis gen. nov. The possession of prominent surface ornament excludes them from the genus Polygonium Vavrdova as emended in this study.

Comparison: Recavisentis uncus Rasul (MS.) comb. nov. differs by having a smaller central body, more numerous processes and a less polygonal form.

Occurrence: Caernarvon, N. Wales, U.K., Arenigian. Hope Shales and Stapeley Shales, Shropshire, U.K. Llanvirnian. Skiddaw Slates, Lake District, U.K., Llanvirnian. Samples C4, C5, W1, W3, SAL 390, SAL 2778, SAL 2781.

Previous Records: (?) Jagoual, Estonia, Lower Ordovician, (Eisenack). Shineton Shales, Shropshire, U.K.; Tremadocian (Downie). Assise Condroz, Sart Bernard, Belgium; Arenigian-Llanvirnian (Martin). Mort Anglaise, Brittany, France; Lower Ordovician (Henry). Sub-surface material, Libya and/or Saudi Arabia; Upper Ordovician (Cramer).

Genus STELLIFERIDIUM Deunff, Gorka and Rauscher, 1974

Type Species: Stelliferidium striatulum (Vavrdova) Deunff, Gorka and Rauscher, 1974 = Baltisphaeridium striatulum Vavrdova, 1966, p. 411, pl. 2, fig. 3. Klabava Shales, Arenigian, Klabava, Central Bohemia.

Original Diagnosis: Shell sub-hemispherical, having a large circular or polygonal polar opening, of which the diameter is equal or greater than the radius of the shell. The opening may be closed by an operculum of the same outline as the opening, whose surface is smooth, granular or reticulate, and which is sometimes denticulate. The single or double wall of the shell is ornamented by varied processes from the bases of which a star-like system of crests diverges. The outlines of the crest systems produce a network of polygonal rings on the shell surface. A membrane can be present. (transl.)

Remarks: The genus was proposed by Deunff et al. (1974) after re-examination and regrouping of forms attributed to Priscogalea Deunff, 1961, and Cymatiogalea Deunff, 1961, emend. Deunff, 1964. (for further discussion see Cymatiogalea Deunff, 1961, emend. Deunff et al., 1974, in this study.

Stelliferidium distinctum Rasul, 1974, comb. nov.

Pl. 13, figs. 2-3(?); pl. 25, fig. 9(?); pl. 29, fig. 8;
pl. 31, figs. 1-3; pl. 33, fig. 10, pl. 34, fig. 9(?);
pl. 35, fig. 4.

1974 Priscogalea distincta Rasul, p. 50, pl. 4, fig. 1; p. 17, fig. 3.

Original Diagnosis: Spherical to hemispherical body possessing acicular, tapering processes (usually 40 in optical section), with multifurcate tips; test wall striate; opening usually polygonal. Processes are solid, thicker at their bases, and taper towards their distal ends where they usually multifurcate; sometimes a few forked or simple processes may also be present. Test wall is finely striate. These striae appear to radiate from the bases of the processes.

Description: The specimens are compressed and have a semi-circular or subcircular outline. The opening is variable, subcircular, often with a polygonal aspect. The processes are numerous. Variable in form, though generally robust, and one-quarter to one-sixth of the maximum central body diameter in length. The process stems are apparently hollow in at least some cases, are cylindrical or slightly tapering, and sometimes have slightly constricted and/or internally thickened bases. Proximal contact between stem and central body is curved. The process tips are usually multifurcate with 2 - 5 pinnae which may either diverge slightly or recurve strongly. Process stems are smooth but the body wall may be microgranulose. Linear ridge-like thickenings are arranged radially about individual process bases. Disc-like operculae are occasionally found still attached. They appear to be of even thickness from centre to rim and do not bear processes.

Dimensions:	Central body diameter:	25.5(31.5)39.5µ
	Length of processes:	4(5.5)7µ
	Width of processes:	1.0 - 2.0µ
	Length of pinnae:	0.5 - 1.5µ
	Ratio of central body diameter to process length:	5.7 : 1
	Approx. number of processes in optical section:	25

Specimens measured: 20

recorded: 51

Remarks: Rasul (1974) describes the processes as 'solid', but this does not always appear to be the case. However, as almost all specimens have suffered strong carbonisation, and because of the rather poor state of preservation of the specimens in which apparently hollow processes

were observed, the diagnosis is not emended. The species is transferred to the genus Stelliferidium Deunff et al., 1974 because of the presence of a radial ridge system about each process base, and the random process distribution.

Comparison: The multifurcate process tips distinguish Stelliferidium distinctum Rasul, 1974 comb. nov. from S. simplex (Deunff) Deunff et al., 1974 in which the tips are either undivided or simple bifurcations. S. fimbrium Rasul comb. nov. differs in having fewer somewhat longer processes which terminate in delicate threads.

Occurrence: Skiddaw Slates, Lake District, U.K.; Llanvirnian. Samples SAL 389, SAL 390, SAL 2778, SAL 2781. Also doubtful specimens from Stapeley Shales, Shropshire, U.K.; Early Llanvirnian; and Menai, N. Wales, U.K.; Early Arenigian. Samples W3 and M2.

Previous Records: Shineton Shales, Shropshire, U.K.; Tremadocian (Rasul).

Stelliferidium fimbrium Rasul, 1974 comb. nov. emend.

Pl. 9, fig. 6; pl. 27, fig. 1; pl. 35, fig. 5.

1974 Priscogalea fimbria Rasul, p. 47, pl. 3, figs. 1-2.

Emended Diagnosis: Spherical to hemispherical body with thick processes of the Baltisphaeridium type, most of which are divided into delicate filamentous threads near their distal ends. Wall thick, granular; opening usually circular, rarely polygonal. Weakly developed ridge-like thickenings radiate from the process bases. Sometimes distal branches of processes are found broken.

Description: The central body is subcircular or semicircular in outline, the operculum subcircular. The processes are approximately equivalent in length to one-quarter of the maximum central body diameter. The process stems are hollow gradually tapering, and normally slightly constricted and internally thickened at the stem bases. The contact between central body and process stem is quite angular. Although the stems are smooth the body wall is granular. The process tips divide into delicate filamentous threads which diverge and/or recurve. Linear ridge-like thickenings radiate from the bases of the processes.

Dimensions:	Central body diameter:	29.5(36)41 µ
	Length of processes:	7.5 - 10.5µ
	Width of processes:	1 - 2µ
	Length of filament threads:	2 - 3µ
	Ratio of central body diameter to process length:	approx. 4 : 1
Specimens measured:		5
recorded:		5

Remarks: The diagnosis of Rasul (1974) is emended to include reference to the radial ridge system, which careful observation has shown to be present about each process base, in the above specimens and the holotype. Transfer to the genus Stelliferidium Deunff et al. is made on the basis of the presence of this characteristic together with the random process distribution.

Comparison: The filamentous process tips and granulose body wall, are characters exclusive in combination, to Stelliferidium fimbrium Rasul, 1974, comb. nov., and therefore diagnose the species.

Occurrence: Bangor, North Wales; Stapeley Shales, Shropshire; Skiddaw Slates, Lake District; U.K.; Arenigian-Llanvirnian. Samples B1, W3, SAL 2781.

Previous Record: Shineton Shales, Shropshire, U.K.; Tremadocian (Rasul).

Stelliferidium striatulum (Vavrdova, 1966)

Deunff, Gorka and Rauscher, 1974.

Pl. 7, fig. 5; pl. 9, figs. 1-4.

1966 Baltisphaeridium striatulum Vavrdova, p. 411, pl. 2, fig. 3.

1970 Priscogalea striatula (Vavrdova) Paris and Deunff, p. 30-31.

1974 Cymatiogalea striatula (Vavrdova) Rauscher, p. 80, pl. 3, figs. 29-30.

1974 Stelliferidium striatulum (Vavrdova) Deunff et al., p. 16, pl. 6, figs. 2, 19-20.

1974 Stelliferidium striatulum (Vavrdova) in Lefort and Deunff, fig. 13.

Original Diagnosis: Shell with circular, rarely oval or subpolygonal outline, with large circular or subpolygonal opening (pylome). Number of radial appendages relatively high (about 35). 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 the base.

Description: The specimens are in reasonable agreement with the above diagnosis. The processes are numerous, and range between one-seventh and one-ninth of the maximum central body diameter in length. The stems

are hollow, cylindrical or slightly tapering and have walls not appreciably different in thickness to the body wall, which is thin. They are usually internally thickened at the proximal contact, and may occasionally be completely infilled. The processes divide at their distal terminations into 2 or 3 branches. Delicate second and third order divisions normally occur. Proximally, the contact between process stem and central body is angular, and radially aligned ridges ornament the stem bases.

Dimensions:	Central body diameter:	34(40)47μ
	Length of processes:	4(5)6μ
	Width of processes:	0.5 - 1.5μ
	Length of first order branches:	2μ approx.
	Ratio of central body diameter and process length:	approx. 8 : 1
Specimens measured:		5
recorded:		12

Remarks: Deunff et al. (1974) in a discussion of the characteristics of the genus Stelliferidium Deunff et al., describe a hexagonal ring-system of process arrangement which is clearly seen in most of the above specimens, although the network is never completely regular over the whole of the central body surface.

Comparison: Stelliferidium stelligerum (Gorka) Deunff et al. is superficially similar, but may be distinguished by its more spheroidal form, collared opening, and relatively simple process terminations.

Occurrence: Bangor, N. Wales, U.K.; Early Arenigian. Samples B1, C1.

Previous Records: Klabava Shales, Rokycany, Central Bohemia; Arenigian (Vavrdova). Montagne Noire, France; Arenigian (Rauscher).

Stelliferidium div. spp.

Five specimens are considered here, only two of which are definitely attributable to the genus Stelliferidium Deunff et al. The three remaining specimens do not appear to possess radial ridge systems around individual process bases. However, the specimens are generally corroded and strongly carbonised, and the apparent absence of this feature may simply be due to the poor preservation.

A single specimen (pl. 6, fig. 2) recovered from sample C4 (Late Arenigian) has an approximately semicircular outline (24μ x 23μ). The processes are numerous and more or less equal to one-sixth of the maximum central body diameter in length. The stems are cylindrical or slightly tapering, constricted at the base and apparently hollow. A system of radially aligned ridges is developed around each process base. Distally, few processes are complete; two of them bifurcate, but further division may have occurred. An operculum, of approximately circular outline (16μ diameter) is visible through the body wall.

Sample SAL 2781 (Late Llanvirnian) yielded a single specimen (pl. 35, fig. 8) having a central body with an almost semicircular outline, and 20-30 robust processes. The process stems are tapering, hollow, and divide distally into 2-3 recurving pinnae with acuminate tips. Stem contact with the central body is curved and a radial ridge system is developed around each process base.

Two specimens (pl. 10, figs. 9, 13) from sample B1 (Early Arenigian) have approximately circular outlines (27.5 - 32μ), large circular openings (15 - 20μ) and a moderate number of randomly distributed processes (4 - 6μ). The process stems are hollow, slightly tapering, often constricted and internally thickened at their bases, and bifurcate distally. The terminal

pinnae diverge and in some cases recurve strongly. Occasional processes may terminate simply. The body wall is slightly granular. The specimens may be the species described by Rasul (1974) as Forma 2 of Priscogalea simplex Deunff, 1961, emend Rasul, 1974.

Sample W1 (Early Llanvirnian) yielded a single specimen (pl. 22, fig. 13) having a sub-ovate outline (37 x 38μ), and hollow stemmed processes (4 - 8μ), furcate distally, and plugged at their bases. Radial ridge systems were not observed, and the specimen is only tentatively referred to Stelliferidium Deunff et al.

Genus TECTITHECA Burmann, 1968

Type Species: Tectitheca valida Burmann 1968, p. 648, pl. 6, fig. 2, Llanvirnian, Germany.

Original Diagnosis: Central body five sided in outline, divided into a conical upper and a cylindrical lower part, with the longitudinal axis shortened or extended. At different levels, in regular arrangement on the central body, are unbranched, generally long, gradually tapering processes, with their inner spaces in communication. The compressed or elongate upper part of the central body is prolonged into a single apical process the alignment of which, with the long axis of the central body, is important in orientation of the test. In the transitional region, from the conical to the cylindrical part of the central body (Mittellinie), are four processes, while around the edge of the antapical pole are two peripheral processes. The number of processes in a normal arrangement is restricted, but may vary on occasion by the insertion of additional processes at different levels on the cylindrical part of the central

body. In most cases the additional processes generally have an alternating arrangement relative to the principal processes. (transl.)

Remarks: By a reduction of the long axis of the body, the genus may be considered to intergrade with Polygonium Vavrdova 1966 (see Tectitheca contracta Burmann, in this study).

Comparison: Dasydiacrodium Timofeev ex Deflandre and Deflandre-Rigaud, may be distinguished by an absence of processes from the central region of the body. Priscotheca Deunff lacks a conical development at either termination of the long axis of the body.

Tectitheca contracta Burmann, 1968

Pl. 17, fig. 7; pl. 22, fig. 3; pl. 26, figs. 4, 9; pl. 33, fig. 9(?).

1968 Tectitheca contracta Burmann, p. 648, pl. 6, fig. 1.

Original Diagnosis: Central body five sided in outline, composed of a robust shortened conical upper part, and a compressed cylindrical lower part. (low length-ratio of conical to cylindrical parts). The conical part extends into a long, gradually tapering apical process with a conically expanded base. In the compressed middle part are four processes with two similar processes around the basal line. The gradual conical expansion of the apical process amounts to approximately one-third of the total length, or less, the basal part of the process appearing greatly expanded. (transl.)

Description: The specimens are in general agreement with the above diagnosis. The central body is hollow with a pentagonal (rarely hexagonal) outline, and acuminate processes. The proximal process contact is

always widely curved so that the bases merge imperceptibly into the central body. The single apical process is surrounded by four to seven similar processes which decorate the central portion of the body. A further two or three processes are arranged around the basal line. Both body wall and processes appear to be single layered and psilate. No excystment structure was observed.

Dimensions:	Central body:	cone height:	7(12)15µ
		cylinder length:	22(28)35µ
		width:	28(33)38µ
	Length of processes:		26(35)47µ
	Width of processes proximally:		2(3)4.5µ
	Ratio of overall central body length to process length:		1.1 : 1
	Number of processes additional to single apical process:		6 - 11

Specimens measured: 17

recorded: 65

Remarks: Although many specimens are in very close agreement with the description of Burmann (1968), there is clearly a considerable range of variability within this species. The central body often displays a regular pentagonal outline and the conical and cylindrical parts of the body therefore lack clear differentiation. Consequently the specimens are difficult to orientate. The problem may be further complicated by the apical and principal processes exhibiting very close similarity in form, and by poor preservation.

If a specimen cannot be orientated it no longer possesses an essential characteristic of the genus Tectitheca Burmann, and transfer to the genus Polygonium Vavrdova, 1966 emend. must be considered. In this study, however,

if these specimens have other features which indicate close affiliation to Tectitheca contracta Burmann they have been attributed to that species. Nevertheless, through such specimens an inter-gradation between the genera Polygonium Vavrdova, 1966 emend. and Tectitheca Burmann must be considered to exist.

Comparison: Specimens attributed to Polygonium gracile Vavrdova, 1966 emend. differ from Tectitheca contracta Burmann by being generally smaller in size and by having a regular arrangement of processes, often in a circular pattern. However, several smaller poorly preserved specimens here allocated to T. contracta Burmann do bear resemblance to P. gracile Vavrdova, 1966 emend., and are within the size range quoted by Vavrdova (1966).

It is of some importance to note that all records of P. gracile Vavrdova, 1966, and P. gracile Vavrdova, 1966, emend. are, with the exception of one doubtful specimen (possibly reworked), Arenigian or of earlier date, while T. contracta Burmann has so far only been recorded from rocks of Llanvirnian age.

Occurrence: Hope Shales and Stapeley Shales, Shropshire, U.K., Llanvirnian. Skiddaw Slates, Lake District, U.K., Llanvirnian. Samples H5, W1, W3, SAL 2778(?).

Previous Record: Arkona, G.D.R., Late Llanvirnian (Burmann).

Tectitheca sp. A

Pl. 8, fig. 1

Description: (single specimen) The central body may be regarded as composed of an upper cone and a lower truncated cone, with only

slight angularity at the juncture. An apical process surmounts the upper cone and is surrounded by five processes at the upper cone base. Four or five similar processes occupy a position just above the basal line, while an additional four processes fringe the basal line itself. The processes have expanded bases and thus, widely curving proximal contacts with the central body. All processes have suffered corrosion or breakage distally. Both body and process walls are apparently single layered and psilate or faintly granulose in texture. No excystment opening is present.

Dimensions:	Central body:	upper (cone) part-height:	9μ
		lower (cylindrical) part-length:	19μ
		width:	16μ
	Length of processes:		12+μ (broken)
	Width of processes proximally:		1 - 5μ
	Ratio of overall central body length to process length:		2.3 : 1
	Number of processes additional to apical process:		13 - 14

Remarks: The specimen is of similar general appearance to species of Tectitheca illustrated by Burmann (1968), but lacks clear differentiation of the central body into a cylindrical lower and conical upper part. In addition the total process number is considerably in excess of that of any of Burmann's described species. The specimen is compressed and damaged, although only lightly carbonised.

Comparison: In overall appearance Tectitheca sp. A resembles T. valida Burmann, but is considerably smaller in size and has many more processes.

Occurrence: Caernarvon, N. Wales, U.K., Llanvirnian. Sample C1.

Tectitheca? sp. B

Pl. 8, fig. 4.

Description: (based on two specimens) The central body is hollow with an elongate pentagonal outline, modified by compressions of the widely expanded process bases. When orientated vertically, apex uppermost, about the long axis, an upper cone and lower cylinder arrangement of the central body may be recognised. The upper cone is surmounted by a single process, with a further three to six processes surrounding the cone base. Four to six similar processes are distributed about the antapical part of the body and approximately four processes fringe the basal line. The processes are hollow with closed acuminate tips and widely curved proximal contacts. Both body and process walls appear to be single layered and psilate or slightly granulose. No excystment opening is present.

Dimensions:	Central body: upper part (cone) height:	5(5.25)5.5µ
	lower part (cylinder) length:	16(18)20µ
	width:	15(16)17µ
	Length of processes:	8(12)14µ
	Width of processes proximally:	2–3µ
	Ratio of overall central body length to process length:	1.75 – 2.1 : 1
	Number of processes additional to apical process:	11–16

Specimens measured: 2

recorded: 2

Remarks: The specimens are moderately carbonised and not well preserved. Although they have a pentagonal outline, the conical extension to the central body could be viewed as a chance compression of a large expanded process base. In addition process distribution is less regular, and total process

number much greater than in any of Burmann's described species. Generic attribution to Tectitheca Burmann is therefore uncertain.

Comparison: Tectitheca? sp. A has an overall conical outline. Tectitheca? sp. C of Potter (MS.) may be the same species.

Occurrence: Caernarvon, N. Wales, U.K., Llanvirnian. Sample C1.

Genus UNCINISPHAERA Wicander , 1974

Type Species: Uncinisphaera lappa Wicander, 1974, p. 34, pl. 18, figs. 4-6. Upper Devonian, U.S.A.

Original Diagnosis: Vesicle spherical, wall thin, granulate; numerous processes, drawn out from vesicle, opening into and communicating freely with vesicle interior; process surface echinate, processes flexible and taper to a sharp point; excystment by splitting of vesicle wall.

Remarks: Wicander (1974) distinguishes this genus from Micrhystridium Deflandre, by its granulate wall and echinate processes. It differs from the genus Polygonium Vavrdova, 1966, emend., by its more rounded form and prominent process decoration. Recavisentis gen. nov. has a less rounded outline with pronounced concavity between adjacent process bases.

Uncinisphaera? exilis sp. nov.

Pl. 7, fig. 6; pl. 17, fig. 2; pl. 23, fig. 6;

Pl. 25, fig. 4; pl. 29, fig. 1; pl. 32, fig. 9; pl. 34, fig. 4.

1970 Baltisphaeridium longispinosum Eisenack var. klabavensis Vavrdova in Burmann, pl. 18, fig. 4.

Derivation of name: Latin, exilis, thin, slender, referring to the processes.

Diagnosis: Central body hollow, with an ellipsoidal or subcircular outline. Wall thin, or of moderate thickness, apparently consisting of a single layer, smooth or microgranulose in surface texture. Processes simple, tapering, distally acuminate, moderate in number (10 to 20 in optical section), and attaining a length one-third to one-half the central body diameter. Process stems hollow, communicating freely with the central body cavity, ornamented by lateral thorn-like projections 0.5μ to 3.0μ in length. Contact between process stems and central body slightly curving.

Holotype: Slide reference: W1 20 2 0.2 1005 451. Early Llanvirnian. Hope Shales, Whitsburn Dingle, Shropshire, U.K. N.G.R. SJ 32890194

Dimensions:	Central body diameter:	32(45)60 x 24(37.5)55μ
	Length of processes:	10(13.5)32μ
	Width of processes proximally:	1 – 2μ
	Ratio of central body diameter to process length:	2.7 – 3.3 : 1
	Height of ornament:	0.5 – 3.0μ
Holotype:	Central body diameter:	55 x 41μ
	Length of processes:	14(19)22μ
	Width of processes proximally:	1 – 2μ
	Ratio of central body diameter to process length:	2.2 – 2.9 : 1
	Height of process ornament:	0.5 – 1.5μ

Specimens measured: 69

recorded: 93

Description: As diagnosis.

Remarks: The specimens are always compressed and are usually strongly carbonised. The process bases are often folded back upon the central body and this has reduced the translucency along lines concentric to the central body margin. All specimens have suffered damage (breakage or corrosion) to at least some of their processes. In addition, the wall of the central body may be completely ruptured, although it is more usual for it to display irregular cracks and splits. Undoubtedly some of these features are effects of preservation, but it is possible that rupture of the wall is associated with excystment.

The Shropshire specimens are, on average, approximately 25% larger than those derived from Lake District samples. This size difference may indicate the existence of more than one form of this species.

Although attributed to the genus Uncinisphaera Wicander, 1974, the species does not have a well developed granulose wall texture. A future investigation of better preserved material may show it to be incorrectly assigned.

Burmann (1970) illustrates, but does not describe, a specimen which she refers to as Baltisphaeridium longispinosum Eisenack var. klabavense Vavrdova, a species which is described by Vavrdova (1965) as having 'narrow sometimes thickened bases'. The specimen does not have these features. Instead the processes have a curved contact with the central body, and lack a basal constriction. From its appearance the specimen is here considered more likely to belong to Uncinisphaera? exilis sp. nov.

Comparison: Uncinisphaera? exilis sp. nov. is larger than U. lappa Wicander, and has a less granulose wall and more slender processes. Recavisentis uncinatus Downie comb. nov. differs in having a less rounded form with the development of concave facets between adjacent process bases.

Occurrence: (?) Caernarvon, N. Wales, U.K.; Hope Shales and Stapeley Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K.; Early and Late Llanvirnian. Samples C1(?), H5, W1, W3, SAL 389, SAL 2778, SAL 2781.

Uncinisphaera? sp. A

Pl. 5, fig. 9; pl. 7, fig. 1; pl. 10, fig. 1; pl. 15, fig. 1; pl. 19, fig. 11; pl. 20, fig. 8; pl. 30, fig. 1; pl. 32, fig. 8.

Description: The central body is hollow, and has a distinctly rounded, approximately circular outline. The wall is firm, moderately thick, and apparently smooth. The processes are short apparently hollow, tapering, often slender, acuminate, and attain a length which rarely exceeds one third the central body diameter. The proximal process contacts are either slightly curving or angular. Process stems are ornamented by short, lateral, thorn-like projections. No definite excystment structure is present.

Dimensions:

Central body diameter:	43(50)60μ
Length of processes:	9(13.5)18.5μ
Width of processes proximally:	1 - 3μ
Ratio of central body diameter to process length:	3.7 : 1
Height of process ornament:	< 2μ

Specimens measured: 16

recorded: 20.

Remarks: Under Uncinisphaera? sp. A are grouped large forms with a circular outline and relatively short ornamented processes. It appears highly probable that the group is a collection of several species. Some specimens, for example, have numerous relatively slender processes,

whilst others possess only a few robust processes.

All specimens are strongly carbonised, often to the extent of being rendered totally opaque. Processes are almost always broken, the point of breakage commonly occurring close to the process base. In some specimens it is only the comparatively robust processes which have survived, and low process number is not necessarily, therefore, the original condition.

It has not been possible to recognise any definite excystment mechanism in these specimens, but the central body has in all cases suffered either rupture or splitting. Considering their generally poor condition these features are regarded as a preservational defects. Because of its apparently smooth wall of moderate thickness, the species cannot be assigned to Uncinisphaera Wicander with certainty. Similar large forms, with reduced process ornament, exhibiting a slight constriction just above the process bases have been attributed to Baltisphaeridium Eisenack emend. Eisenack, 1969.

Comparison: Uncinisphaera? sp. A is distinguished from Uncinisphaera? exilis sp. nov. by its firm wall and distinctly rounded form. U. lappa Wicander, differs in being much smaller in size.

Occurrence: Bangor, Menai and Caernarvon, N. Wales, U.K.; Arenigian. Hope Shales and Stapeley Shales, Shropshire, U.K.; Llanvirnian. Skiddaw Slates, Lake District, U.K.; Llanvirnian. Samples B1, M3, C1(?), C4, H5, W1, SAL 390, SAL 2778.

Genus VULCANISPHAERA Deunff, 1961, emend. Rasul, 1976

Type Species: Vulcanisphaera africana Deunff, 1961, p. 42, pl. 2, fig. 1.

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

Remarks: The diagnosis was emended by Rasul (1976) to include forms with variable processes and central body shapes, and to exclude reference to colour.

Vulcanisphaera cirrita Rasul, 1976

Pl. 4, fig. 1; pl. 6, fig. 20(?); pl. 7, fig. 2.

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

1976 Vulcanisphaera cirrita Rasul, p. 481-2, pl. 1, fig. 3, text-fig. 1:2.

Diagnosis: Central body spherical, with processes emerging from conical protuberances and grouped in tufts of two to five; distally process tips divide into numerous filamentous threads, which form net-like structure.

Description: (based on 2 specimens and additional fragments) The central body is sub-ovate in outline. In optical section approximately 15 conical

protuberances project from the outer margin. Each protuberance is surmounted by slender, slightly tapering processes, typically 3 in number, and divergent. The processes divide repeatedly at their tips forming a mass of threads. Adjacent distal thread complexes intermesh. The central body surface has a somewhat micro-granulose appearance. No excystment structure was observed. The specimens are partially carbonised.

Dimensions:	Central body diameter:	38.5(44)48μ
	Process length:	10 - 15μ approx.
	Height of conical protuberances:	2.5μ

Remarks: The specimens have a much lower process density than the well preserved holotype.

Comparison: The species differs from Vulcanisphaera africana Deunff, in having longer processes which develop into a distal complex of filamentous threads.

Occurrence: Caernarvon, N. Wales, U.K.: Late Arenigian - Early Llanvirnian. Samples C5, C4 (fragment), C1.

Previous Records: Shineton Shales, Shropshire, U.K.; Tremadocian (Downie (1958) and Rasul (1976)).

Subgroup CORYMORPHITAE Vavrdova, 1973

Acritarchs having spherical to polyhedral vesicles, processes or other sculpture elements concentrated on several (more than two) areas adjoining corners of central body. Other parts of vesicle laevigate or with different sculpture (granulate, echinate, striate). Processes are numerous, homomorphe or heteromorphe.

Genus CORYPHIDIUM Vavrdova, 1972

1974 Octogonium Martin, p. 23.

Type Species: Coryphidium bohemicum Vavrdova, 1972, p. 84-5, pl. 1, figs. 1-2; Klabava Shales, Arenigian, Klabava, Bohemia.

Original Diagnosis: Acritarchs with polyhedral main body, angles rounded, wall thin, single layered, in places sculptured with very fine ribs. Numerous processes, equal in length, symmetrically distributed at angles of polyhedron and adjoining edges. Processes are conical, proximally opened, distally heteromorphic (truncate, bifurcate, plurifurcate).

Remarks: Vavrdova (1972) observed an opening on some specimens corresponding in position to the precingular archeopyle of fossil dinoflagellates. No such openings were observed in this study.

The genus Octogonium Martin, 1974, is a junior synonym of Coryphidium Vavrdova, 1972. It was recognised as such by Martin (1974) in an additional note (p.63).

Coryphidium bohemicum Vavrdova, 1972

Pl. 3, fig. 14; pl. 4, fig. 14; pl. 5, figs. 15–17;

Pl. 10, figs. 3–4; pl. 11, fig. 2(?); pl. 12, fig. 9(?);

Pl. 14, figs. 1–3; pl. 16, fig. 8; pl. 29, figs. 9–11.

1970 Indéterminé form A in Martin et al., p. 346, pl. 1, fig. 3.

1970 ?Baltisphaeridium obtusatum Burmann, p. 309, pl. 7, fig. 7.

1972 Coryphidium bohemicum Vavrdova, p. 84–5, pl. 1, figs. 1–2.

1974 Coryphidium bohemicum Vavrdova in Rauscher, p.79, pl.3, figs. 21–2, 27–8.

1974 Octogonium vanguestainii Martin, p. 23–4, pl. 4, figs. 119, 121, text-fig. 10.

1974 Coryphidium bohemicum Vavrdova in Cramer et al., p. 184.

1974 Coryphidium bohemicum Vavrdova in Cramer and Diez, p. 137–54

1976 Coryphidium bohemicum Vavrdova in Eisenack et al., p. 145–6.

Original Diagnosis: Outline rhombic, octagonal, or sub-polygonal, sides convex, straight or concave. Wall single-layered, with microrugulate to microstriate sculpture. Ribs are positive, closely spaced (about two microns), parallel to edges, diminishing towards angles. Numerous conical processes (usually from 40 to 60 in number) are heteromorphic, proximally opened. Distally processes are closed, truncated, bifurcate, plurifurcate (both ombrellate and roset-like), laciniate, filled at their terminations. The distribution of processes is symmetrical with an obvious concentration to the angles.

Description: The specimens conform closely to the above diagnosis. The body sides are sometimes markedly concave in outline. In such specimens the corners are accentuated and there is always a strong concentration of processes in these areas. The wall is decorated by striae, the outer ones paralleling the body outline, the inner ones incurving towards the centre.

Dimensions:	Central body:	17(19)34μ
	Length of processes:	2(3)7μ
	Width of processes:	0.5 - 1.5μ
	Spacing of striation:	<1μ
Specimens measured:	20	
recorded:	38	

Remarks: Shape, process style, process distribution and body sculpture are particularly variable in this species. It is, however, apparently restricted in range, occurring in the Arenig and possibly also in the lowest Llanvirn.

Comparison: Coryphidium bohemicum Vavrdova may be distinguished from C. elegans Cramer et al. by its variable truncate or furcate processes.

Occurrence: Bangor, Menai and Caernarvon, N. Wales; Skiddaw Slates, Lake District, U.K.: Arenigian-Early Llanvirnian. Samples B1, B2(?), M2, M3, C4, C5, C6, SAL 389.

Previous Records: Klabava Shales, Rokycany, Central Bohemia; Arenigian; Vavrdova. La Montagne Noir, Massif Central, France; Arenigian (Rauscher).

Ombret, Belgium, Caradocian - here considered reworked (Martin et al.)

Deerlijk, Belgium; Lower Llandovery - here considered reworked (Martin).

Coryphidium elegans Cramer, Allam, Kanes and Diez, 1974a

Pl. 6, fig. 15; pl. 14, fig. 4.

1974a Coryphidium elegans Cramer, Allam, Kanes and Diez, p. 184, pl. 27, figs. 12-19.

1976 Coryphidium elegans Cramer et al., in Eisenack et al., p. 147-8.

Original Diagnosis: Central body hollow, subsquare with rounded corners. The vesicles are plate-like in form, much flatter than wide. The vesicle is covered by a combination of short filose sculptural elements and short, non-accidental, low rugulae. The distribution of these sculptural elements show areas of preference: the filose sculptural complexity, quantity, and size has been found to be quite variable from specimen to specimen in the same sample. The filose sculptural elements are essentially solid, slender and vary from flexible spines to hairs; occasionally they may show some kind of tiny knob at the extreme distal termination. These elements are up to about one micron thick (about one-half micron is normal) and up to ten microns long (but generally they are shorter: three to five is normal). At their bases they are a bit wider: up to three microns; they taper rapidly. The rare knobs are about one micron in diameter in all directions. The rugulate elements are about one micron both high and wide, two or three microns apart and of variable length. Generally they are about ten microns long. The vesicle wall is about one micron thick. Mode of opening not known; no endodermal structures observed.

Description: The specimens are in close agreement with the above diagnosis. They are slightly carbonised and carry rather faint sub-parallel striations (rugulae). The processes are short (usually 2-4μ), tapering, and have a curving contact with the central body.

Dimensions:	Central body:	15.5(18)21μ
	Length of processes:	1.5(3)4.5μ
	Width of processes:	< 1μ
	Spacing of striae:	< 1μ

Specimens measured: 6

recorded: 6

Remarks: The specimens are somewhat smaller than those recorded by Cramer et al. (1974).

Comparison: See Coryphidium bohemicum Vavrdova, 1972, in this study.

Occurrence: Caernarvon and Menai, N. Wales, U.K.; Early Arenigian. Samples C4, M2.

Previous Records: Sub-surface material, Tadla Basin, Morocco; Late Arenigian - Early Llanvirnian (Cramer et al).

Subgroup DIACROMORPHITAE Downie, Evitt and Sarjeant, 1963

Acritarchs having a spherical to ellipsoidal test, without an inner body. Equatorial zone smooth or slightly wrinkled, polar areas ornamented with punctae, tubercles or spines. No openings observed.

Genus ACANTHODIACRODIUM Timofeev, 1958b ex Deflandre and Deflandre-Rigaud, 1962

Type Species: Acanthodiacrodium dentiferum Timofeev, 1958b, p. 831.

Emended Diagnosis: Globular-ellipsoidal micro-organisms; equatorial zone smooth or folded; poles similar, ornamented with hairs, spines or horns; transverse wrinkles present or absent; membrane thin or with double outline. (transl.)

Remarks: The genus was validated and the diagnosis emended by Deflandre and Deflandre-Rigaud (1962) to include, as synonyms, the genera Acanthorytidodiacrodium Timofeev, and Acanthozonodiacrodium Timofeev.

When in 1958 Timofeev proposed the genera Acanthodiacrodium and Lophodiacrodium he distinguished one from the other by differences in polar ornament. Deflandre and Deflandre-Rigaud maintained this distinction when they validated and emended the genera in 1962. Since 1962, species intermediate in character between the two genera have been discovered. The situation led Cramer (1970) to suggest an arbitrary numerical standard for polar process length, 5μ being regarded as an acceptable maximum for the ornament of Lophodiacrodium and minimum for Acanthodiacrodium.

Cramer's proposal is not here considered acceptable as the type species of Acanthodiacrodium Timofeev ex Deflandre and Deflandre-Rigaud (A. dentiferum Timofeev) would need to be transferred to the genus Lophodiacrodium Timofeev ex Deflandre and Deflandre-Rigaud, on account of possession of polar ornament less than 5μ in length. Furthermore, the problem of assigning border-line species to the appropriate genus would remain.

?Acanthodiacrodium concaviusculum Burmann, 1970

Pl. 27, fig. 3.

1970 Acanthodiacrodium concaviusculum Burmann, p. 314, pl. 17, figs. 8-10.

1976 Acanthodiacrodium concaviusculum Burmann in Eisenack et al., p. 11-2.

Original Diagnosis: Central body tetragonal, straight sided and slightly elongate. At the corners, the processes are arranged projecting away from the central body. The processes taper very little and are terminally (secondarily?) rounded. Characteristic peculiarities include the tendency

for a slight concave depression to develop near the middle part of all sides, and the presence of one or two intersecting diagonal folds in the central part of the central body. It is possible that these characters are secondary phenomena but they nevertheless repeatedly unite similar specimens. (transl.)

Description: In most features the specimens agree with the above diagnosis. The central body is rectangular in outline and compressed (primary feature?), and the four processes apparently lie in the same plane. The sides are occasionally marked by a small concave depression at the mid point, and the central body surface by one or more folds which may intersect. Processes are cylindrical to tapering with closed evexate terminations. The test surface has a microgranulose appearance, and a slit like opening along the edge of a side may be present in one of the specimens.

Dimensions:	Central body:	23(23.5)24 x 22(22.5)23µ
	Length of processes:	4(broken?) - 15µ
	Process width at base:	1.5 - 3µ
Specimens measured:	3	
recorded:	5	

Remarks: The specimens described above are only tentatively allocated to this species. Their poor state of preservation has made interpretation difficult and two of the features which diagnose the species (the tendency for a small concave depression to develop along the edges of the sides, and intersecting folds on the central body) cannot always be observed.

The attribution of this species to the genus Acanthodiacrodium Timofeev ex Deflandre and Deflandre-Rigaud may be incorrect. The original

body form is difficult to determine, but an ellipsoidal or cylindrical shape (generic diagnosis) does not seem to have been very likely.

Comparison: The species is distinguished from other similar rectangular forms, placed in the genus Acanthodiacrodium Timofeev ex Deflandre and Deflandre-Rigaud (for example, A. schmidti Timofeev, A. quadrangularis (Naumova)), by the occurrence of small depressions at the mid-points of the sides, together with the bluntly terminating processes.

Occurrence: Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Sample W3.

Previous Record: Aufschlüsse, G.D.R.; Late Llanvirnian, (Burmann).

Acanthodiacrodium costatum Burmann, 1968

Pl. 27, fig. 4.

1968 Acanthodiacrodium costatum Burmann, p. 640, pl. 1, fig. 5.

1970 Acanthodiacrodium costatum Burmann in Martin et al., p. 344-6, pl. 1, fig. 9.

1976 Acanthodiacrodium costatum Burmann in Eisenack et al., p. 15-6.

Original Diagnosis: Bipolar form with cylindrical middle part (equatorial zone), and spine-bearing hemispherical pole caps. The equatorial zone is of medium length (ratio of length to breadth = 10 : 22), and is marked by widely spaced, parallel, longitudinal ribbing. At the transition to the pole-caps, the ribs bear processes. The pole caps are provided with unbranched medium length processes, moderately close-packed, whose bases are conically expanded. (transl.)

Description: (based on a single specimen) The specimen is in close agreement with the above diagnosis, but damaged and partially overlain by debris. Approximately six processes survive at one pole, ten at the other. No excystment structure or fragmentation pattern was observed.

Dimensions:		
	Central body:	27.5 x 19μ
	Length of processes:	6 - 10μ
	Polar extension:	8μ (approx.)
	Length of equatorial zone:	11μ
	Spacing of longitudinal ribbing:	3μ
	Ratio of polar extension to length of equatorial zone:	1 : 1.4
	Ratio of central body length to breadth:	1 : 0.7

Remarks: Although there is no direct indication of process number in the original species description the illustration of the holotype suggests the presence of approximately ten processes in optical section at each pole.

Comparison: Acanthodiacrodium costatum Burmann is distinguished from A. rectinerve Burmann by its more closely spaced longitudinal ribbing, and smaller size overall.

Occurrence: Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Sample W3.

Previous Records: Arkona, G.D.R.; Late Llanvirnian (Burmann). Ombet, Belgium; Early Caradocian (Martin et al.).

?Acanthodiacrodium duplicatum Burmann, 1970

Pl. 22, fig. 11.

1970 Acanthodiacrodium duplicatum Burmann, p. 313-4, pl. 17, fig. 4.

1976 Acanthodiacrodium duplicatum Burmann in Eisenack et al., p. 17.

Original Diagnosis: Central body cylindrical, moderately elongate, with homopolar differentiation. At the corners of the flat pole caps there originate two long gradually tapering processes, so that each pole bears two pairs of processes. The central body shows very widely spaced longitudinal parallel ribbing (true distance between ribs 7μ). The method of opening is by a smooth-edged split along one of the long sides. (transl.)

Description: (based on a single specimen) The central body is compressed, hollow, with a slightly elongate, approximately rectangular outline and straight to slightly incurving sides. The wall is carbonised and apparently single layered, although original thickness is difficult to determine. The specimen is incomplete, but seems to have possessed a pair of tapering, equal length processes at each "angle" of the central body. Proximal process contacts are curved while process terminations are evexate to acuminate. The processes are apparently hollow and communicate with the internal chamber of the central body. Process and body surfaces are smooth. No definite excystment structure is present.

Dimensions:		
	Central body:	33 x 24μ
	Length of processes:	22μ
	Ratio of central body length to breadth:	1.4 : 1

Remarks: The specimen is in a poor state of preservation. The size of the central body in the described example is slightly less than that of the holotype, but the processes are considerably shorter (22μ,

compared with 40μ in the holotype). No central body striation is detectable, but this may be accounted for by the strong carbonisation.

Comparison: Only Acanthodiacrodium duplicatum var. parva Burmann, has a similar body form and appendage arrangement. A. duplicatum Burmann, may be distinguished from this species by its larger size.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Previous Record: Aufschlusse,G.D.R.; Early Llanvirnian, (Burmann).

Acanthodiacrodium rectinerve Burmann, 1968

Pl. 8, fig. 3.

1968 Acanthodiacrodium rectinerve Burmann, p. 641, pl. 1, fig. 7; pl. 7, fig. 5.

1976 Acanthodiacrodium rectinerve Burmann in Eisenack et al., p. 31.

Original Diagnosis: Bipolar form with cylindrical middle part (equatorial zone) and spine bearing hemispherical pole caps. The equatorial zone is of medium length (ratio of length to breadth = 12 : 21) and covered by widely spaced parallel longitudinal ribbing. The pole caps are covered by a moderate number of slender unbranched medium length processes which are conically expanded at their bases and taper gradually towards their tips. (transl.)

Description: (based on a single specimen) The specimen is in overall agreement with the above diagnosis, although the polar extension, length along the spinose axis, and process number (approximately ten are visible in optical section at each pole) are difficult to determine due to distortion and overlying debris. The wall of the equatorial zone is

particularly thin, and the longitudinal ribs stand out against its translucency. No excystment structure was observed.

Dimensions:	Central body:	28.5 x 22μ approx.
	Length of processes:	7μ
	Polar extension:	7-9μ
	Length of equatorial zone:	12μ
	Spacing of longitudinal ribbing:	4-5μ
	Ratio of length of equatorial zone to polar extension:	1.3 - 1.7 : 1
	Ratio of central body breadth to length:	0.77 : 1

Remarks: The specimen is in a rather poor state of preservation and length along the spinose axis is probably reduced due to distortion. The illustration of the holotype indicates the presence of approximately twelve processes in optical section at each pole.

Comparison: This species differs from Acanthodiacrodium costatum Burmann by its more widely spaced longitudinal ribbing and slightly larger size.

Occurrence: Caernarvon, N. Wales, U.K.; Early Llanvirnian. Sample C1.

Previous Record: Arkona, G.D.R.; Late Llanvirnian (Burmann).

Acanthodiacrodium simplex Combaz, 1967

1967 Acanthodiacrodium simplex Combaz, p. 14, pl. 3, figs. 44-7.

1971 . Acanthodiacrodium simplex Combaz in Rauscher, p. 293, pl. 1, figs. 18-9.

1972 Acanthodiacrodium simplex Combaz in Martin, p. 35, pl. 1, fig. 10, pl. 4, fig. 12; pl. 5, fig. 22; pl. 6, fig. 13.

1974 Acanthodiacrodium simplex Combaz in Rauscher, p. 64, pl. 1, figs. 23-6.

1976 Acanthodiacrodium simplex Combaz in Eisenack et al., p. 42-2.

Original Diagnosis: Vesicle spherical or slightly elliptical, thickness of wall approximately 1μ; presence of 1, 2 or several very short appendages (one third of the radius), slender and pointed, limited to diametrically opposed points of the vesicle (bipolarity). (transl.)

Acanthodiacrodium cf. simplex Combaz, 1967

Pl.11, figs. 8–10.

Description: The central body is hollow, compressed, with a sub-circular outline, and smooth wall of moderate thickness. The processes, always two in number, are located close to diametrically opposed points on the central body. They are slender and tapering, with acuminate tips, and between one-quarter and three-quarters of the central body diameter in length. No definite excystment opening is present.

Dimensions:		
	Central body diameter:	10(13)16μ
	Length of processes:	6(8)10μ

Specimens measured: 5

recorded: 7

Remarks: The specimens described here differ from the holotype in having a relatively small central body, but rather long processes.

Occurrence: Bangor, N. Wales, U.K.; Early Arenigian. Sample B1.

Acanthodiacrodium tasselii Martin, 1969

Pl. 3, fig. 1.

1969 Acanthodiacrodium tasselii Martin p. 126, pl. 5, figs. 223, 229, 231; pl. 6, fig. 283.

non 1972 Acanthodiacrodium tasselii Martin in Vavrdova, p.80–1, fig. 1.

1976 Acanthodiacrodium tasselii Martin in Eisenack et al., p. 45–6.

Original Diagnosis:

Central body: ellipsoidal outline, rounded poles, equatorial zone without concavity or slightly so. Length 15 to 34μ, width 14 to 29μ. The ratio of length to width is from 1.2 to 1.6

Appendages: about 15 to 20 in number at each pole, length 15 to 20μ, generally a little greater than two-thirds the length of the central body. Form conical, slender, with the bases a little flared, and fine, simple extremities.

Ornamentation: the surface of the central body shows some longitudinal wrinkles, more or less pronounced, either parallel or arranged two by two in irregular V's or X's. The surfaces of the appendages, sometimes carry fine hairs. (transl.)

Description: (based on a single specimen) The central body is hollow, ellipsoidal in outline, moderately thin walled and apparently single layered. A partial rupture is present along an irregular longitudinal line, together with an ovate opening (10 x 5μ) close to a polar–equatorial junction. Processes are hollow, tapering, distally acuminate and possess broadly curving proximal contacts. Although the processes are all similar in style, a slight size variation exists between them. The process interiors and central body cavity appear to communicate freely. The equatorial zone of the central body is marked by longitudinal striations

with a spacing of approximately 5μ. Otherwise both the process and central body surfaces are smooth at x1000.

Dimensions:	Central body:	33 x 26.5μ
	Length of processes:	12μ (approx.)
	Polar extension:	9μ
	Equatorial length:	15μ
	Spacing of longitudinal ribbing:	5μ
	Ratio of polar extension to equatorial length:	0.6 : 1
	Ratio of central body length to breadth:	1.1 : 1

Remarks: The number of processes occurring at the poles in the specimen described above (12 and 14) is less than the number quoted for the species (15 to 20 in the diagnosis of Martin). However, this discrepancy, and the reduction of process length is attributed to breakage.

Vavrdova (1972) briefly discusses the occurrence of Acanthodiacrodium tasselii Martin in the Ordovician of Bohemia and illustrates a specimen from Klabava (p. 81, fig. 1) which she assigns to the species. Although the specimen possesses several features in common with A. tasselii Martin, the present author considers that it is probably a different species, primarily because of its much shorter processes (7 to 9μ, approximately one quarter of the central body length).

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian, Sample C6.

Previous Record: Wépion, Rigenée, Sart-Bernard and Jonquoi, Belgium; Tremadocian, Arenigian, Llanvirnian and Wenlockian (Martin)

Acanthodiacrodium sp. A

Pl. 11, fig. 13.

Description: (based on a single specimen) The central body is hollow with an elongate oval outline, and straight to slightly incurving sides. The processes are slender, tapering, distally acuminate, apparently hollow, and have a sharply curved contact with the central body. Proximally the processes contain a carbonised plug of material which appears to prevent or restrict communication between the process interiors and the central body cavity. The central body surface is unormanented, but the processes bear minute lateral thorn-like projections. The body wall is ruptured but this is probably a preservational feature rather than a mode of excystment.

Dimensions:

Central body:	27.5 x 20μ
Length of processes:	8 - 10μ
Polar extension:	9μ
Equatorial length:	9.5μ
Ratio of polar extension to equatorial length:	approx. 1 : 1
Ratio of central body length to breadth:	approx. 1.3 : 1

Comparison: Acanthodiacrodium sp. A may be distinguished from A. ubui Martin by its smooth equatorial zone and smaller size. Rasul (1971, MS.) describes several Tremadocian species which possess ornament (A. irroratum, A. comptulum, A. quadrum and A. conulum), but they are distinguishable from Acanthodiacrodium sp. A by other morphological features.

Occurrence: Bangor, N. Wales. U.K.; Early Arenigian. Sample B1.

Acanthodiacrodium sp. B.

Pl. 3, fig. 2.

Description: The central body is hollow, with a slightly elongate rectangular outline. The wall is of moderate thickness and single layered. Each pole carries several (5 to 12) long, tapering, hollow processes having broadly curved proximal contacts with the central body. Distally the processes are acuminate. The equatorial zone is marked by longitudinal striations spaced at intervals of approximately 2 to 3μ, otherwise process and central body surfaces are smooth at x1000.

Dimensions:		
	Central body:	27.5 x 23μ
	Length of processes:	17.5μ (max.)
	Polar extension:	8μ
	Equatorial length:	11.5μ
	Ratio of polar extension to equatorial length:	0.7 : 1
	Ratio of central body length to breadth:	1.2 : 1

Specimens measured: 2

recorded: 2

Remarks: The specimens are fragmentary and carbonised. They resemble Acanthodiacrodium uniforme Burmann, 1968 (nom. illegit.) except that the process number is greater in Acanthodiacrodium sp. B.

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian. Sample C6.

Acanthodiacrodium sp. C

Pl. 25, fig. 7.

Description: (based on a single specimen) The central body is hollow thin walled and reniform. Each pole carries (?)10-20 short, tapering,

distally acuminate processes, which have a broadly curving proximal contact with the central body. The equatorial zone is faintly marked by longitudinal striations spaced at intervals of about 2 to 3μ. The central body and processes are otherwise smooth at x1000. No excystment structure is apparent.

Dimensions:	Central body:	36.5 x 25.5μ
	Length of processes:	6.5μ
	Polar extension:	10μ
	Equatorial length:	16.5μ
	Ratio of polar extension to equatorial length:	0.6 : 1
	Ratio of central body length to breadth:	1.4 : 1

Remarks: The specimen figured by Vavrdova (1972, p. 81, fig. 1) as Acanthodiacrodium tasselii Martin, is morphologically very similar to Acanthodiacrodium sp. C, except that the central body of the latter is slightly more elongate.

Occurrence: Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Sample W3.

Acanthodiacrodium sp. D

Pl. 8, fig. 2.

Description: (based on a single specimen) The central body is hollow, with an ovate outline and a relatively transparent equatorial region. The processes are long, hollow, tapering and number approximately 10 at each pole. They possess acuminate terminations and a broadly curved contact with the central body. The wall is apparently composed of a single layer, and there appears

to be free communication between the process interiors and the central body cavity. Evidence of excystment is lacking.

Dimensions:	Central body:	25.5 x 17.5μ reducing to 13μ in the equatorial region
	Length of processes:	12μ
	Polar extension:	9μ
	Equatorial length:	7.5μ
	Ratio of polar extension to equatorial length:	1.2 : 1
	Ratio of central body length to breadth:	1.4 : 1

Remarks: The equatorial zone has the appearance of being less carbonised than the polar regions. The condition may reflect an original variation in wall thickness between polar and equatorial regions.

Occurrence: Caernarvon, N. Wales, U.K.; Early Llanvirnian. Sample C1.

Acanthodiacrodium sp. E

Pl. 5, fig. 18.

Description: (single specimen) The central body is hollow, with a short longitudinal axis and an approximately rectangular outline. The poles are slightly convex and the equatorial zone constricted. Processes are numerous (perhaps 20 - 30 at each pole), short and thorn-like. The equatorial zone is much wider than long and marked by closely spaced striae which parallel the longitudinal axis. The wall is of moderate thickness. Both the processes and process bases are more opaque than the body wall. No definite excystment structure is present.

Dimensions:	Central body:	21 x 24μ
	Polar extension:	7 - 10μ
	Equatorial zone:	4 - 5μ
	Length of processes:	0.5 - 2.0μ
	Spacing of striae:	0.5μ approx.

Remarks: The short longitudinal axis is a notable feature in this specimen. The polar regions are separated from the equatorial zone by rather irregular lines.

Comparison: Acanthodiacrodium sp. E differs from Acanthodiacrodium sp. F in having a narrower equatorial zone and more widely spaced striations.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian. Sample C4.

Acanthodiacrodium sp. F

Pl. 18, fig. 10.

Description: (single specimen) The central body is ovate in outline, and has a distinct equatorial zone with light striation, which parallels the longitudinal axis. The processes are in the form of irregular blunt spines, perhaps numbering 20 - 25 at each pole. The wall is firm, of moderate thickness, but less opaque than the processes and process bases.

Dimensions:	Central body:	31 x 25μ
	Polar extension:	9 - 13μ
	Equatorial zone:	6 - 8μ
	Length of processes:	0.5 - 1.5μ
	Spacing of striae:	0.25μ approx.

Remarks: The specimen is slightly corroded and the processes may be longer in better preserved specimens.

Comparison: See under Acanthodiacrodium sp. E.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample H5.

Acanthodiacrodium div. spp.

The five specimens referred to here are poorly preserved and cannot be assigned with certainty to any previously described species. Their occurrence is nevertheless interesting and they are figured in the assemblages where appropriate.

A single specimen (pl. 3, fig. 3) from sample C6 (Early Arenigian) has an ovate outline (25 x 20μ) and at least eight hollow, tapering processes (8μ) at each pole. They have acuminate tips and a curving contact with the central body. The equatorial zone lacks striation. The specimen bears some resemblance to Acanthodiacrodium bullatum Rasul (1971, MS.).

Sample B1 (Early Arenigian) yielded two specimens both having an approximately ovate outline (31 x 21μ and 25 x 19μ), and slender, tapering processes at each pole) 6.5μ). The equatorial zone appears to be decorated by widely spaced striations parallel to the longitudinal axis (pl. 11, fig. 12).

A specimen having a more or less rectangular outline (37 x 21μ) was obtained from sample C1 (Early Llanvirnian). Although the specimen (pl. 8, fig. 5) is incomplete it is probable that at least four tapering processes (20 - 34μ) were present at each 'pole'. A distinct equatorial

region is absent, and the specimen has a rather flattened appearance. It is only tentatively referred to this genus. Rauscher (1974) illustrates a similar specimen (pl. 3, fig. 16).

The fragmentary and corroded specimens (pl. 12, fig. 11; pl. 28, fig. 7) from samples B2 and R1 are included primarily to indicate the occurrence of the genus in these assemblages.

Genus ARBUSCULIDIUM Deunff, 1968a

Type Species: Arbusculidium destombesii Deunff, 1968a, p. 102, figs. 1-3, 5-9, 11-14. Tremadocian, Morocco.

Original Diagnosis: Shell subcylindrical or slightly prismatic, elongate, smooth or finely reticulate, carrying a process cluster opposed at the other end by different processes. Occasionally one or several processes occur on the median part. One of the extremities has a few simple processes, enlarged at the base and slender at the tip; the other has short, ramifying processes, often bound by filaments between them, possibly able to support a membrane. Total length 30 to 90μ. (transl.)

Remarks: The sub-commission 'Acritarchs' of the C.I.M.P., Liège, 1969 recommended that disymmetrical diacrodians, if bearing simple processes, should be attributed to the genus Dasydiacrodium Timofeev, 1959, emend Deflandre and Deflandre-Rigaud, while those with simple processes at one pole and a ramifying network at the other should be placed in the genus Arbusculidium Deunff 1968a. The two genera are therefore distinguished on this feature.

Arbusculidium bicuspidatum Burmann, 1968, comb. nov.

1968 Dasydiacrodium bicuspidatum Burmann, p. 643, pl. 2, figs. 3-4.

Original Diagnosis: The cylindrical central body passes, at two peripheral locations on the apical pole, into hollow, undivided processes, without a basal constriction, which conically expand at the base and gradually taper distally. The antapical pole carries a fine network without peripheral supporting processes. However, the holotype has single supporting stays which end freely. Striation of the central body is dependant upon the degree of carbonisation during preservation and is not proven. (transl.)

Arbusculidium cf. biscuspidatum Burman, 1968, comb. nov.

Pl. 2, fig. 1.

Description: (based on two specimens) The central body is hollow, and approximately rectangular in outline. One pole (the antapical pole of Burmann, 1968) is slightly convex and bears at least 17 hollow stemmed processes which vary in size, and have curving proximal contacts. The opposite pole (the apical pole of Burmann, 1968) terminates bluntly and carries only two processes which develop and diverge from the corners of the body. They are larger than the processes of the antapical pole, but are similarly hollow and communicate freely with the central body cavity. The body wall is of moderate thickness and decorated by striae, spaced 6-9μ apart, which merge with the antapical process complex and run longitudinally for approximately three quarters the length of the body, towards the apical pole. As the specimens are strongly compressed, both sides of the body are in almost the same plane of focus and the striae of the undersurface appear to intersect those above.

Dimensions: Central body: 61.5 x 40.5μ

Length of processes at the antapical pole: 10–22μ (broken)

Spacing of striae: 6–9μ

Only one specimen was sufficiently well preserved to be measured.

Remarks: The specimens differ from Arbusculidium bicuspidatum Burmann, 1968, comb. nov. in possessing a distinctly striate central body. Burmann (1968) however, considered that the absence of striae in specimens from the Grifferschiefer could be due to their carbonised state. The better preserved of the two specimens described above is also somewhat larger than the holotype of A. bicuspidatum Burmann, 1968, comb. nov.

As all major process terminations are missing, the possibility that the above specimens correspond to the form Dicrodiacrodium bicrure Burmann cannot be excluded. However, a strong divergence of the two major processes and a domed antapical pole are features more indicative of Arbusculidium bicuspidatum Burmann, 1968, comb. nov.

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian. Sample C6.

Genus DICRODIACRODIUM Burmann, 1968

Type Species: Dicrodiacrodium ancoriforme Burmann, 1968, p. 643–4, pl. 3, fig. 1; pl. 7, fig. 2a–c. Late Llanvirnian, Arkona, G.D.R.

Diagnosis: Heteropolar form with a distinctly elongate oval, or cylindrical central body. The apical pole carries one, two or more processes. The termination divides palmately into simple filaments. The length ratio of apical process to central body is variable (about 0.2 : 1). The central body is smooth or marked with parallel longitudina

ribs, and is rarely sculptured. The antapical pole carries a lattice, usually only at the pole, but it may also spread onto the central body. The lattice consists only of delicate arches and stays, or is borne by strong supporting processes (two main peripheral processes and/or several finer processes). (transl.)

Remarks: To accomodate the forms which she considered attributable to this genus, Burmann (1968) proposed two species and three varieties for single apical process types, and a further three species and one variety for types with numerous apical processes. Only those forms possessing a single apical process have been encountered in this study. Similarly, Cramer et al. (1974a) comment that forms with numerous processes were absent from Moroccan sub-surface material (Arenigian-Llanvirnian). Cramer et al. (1974a) also remark that they were unable to distinguish the taxa of Burmann (1968) due to the presence of transitional forms. Most of the specimens met with in this study can be assigned to one or other of the species proposed by Burmann (1968) without great difficulty. Whilst, therefore, the occurrence of transitional forms is recognised as a possibility, the taxa of Burmann (1968) are here maintained. Eisenack et al. (1976) also retain the species proposed by Burmann (1968).

?Dicrodiacrodium ancoriforme minutum Burmann, 1968

Pl. 32, fig. 3.

1968 Dicrodiacrodium ancoriforme var. minutum Burmann, p. 644, pl. 5, fig. 5.

1974 Dicrodiacrodium ancoriforme Burmann in Cramer et al., p. 188. (pars.)

1976 Dierodiacrodium ancoriforme minutum Burmann in Eisenack et al., p. 207-8.

Original Diagnosis: The heteropolar differentiated central body is apically rather sharply domed, and antapically slightly arched. The apical process is relatively short but strong, without taper, and divides terminally into about six simple filaments. The marked translucency of the test is accentuated by the strongly pigmented process base. The antapical pole carries an incomplete, poorly preserved, closely meshed network, without supporting processes. (transl.)

Description: (based on a single fragmentary specimen) The central body is an elongate oval, terminating rather bluntly at the antapical pole, which carries an imperfect network of fine irregularly branched processes. The apical pole is incomplete although its termination appears to have been rather acute. The apical process is missing. No longitudinal ribbing is detectable and no excystment structure was observed.

Dimensions: Central body: 35+ x 20µ

Length of apical process: unknown

Remarks: This very fragmentary specimen is tentatively referred to Dicrodiacrodium ancoriforme minutum Burmann, primarily because of its relatively small size. The antapical pole is less flattened than in the holotype. Carbonisation and damage to the test make it impossible to comment on original transparency, pigmentation, and form of the apical process.

Comparison: According to Burmann (1968) Dicrodiacrodium ancoriforme minutum Burmann, though similar to D. ancoriforme Burmann var. ancoriforme nom. nov. in general appearance, differs by its much smaller size.

Occurrence: Skiddaw Slates, Lake District, U.K.; Late Llanvirnian, (Burmann). Subsurface material, Tadla Basin, Morocco, and in Tunisia; Arenigian - Llanvirnian and Llanvirnian; (Cramer et al.).

Dicrodiacrodium normale doliiforme Burmann, 1968

Pl. 33, figs. 5-6.

1968 Dicrodiacrodium normale var. doliiforme Burmann, p. 645, pl. 3, figs. 5-6.

1974 Dicrodiacrodium ancoriforme Burmann in Cramer et al., p. 188 (pars.)

1976 Dicrodiacrodium normale doliiforme Burmann in Eisenack et al., p. 219-20.

Diagnosis: Heterpolar differentiation of the central body, barrel-shaped in outline, with widely spaced, parallel, longitudinal ribbing. The apical process is relatively short (low length ratio of process : central body), and terminally divides palmately into several filaments. The base is strongly pigmented. The antapical pole carries a fine mesh without additional processes. (transl.)

Description: Three specimens agree with the above diagnosis, although strong carbonisation has masked the longitudinal ribbing of the central body. The ratio of central body width: length is low, the central body being almost circular in outline. The test surface appears smooth at x1000. No excystment structures are apparent.

Dimensions:

Central body::	33(36)40.5 x 31(34)38.5µ
Length of apical process:	14.5(15)15.5µ
Ratio of width to central body length:	0.94 : 1
Ratio of process length to central body length:	0.42 : 1

Specimens measured: 3

recorded: 4

Remarks: The specimens are 20 - 35% smaller than the holotype.

Comparison: See D. normale Burmann, var. normale nom. nov.

Occurrence: Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Sample SAL 2778.

Previous Records: Arkona, G.D.R.; Late Llanvirnian (Burmann). Subsurface material, Tadla Basin, Morocco and in Tunisia; Arenigian-Llanvirnian and Llanvirnian, respectively (Cramer et al.)

Dicrodiacrodium normale cylindricum Burmann, 1968

Pl. 34, fig. 7.

1968 Dicrodiacrodium normale var. cylindricum Burmann, p. 645, pl. 3, figs. 3-4; pl. 7, fig. 3.

1974 Dicrodiacrodium ancoriforme Burmann in Cramer et al., p. 188 (pars.)

1976 Dicrodiacrodium normale cylindricum Burmann in Eisenack et al., p. 217-8.

Original Diagnosis: Heteropolar differentiation of the central body, the middle part cylindrical, with strongly domed pole-cap, antapically rather flattened, with or without widely-spaced, longitudinally directed, parallel ribbing. The moderately long (intermediate ratio of process length to central body length) and rather stout apical process, terminally divided into about six simple, gradually tapering filaments. The base is strongly pigmented. The network of the antapical pole branches freely, and is in part loose meshed without process rods. (transl.)

Description: A single specimen conforms to the above diagnosis. The process termination is unfortunately absent and the test carbonised. However a longitudinal lineation is detectable on the central body with a spacing of 3-5μ. Apart from this light ribbing the test surface appears smooth. The antapical net is well developed extending for up to 15μ. No excystment structure is apparent.

Dimensions:

Central body:	44 x 29.5μ
Length of apical process:	not known
Ratio of central body length to width:	1 : 0.67

Remarks: In size the specimen is closely comparable to the paratype, though 15-20% smaller than the holotype.

Comparison: See D. normale Burmann var. normale nom. nov.

Occurrence: Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Sample SAL 2781.

Previous Records: Arkona, G.D.R.; Late Llanvirnian (Burmann). Subsurface material, Tadla Basin, Morocco, and in Tunisia; Arenigian-Llanvirnian, and probable Llanvirnian, respectively. (Cramer et al.).

Dicrodiacrodium normale Burmann, 1968, var normale nom. nov.

Pl. 26, fig. 5(?); pl. 33, fig. 4.

1965 Dadydiacrodium sp., in Vavrdova, p. 356, pl. 2, fig. 2.

1968 Dicrodiacrodium normale Burmann, p. 644-5, pl. 3, fig. 2.

1974 Dicrodiacrodium ancoriforme Burmann in Cramer et al., p. 188 (pars.)

1976 Dicrodiacrodium normale Burmann in Eisenack et al., p. 215-6.

Original Diagnosis: Heteropolar central body, elongately oval tapering to a slight dome at the apical pole. Central body lined with parallel longitudinal ribbing with a separation of approximately 7μ. The medium length, moderately strong, simple, apical process divides palmately into about six simple filaments. A constriction at the base of the process is not clearly recognisable. However, there is strong pigmentation of the base. The antapical pole carries a fine compact mesh. Supporting processes are absent. (transl.)

Description: Four fragmentary and carbonised specimens were encountered, which are in general agreement with the above diagnosis. One specimen lacks discernible longitudinal striation. However, this is believed to be due to the strong carbonisation and resulting opacity. No other surface ornament is apparent, and definite excystment structures were not observed.

Dimensions:		
	Central body:	44(46)48.5 x 26.5(27)28μ
	Length of apical process:	20μ (only one process available for measurement)
	Ratio of width to central body length:	0.61 : 1
	Ratio of process length to central body length:	0.43 : 1

Specimens measured: 2

Remarks: The specimens are 20 - 30% smaller than the holotype.

In accordance with Articles 25 and 26 of the I.C.B.N. the name of this taxon is changed to Dicrodiacrodium normale Burmann var. normale.

Comparison: The elongate oval outline is characteristic of Dicrodiacrodium normale Burmann var. normale nom. nov., and serves to distinguish it from

D. normale cylindricum Burmann, which has a cylindrical central body. D. normale doliiforme Burmann has a smaller central body length to width ratio than either of the two aforementioned species.

Occurrence: Skiddaw Slates, Lake District, U.K.; Stapeley Shales, Shropshire, U.K.; Llanvirnian. Samples SAL 2778, W3(?).

Previous Records: Arkona, G.D.R.; Late Llanvirnian (Burmann). Sub-surface material, Morocco and Tunisia; Late Arenigian - Early Llanvirnian (Cramer et al.). Klabava Shales and Bohdalec Shales, Bohemia. Arenigian, Caradocian (Vavrdova).

Genus SCHIZODIACRODIUM Burmann 1968

Type Species: Schizodiacrodium ramiferum Burmann, 1968, p. 642, pl. 1, figs. 3-4. Arenigian, Vogtland, G.D.R.

Original Diagnosis: Test bipolar, the poles are separated by an equatorial zone and carry bisymmetrically arranged branching processes which divide distally. (transl.)

Remarks: The genus differs from Acanthodiacrodium Timofeev 1958, emend. Deflandre and Deflandre Rigaud, 1962, in possessing processes which divide distally.

Schizodiacrodium sp. A.

Pl. 3, fig. 6.

Description: (based on a single specimen) The central body is hollow, with a slightly extended ovate outline, and wall of moderate thickness. The processes are concentrated at two poles, separated by an intermediate equatorial zone more or less devoid of processes, but with the possibility of closely spaced longitudinal striation. The processes number approximately

20 - 30 at each pole, each process having a hollow, slender, tapering stem, not exceeding one-sixth of the axial diameter in length. Distally the processes are slightly swollen at the tip and may carry a minute bifurcation or trifurcation. Details of internal structure are masked by carbonisation. No definite excystment structure is present.

Dimensions: Central body: 25 x 22μ

Length of processes: 3 - 4μ

Length of polar extension: 7.5μ

Length of equatorial zone: 10μ

Remarks: There are indications of fine longitudinal striation in the equatorial region, but in general such detail is obscured by strong carbonisation and corrosion.

Rasul (1970, MS.) records a single specimen from the Tremadocian (p. 155, pl. 19, fig. 6) which closely resembles the above specimen.

Comparison: Schizodiacrodium sp. A is superficially similar to Schizodiacrodium inexpectatum Burmann, but differs in being considerably smaller in size, and in having a less elongate central body.

Occurrence: Caernarvon, N. Wales, U.K.; Early Arenigian. Sample C6.

Schizodiacrodium sp. B

Pl. 1, figs. 1-2; pl. 5, fig. 11; pl. 15, fig. 5.

Description: (based on four fragmentary strongly carbonised specimens) The compressed central body appears to have had a more or less rectangular outline with three, or possibly four processes, at each of the two poles along the longitudinal axis. The processes are broad and hollow, and

open directly into the central body cavity. At their tips they divide into 2 to 4 pinnae, which diverge to form an acute angle with the stem axis. The processes do not exceed the central body in length. Proximally the process stems pass smoothly into the central body. No definite excystment structure is present.

Dimensions:	Central body:	45 x 32μ (?)
	Length of processes:	18.5μ (?)
	Length of pinnae:	6μ
	Ratio of central body length to process length:	approx. 2.5 : 1

Remarks: A specimen having similar characteristics is recorded by Cramer et al. (1974) from the Late Arenigian to the Early Llanvirnian of Morocco (Schizodiacrodium sp., pl. 25, fig. 3).

Comparison: The broad-stemmed pinnate processes of Schizodiacrodium sp. B are sufficient to distinguish it from all other described species of this genus.

Occurrence: Menai and Caernarvon, N. Wales, U.K.; Early Arenigian. Samples M3, C4, C6.

Subgroup HERKOMORPHITAE Downie, Evitt and Sarjeant, 1963.

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

Genus · CYMATIOGALEA Deunff, 1961 emend.

Deunff, Gorka and Rauscher, 1974

Type Species: Cymatiogalea margaritata Deunff, 1961, p. 41-2, pl. 1, fig. 1. Tremadocian, N. Africa.

Emended Diagnosis: Vesicle subhemispherical comprising a large polar opening, circular or polygonal, the diameter of which is equal or greater than the radius of the vesicle. The opening may be closed with an operculum. The surface of the vesicle is divided into polygonal fields the margins of which carry processes, which may or may not be supported by a membrane network. (transl.)

Remarks: The genus Cymatiogalea was introduced with Priscogalea by Deunff (1961) to accomodate spherical and subspherical Palaeozoic forms having a large circular opening, closed by an operculum. Cymatiogalea Deunff was distinguished from Priscogalea Deunff by the presence of membranes which, with the processes, were often seen to define polygonal areas on the central body surface.

Although nomenclaturally valid their introduction was much criticised by later authors. Deunff (1961) had considered the genera to be Palaeozoic counterparts of Galea Maier, 1959, and this was reflected in his choice of names. Galea Maier had been introduced for certain subspherical Mesozoic and Tertiary species having a large circular to oval opening. However, the genus Galea was considered systematically unjustified (see Gerlach (1961), Eisenack (1962)), because it was primarily based on the presence of a pylome a feature which was present in other previously introduced genera. In addition the name was preoccupied, and usage in the sense of Maier was invalid. Although these criticisms of Galea Maier did not invalidate

Priscogalea Deunff and Cymatiogalea Deunff, their introduction unfortunately tended to perpetuate the nomenclaturally incorrect genus Galea. Furthermore, Priscogalea Deunff and Cymatiogalea Deunff were also subject to the criticism that a primary characteristic, the large pylome, was not unique.

Deunff (1964) considered that his critics had over emphasised the importance of the pylome, and had paid insufficient attention to other differences. He nevertheless conceded that the genus Priscogalea Deunff, as defined, was not distinguishable from Baltisphaeridium Eisenack, 1958, and he consequently proposed that the genus be abandoned, with four species being transferred to Baltisphaeridium Eisenack, 1958, and four to Cymatiogalea Deunff emend. The emendation to Cymatiogalea Deunff laid greater stress on the presence of polygonal fields on the central body surface, a feature which clearly distinguished the genus from Baltisphaeridium Eisenack, 1958. Cymatiosphaera O. Wetzel, 1933, was considered to differ in lacking a pylome.

In spite of the proposed abandonment of Priscogalea Deunff, several authors considered the genus to be worthy of conservation ,and it continued in use (see, for example, Martin, 1969; Loeblich, 1970).

More recently (1974), the species attributed to both genera have been studied in considerable detail by Deunff, Gorka and Rauscher, using the scanning electron microscope. Their observations revealed that the species could be divided into two groups, as follows:

1. Forms in which the vesicle surface was divided into a number of polygonal fields, bounded by processes, with or without the addition of membranes.

2. Forms in which the processes had a star-like arrangement of radial ridges at their bases, with or without the addition of membranes.

The first group corresponded with the genus Cymatiogalea Deunff emend. Deunff, but a further emendation was considered necessary in order to lay additional emphasis on the requirement of process bounded polygonal fields. Forms of the second group were attributed to a new genus, Stelliferidium Deunff et al.

During this reassessment, the type species of Priscogalea Deunff, P. barbara Deunff, was rediagnosed as having processes which outlined polygonal fields on the vesicle surface. As this feature, with hemispherical form, is diagnostic of Cymatiogalea Deunff emend. Deunff et al., P. barbara Deunff was transferred to this genus. The move necessitated the reattribution of the other species of Priscogalea Deunff, some being transferred to Cymatiogalea Deunff emend. Deunff et al., and some to Stelliferidium Deunff et al.

If the rediagnosis of the type species of Priscogalea Deunff is accepted, then clearly the genus must be abandoned. Stelliferidium Deunff et al. is nomenclaturally correct and appears systematically justified in view of the fact that at least eight species are known to possess random process distribution, radial ridge systems, and a large, more or less circular, opening (see Deunff et al., 1974, p. 14-6). In addition, two of the species recently introduced by Rasul (1974) (Priscogalea distincta Rasul, and P. fimbria Rasul) also appear to be attributable to Stelliferidium Deunff et al.

The work of Rasul (1974), and the emendations to Priscogalea Deunff and Cymatiogalea Deunff proposed by him, were to some extent

out-dated by the detailed study of Deunff et al. (1974), and consequently are not here accepted.

Cymatiogalea granulata Vavrdova, 1966

1966 Cymatiogalea granulata Vavrdova, p. 412, pl. 3, fig. 2.

Original Diagnosis: Shell with circular, rarely oval or subpolygonal outline, with large circular or subpolygonal opening (pylome). Surface of the shell divided into large polygonal fields. Sutures of fields provided with relatively high (about 12μ) thin membranes, supported by long variably branched processes. Small verrucae (1-2μ) are regularly placed on the shell surface.

Cymatiogalea cf. granulata Vavrdova, 1966

Pl. 6, fig. 1.

Description: (based on a single specimen) The central body is hollow with a subcircular outline. The body wall is apparently single layered and of moderate thickness, and has a well developed ornament of granules. The processes are approximately one-quarter of the maximum central body diameter in length, and by their arrangement define polygonal fields on the central-body surface. The process stems are hollow, slightly tapering and usually divide distally. The terminal pinnae diverge and may recurve. The proximal contact between stem and central body is slightly curving.

Dimensions:		
	Central body:	27.5 x 23μ
	Length of processes:	6(7)8μ
	Length of terminal pinnae:	1 - 3μ
	Ratio of central body diameter to process length:	2.8 - 4.6 : 1

Remarks: Though otherwise reasonably preserved the specimen has suffered some carbonisation. It differs from the specimens described by Vavrdova (1966) in that the processes do not support membranes. The membranes are described by Vavrdova as thin and their absence may be due to imperfect conditions of fossilisation.

Also worthy of note are the rather short processes and relatively small body size. The original shape of the opening cannot be determined because of its compressed state.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian. Sample C4.

Cymatiogalea cuvillieri (Deunff, 1961) Deunff, 1964

Pl. 10, fig. 11.

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

1964 Priscogalea cuvillieri Deunff in Downie and Sarjeant, p. 141.

1964 Cymatiogalea cuvillieri (Deunff) Deunff, p. 124, pl. 1, figs. 2-3.

1970 Cymatiogalea cuvillieri (Deunff) in Martin et al., p. 346, pl. 1, fig. 1.

1972 Priscogalea cuvillieri Deunff in Martin, p. 17-8, pl. 3, figs. 11, 15; pl. 4, figs. 3-4, 11, 17, 19; pl. 5, figs. 23, 28; pl. 6, fig. 5; pl. 9, fig. 6; text-figs. 6-7.

1974 Cymatiogalea cuvillieri (Deunff) in Deunff et al., p. 11, pl. 6, figs. 6-8.

Emended Diagnosis: (Deunff, 1964) Shell spheroidal, 20 to 25μ in diameter, having at one pole a sub-circular opening of about 16μ in diameter, frequently provided with an operculum of 10 to 15μ in diameter.

The surface of the shell is covered with polygonal fields, of which the boundaries are formed by more or less delicate, low irregularities or granulations of 1μ in height, three to five in number per boundary.

(transl.)

Description: (based on a single specimen) The central body is hollow and has a more or less subcircular outline. The wall appears single layered and of moderate thickness. Granules define polygonal areas on the surface of the test. The body wall is otherwise microgranulose or psilate.

Dimensions:		
	Central body diameter:	35 x 27.5μ
	Height of granules:	1μ
	Number of granules per boundary:	approx. 3-5

Remarks: The specimen is moderately carbonised.

Comparison: According to Martin (1972) the species is distinguishable from Priscogalea cuvillieri furcata Martin by its larger size and greater development of ornament, and from Priscogalea aff. cuvillieri Deunff by its shorter spines.

Occurrence: Bangor, N. Wales, U.K.; Sample B1. Early Arenigian.

Previous Records: Argiles d'El Gassi, Sahara; Tremadocian; (Deunff, 1961), Ombret, Belgium; Caradocian - here considered reworked; (Martin et al.). Montagne Noir, France; Lower Ordovician; (Martin).

Cymatiogalea ancora Paris and Deunff, 1970

1970 Cymatiogalea ancora Paris and Deunff, p. 34-5, pl. 2, fig. 22, pl. 3, figs. 1a-b.

Original Diagnosis: This organism of clear brown colouration, carries long processes, terminated by 2 or 3 spines which are usually recurved. This extremity has the form of a grapnel. The sides of the opening appear to show a thickening and to carry 6 processes arranged at the angles of a hexagon. Seven other processes are placed on the periphery of the shell. Finally, one can see 4 long processes on the pole opposite the opening. The remains of veils, which probably connected the various processes, are also seen in the organism described.

(transl.)

Cymatiogalea cf. ancora Paris and Deunff, 1970

Pl. 6, fig. 14; pl. 10, figs. 6, 12.

Description: The central body is hollow, thin walled, apparently single layered and has a polygonal appearance. The process stems are hollow tapering, variable in width, and have a curved contact with the central body. The processes divide at their tips into two or three recurved pinnae. The body wall has a slightly granular appearance.

Dimensions:	Central body diameter:	16(18)21μ
	Length of processes:	4.5(6)8μ
	Width of processes:	1 - 2μ
	Length of pinnae:	2 - 4μ

Specimens measured: 3

recorded: 4

Remarks: The specimens are fragmentary and carbonised. In body outline, process style, and process number, they correspond to Cymatiogalea ancora Paris and Deunff. However, the processes do not

appear to be systematically arranged, and are also rather short relative to body diameter. In addition, body size is small relative to the specimens described by Paris and Deunff (1970).

Occurrence: Bangor and Caernarvon, N. Wales, U.K.; Early and Late Arenigian. Samples B1, C4.

Subgroup NETROMORPHITAE Downie, Evitt and Sarjeant, 1963

Acritarchs having an elongate to fusiform test, without an inner body. Surface generally smooth, rarely granular. One or more spines, closed distally, may be present at one or both poles. Openings not observed.

Genus LEIOFUSA Eisenack, 1938 emend. Cramer, 1970

Type Species: Leiofusa fusiformis (Eisenack) Eisenack 1938, p. 28 = Ovum hispidum fusiformis Eisenack 1934, p. 65, pl. 4, fig. 19. Silurian, Baltic.

Emended Diagnosis: Vesicle hollow, fusiform with simple pointed processes at each pole. Processes varying in length from less than one tenth to as much as 5 times the length of the body. Vesicle wall unilayered, psilate to microgranulate. Sculptural elements not arranged in longitudinal rows. The long axis of the vesicle coincides with the longitudinal vesicles symmetry axis. Vesicle symmetry longitudinal, holomorphic. Longitudinal axis straight or essentially so. Pylome circular, slit shaped or formed by equatorial splitting.

Remarks: The emendation differs from the original diagnosis in allowing micro-gramulation of the test, and in its attention to other minor details. The genus Navifusa Combaz et al., 1967 differs by its elongate elliptical form without processes.

Leiofusa sp. A

Pl. 20, fig. 3; pl. 27, figs. 13-14.

Description: The central body is hollow, thin walled and fusiform in outline. At each pole there is a slender, tapering, acuminate process, the length of which does not usually exceed that of the central body. The wall is single layered and smooth at the surface. No definite excystment structuré is present.

Dimensions: Central body: 12(13.5)14.5 x 7.5(9)10μ

Process length: 7(9.5)14μ

Specimens measured: 4

recorded: 9

Remarks: The specimens are corroded but not strongly carbonised. Some have suffered deformation through the internal growth of pyrite. Their small size eliminates most possibilities of attributing them to previously described species.

Comparison: Leiofusa ampulliformis Martin, 1965, differs in possessing microgranulation of the body wall.

Occurrence: Hope and Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Samples W1, W3.

Leiofusa div. spp.

The five specimens considered here are all poorly preserved and partly because of this cannot positively be attributed to any previously described species. As such, they do not warrant separate detailed description. Nevertheless, they are interesting as indicators of the occurrence of this genus and are figured in the assemblages where appropriate.

A single specimen (pl. 2, fig. 10) recorded from sample C6 (Early Arenigian) has a hollow central body (12 x 11μ) with fusiform outline, and long, slender (hollow?) processes (23μ), which taper to an acuminate tip. The body wall has a smooth surface. The specimen differs from Leiofusa sp. A in being rather less elongate in the body and in possessing longer processes. Rasul (1971, MS.) illustrates a somewhat similar specimen (pl. 24, fig. 1), which is referred to as Leiofusa cf. banderillae Cramer, 1964.

Two other specimens (pl. 2, figs. 8-9) from sample C6 (Early Arenigian), have fusiform outlines, hollow central bodies (22 x 12.5μ) and short, tapering processes (7μ) with acuminate tips. The body wall appears smooth at x1000. They are distinguished from Leiofusa sp. A by their larger body size.

Sample W1 (Early Llanvirnian) yielded two specimens (pl. 22, fig. 2) both heavily carbonised and corroded. Few features remain except their fusiform outline and large size (230 - 322μ x 37 - 55μ). They occurred with other broadly spindle-shaped forms, interpreted as rolled leiospheres.

Genus PIREA Vavrdova, 1972

Type Species: Pirea dubia Vavrdova, 1972, p. 83, pl. 1, fig. 4. Arenigian, Central Bohemia.

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: The circumscription of this genus is similar to that of Deunffia Downie, 1960, but differs on the question of process termination. In Deunffia Downie the apical process is described as terminating in a point or branches, whilst in Pirea Vavrdova it is described as clavate or capitate. This distinction between the two genera is to some extent lost if the emendation of Deunffia Downie, 1960, by Cramer (1970) is followed.

Burmann (1970) attributes nine species to the genus Deunffia Downie. They are here considered to be species of the genus Pirea Vavrdova, 1972 and are transferred as follows.

Pirea ambigua Burmann comb. nov.	= =	Deunffia ambigua Burmann, 1970
Pirea capitata Burmann comb. nov.	=	Deunffia capitata Burmann, 1970
Pirea capitulifera Burmann comb. nov.	=	Deunffia capitulifera Burmann, 1970
Pirea colliformis Burmann comb. nov.	=	Deunffia colliformis Burmann, 1970
Pirea inflata Burmann comb. nov.	=	Deunffia inflata Burmann, 1970
Pirea lagenaria Burmann comb. nov.	=	Deunffia lagenaria Burmann, 1970
Pirea nervata Burmann comb. nov.	=	Deunffia nervata Burmann, 1970
Pirea ornata Burmann comb. nov.	=	Deunffia ornata Burmann, 1970
Pirea transitoria Burmann comb. nov.	=	Deunffia transitoria Burmann, 1970

With the exception of Deunffia monocantha (Deunff) Downie, all species which remain attributed to the genus Deunffia Downie, are restricted to the Silurian.

Pirea dubia Vavrdova, 1972

1972 Pirea dubia Vavrdova, p. 83, pl. 1, fig. 4.

Original Diagnosis: Shell more or less elongate, outline oval with short conical apical horn. Horn broad-based, tapering gradually from main body, distally closed, slightly widened (clavate). Antapical end broadly rounded. Wall thin, single-layered, smooth or granulate (about 50% of specimens). No regular opening observed.

Pirea cf. dubia Vavrdova, 1972

Pl. 22, fig. 12.

Description: (single specimen) The central body is hollow, thin walled, and ovate in outline. The process is hollow, tapering and swollen at the tip. Communication between the process interior and central body cavity is unrestricted. The process stem has a curving contact with the central body and merges into it smoothly. The body wall is psilate or slightly granulose, and ruptured by a split which parallels the longitudinal axis. The body is deformed by an internal growth of pyrite.

Dimensions:		
	Central body: (length includes process)	41 x 17.5μ
	Width of process:	2.5μ (approx.)
	Width of process at tip:	3.5μ

Remarks: The specimen, although falling within the quoted size range for Pirea dubia Vavrdova, is small for this species. In addition, Vavrdova's illustration of the holotype suggests a rather narrow, more rapidly tapering process without a definite terminal swelling.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Pirea sp. A

Pl. 22, fig. 9.

Description: (single specimen) The central body is hollow and has a more or less pyriform outline, with gradual taper to a short cylindrical process. The wall is of moderate thickness and smooth or slightly granulose in texture. The process tip is swollen (clavate process). The body wall is folded along a line parallel to the long axis. No excystment opening is present.

Dimensions:		
	Central body: (length includes process)	115 x 56μ
	Width of process:	5μ
	Width of process at tip:	7μ

Remarks: In outline, the antapex and the body sides do not form part of the same curve. With a single specimen it is clearly impossible to say whether the slight angularity between them is morphologically important or not. The specimen is moderately carbonised and slightly deformed by the internal growth of pyrite.

Comparison: In size and relative proportions Pirea sp. A cannot be matched to any of the other previously recorded species attributed to this genus.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian.

Sample W1.

Pirea? sp. B

Pl. 22, fig. 7.

Description: (based on two poorly preserved specimens) The central body is hollow, approximately ovate in outline and has a single, hollow, tapering process. The wall is thin and slightly granulose in texture.

Dimensions: Central body (excluding process): 21 - 30 x 20 - 22μ

Length of process: 14 - 15μ (?)

Remarks: The body wall is deformed by pyrite and in one specimen it appears to be ruptured. The processes are damaged at their tips, and the specimens cannot therefore be attributed to *Pirea* Vavrdova with certainty.

Comparison: The specimens bear some resemblance to the Silurian species *Deunffia brevispinosa* Downie, but the poor preservation precluded a detailed comparison.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Genus POIKILOFUSA Staplin, Jansonius and Pocock, 1965

1970 *Eupoikilofusa* Cramer, p. 83-4.

Type Species: *Poikilofusa spinata* Staplin, Jansonius and Pocock, 1965, p. 186, pl. 18, figs. 25-6. Middle Ordovician, Trenton Fm., Anticosta Island, Canada.

Original Diagnosis: Vesicles fusiform, with small spines or muri; no openings (pyloms) observed; wall firm but relatively thin, similar to that in micrhystrids.

Remarks: In the two species originally described (Poikilofusa spinata and P. striata) the sculptural elements are arranged in rows.

In a review of leiofusid acritarchs, Combaz, Lange and Pansart (1967) considered Poikilofusa Staplin et al., 1965, to be a junior synonym of the genus Dactylofusa Brito and Santos, 1965. However, the latter genus, as represented by its type species, D. maranhensis Brito and Santos has a navicular outline and distinctive claviform processes arranged longitudinally. The resemblance to Poikilofusa Staplin et al. is thus superficial, and both genera are here maintained.

Cramer (1970) considered Poikilofusa Staplin et al. to be a partial junior synonym of Dactylofusa Brito and Santos, but rather than effecting emendations to these genera Cramer chose instead to propose Eupoikilofusa Cramer for forms having an ornament of 'rugulae, striae, fossulae, or micro-echinate elements' in longitudinal rows. Eupoikilofusa Cramer is here treated as a junior synonym of Poikilofusa Staplin et al.

Poikilofusa sp. A

Pl. 10, fig. 2.

Description: (single specimen) The body is thin walled, hollow and fusiform. A relatively short tapering process is present at each pole. The body ornament consists of small irregular echinate sculptural elements approximately 0.25μ in height and 0.5μ apart, arranged in longitudinal

rows. Most echinae are surmounted by a fine hair, up to 0.5μ in length. Adjacent rows are set 1μ apart. The body wall is ruptured, but whether or not this is associated with excystment is not clear.

Dimensions:	Central body:	60 x 28.5μ
	Length of processes:	8μ
	Height of echinae:	0.25μ (approx.)
	Length of hairs:	< 0.5μ
	Spacing between rows:	1.0μ (approx.)

Remarks: The longitudinally arranged sculptural elements may occur either separately or interconnected. The specimen is incomplete and slightly carbonised.

Comparison: Poikilofusa chalaza Rasul (1971, MS.) is superficially similar in form, but may be distinguihsed by its more slender outline, and ornament of echinae without hairs.

Occurrence: Bangor, N. Wales, U.K.; Early Arenigian. Sample B1.

Subgroup POLYGONOMORPHITAE Downie, Evitt and Sarjeant, 1963

Acritarchs having a pronouncedly polygonal test, without an inner body and without crests. Processes isolate or fusing at the bases, few in number, normally simple, rarely branching.

Genus ARKONIA Burmann, 1970

1974a Rugulidium Cramer, Kanes, Diez and Christopher, p. 60 (pars.)

Type Species: Arkonia virgata Burmann, 1970, p. 298, pl. 7, fig. 6.

Late Llanvirnian, Aufschlusse A/16, G.D.R.

Original Diagnosis: The central body is triangular with a triradial arrangement of simple processes. The central body is provided with close or widely spaced ribbing, which spreads over the central body in a fan-like manner from the bases of the processes. From their origin on the three process bases the ribs extend onto the central body, and take an approximately parallel attitude to the sides, or slightly incurve. In the central area, the ribs running in from the three directions, gradually disappear or diverge strongly. In general, the centrally situated ribs show a stronger degree of curving than those nearer the periphery. The peripheral ribs of adjoining fan-systems can merge into one another or cross-cut the intervening spaces, touch, then merge. The fan-like striations can be represented by distinct ribbing or by a similar arrangement of finer sculptural elements. (transl.)

Remarks: The genus Rugulidium Cramer et al., 1974, was proposed for quadrate and triangular striate forms. It is in part, therefore, a junior synonym of Arkonia Burmann, 1970.

Arkonia tenuata Burmann, 1970

Pl. 19, figs. 5-6; pl. 20, fig. 6; pl. 26, fig. 7; pl. 31, fig. 9.

1970 Arkonia tenuata Burmann, p. 299, pl. 7, figs. 3, 5.

?1974a Rugulidium triangulatum Cramer et al., p. 62, pl. 26, figs. 10-3, 25.

1976 Arkonia temuata Burmann, in Eisenack et al., p. 81.

?1976 Striatotheca triangulata (Cramer et al.) Eisenack et al., p. 789-90.

Original Diagnosis: Central body triangular with a triradiate array of slender, medium length, unbranched, gradually tapering processes. The central body is covered with fine ribbing which spreads from the bases of the processes onto the central body in a fan-like pattern. The peripheral ribs adopt a sub-parallel attitude to the sides of the central body, while the centrally situated ribs of the fan system are strongly curved and diverge. Approximately 10-12 ribs are situated parallel to the sides (including the traces beneath). The processes are conically expanded at the base and only slightly differentiated from the central body. They are not ribbed. (transl.)

Description: The central body is strongly compressed and triangular in outline, with sides either slightly convex or straight. A single, apparently hollow, slender, tapering process emerges from each corner. In length, it may exceed the height of the central body. The central body is marked by a series of fine often discontinuous striations which either sub-parallel one of the edges, or incurve strongly when close to the centre of the body. The striate ornament may or may not extend onto the processes proximally.

Dimensions:		
	Central body height:	21(28)36µ
	Length of processes:	26(35)42µ
	Density of ribbing:	approximately 10-12 ribs. from outer margin to centre, usually 0.5µ apart

Specimens measured: 5

recorded: 34

Remarks: In some cases the ribbing of the central body is extremely faint and may only be seen under high magnification (x1000). No excystment openings were observed.

As far as can be ascertained from the description and illustrations the taxon Striatotheca triangulata (Cramer et al.) Eisenack et al., differs only in having somewhat shorter processes, and it is here considered a probable synonym of Arkonia tenuata Burmann.

Comparison: Arkonia tenuata Burmann is characterised by the fineness and close spacing of its central body ornament, and may on this feature be distinguished from A. virgata Burmann, which has much coarser, and more widely spaced ribs.

Occurrence: Hope Shales and Stapeley Shales, Shropshire; Skiddaw Slates, Lake District, U.K.; Early Llanvirnian. Samples H5, W1, W3, SAL 390.

Previous Records: Arkona, G.D.R.; Late Llanvirnian, (Burmann). ? Subsurface material, Tadla Basin, Morocco, and material of similar age from Almondóvar del Campo, Spain, and from Tunisia and Saudi Arabia; Late Arenigian, Early Llanvirnian, (Cramer et al.).

Arkonia virgata Burmann, 1970

Pl. 17, fig. 4; pl. 29, fig. 3; pl. 31, fig. 7.

1970 Arkonia virgata Burmann, p. 298, pl. 7, fig. 6.

?1970 Arkonia cf. virgata Burmann, p. 298, pl. 7, fig. 6.

1973 Arkonia virgata Burmann in Vanguestaine (MS.).

1976 Arkonia virgata Burmann in Eisenack et al., p. 83-4.

Diagnosis: Central body triangular in outline, with a triradiate array of long unbranched gradually tapering processes. The central body bears a fan-like system of relatively coarse ribs, which spread from the bases of the processes onto the central body. The peripheral ribs adopt a subparallel attitude to the sides of the central body while in the central

area, the ribs of the fan system are strongly curved and diverge. Approximately 7 ribs parallel the long sides of the central body (including the traces beneath). The slender processes are conically expanded at the base, and only slightly differentiated from the central body. They are not ribbed. (transl.)

Description: The central body is strongly compressed and triangular in outline with straight or slightly convex sides. A single, gradually tapering, slender hollow process emerges from each of the three corners. The central body is marked by a series of coarse ribs which lie more or less parallel to one of the edges of the central body, though incurve strongly when closer to the centre. The striate ornament of the central body does not extend onto the processes. No definite excystment openings were observed, although some specimens were ruptured along irregular lines.

Dimensions:	Central body:	22(25)28μ
	Length of processes:	12+ - 16+μ (inaccurate due to breakage)
	Density of ribbing:	5–8 ribs from the edge to the centre, 0.5 - 1.0μ in width

Specimens measured: 5

recorded: 11

Remarks: According to Burmann (1970), the features which distinguish this species from Arkonia tenuata Burmann, are both its longer processes and coarse striation. None of the specimens here attributed to A. virgata Burmann have processes which are complete, and it has therefore been impossible to verify that these two features consistently accompany one another.

Process length was noted to be a rather variable feature in A. tenuata Burmann, and it seems possible that it may also be variable in A. virgata Burmann. Recognisable, and of constant occurrence, however, are the two forms of body ornament; fine, closely spaced and coarse, more widely spaced, striations. Almost all of the specimens encountered in this study, generically attributable to Arkonia Burmann, could be placed in one or other of these groups without difficulty. If doubt existed it was usually due to poor preservation of the specimen.

Comparison: Arkonia virgata Burmann, differs from A. tenuata Burmann, in having relatively coarse, widely spaced striate ornament.

Occurrence: Hope Shales, Shropshire; Skiddaw Slates, Lake District, U.K.; Early Llanvirnian. Samples H5, SAL 389, SAL 390.

Previous Records: Arkona, G.D.R.; Late Llanvirnian (Burmann).

Genus ASTROPHEOS gen. nov.

Derivation of Name: Greek, astro, from astron, star, referring to the star-like appearance of the test, and pheos, a spiny plant, referring to the thorn-like decoration. Gender feminine.

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 body cavity and process interiors communicate freely. The process stems are decorated by small spines, which may develop a hair-like fineness distally. The ornament may extend onto the central body surface.

Type Species: Astropheos celestum Martin, 1969, comb. nov. = Veryhachium celestum Martin, 1969, p. 89, pl. 3, fig. 147; pl. 4, fig. 206 (Hol.); pl. 35, fig. 1. Silurian, Assise de Dave, Neuville-sous-Huy, Belgium.

Remarks: The star-like test of Astropheos gen. nov. distinguishes it from the genus Uncinisphaera Wicander, 1974, which accomodates forms having spherical or sub-spherical central bodies and relatively slender processes. In Estiastra Eisenack, 1959, the processes are usually more regular in arrangement and size, and have much broader bases. The genus Polygonium Vavrdova, 1966 emend. differs in that forms having prominent surface ornament are not included. Veryhachium Deunff ex Downie, 1959, emend. can be distinguished by its low number of processes and pillow-like form. Goniosphaeridium Eisenack is typified by large thin walled forms having broad processes which may become infilled distally. Certain decorated forms attributed to Goniosphaeridium (Eisenack) Kjellström, 1971a, by Kjellstrom (1971a), and to Goniosphaeridium Eisenack, 1969a, by Eisenack et al. (1973) are here regarded as incorrectly assigned.

Astropheos celestum Martin, 1969, comb. nov.

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.

1969 Veryhachium celestum Martin, p. 89, pl. 3, fig. 147; pl. 4, fig. 206; pl. 6, fig. 252.

?1970 Baltisphaeridium echinulatum Burmann, p. 309-10, pl. 18, fig. 3.

1972 Veryhachium celestum Martin in Martin, p. 26, pl. 7, fig. 3.

1974 Polygonium spinosum Jardine et al., p. 117-8, pl. 11, fig. 3.

Original Diagnosis:

Central body: diameter 20 to 38μ, generally 25μ star-like form.

Processes: 8 to 15 in number. Length, a little more than that of the central body diameter. Form conical, with flared bases and slender, simple tips.

Ornamentation: all the surface is rough due to numerous spines 1 to 2.5μ in length.

(transl.)

Description: The central body has a more or less polygonal outline formed by the expanded process bases. The processes of individual specimens may show variation in length and width. Their arrangement often lacks strict symmetry. The process terminations are acuminate although there may be complication due to the process decoration, which is composed of short, thorn-like elements. Although showing greatest development along the process stems, the ornament extends onto the central body. Most specimens are compressed, and all have suffered damage to one or several processes.

Dimensions:

Central body diameter:	27(29.5)33μ
Length of processes:	25(30)40μ
Width of processes proximally:	6(9)16μ
Ratio of central body diameter to process length:	1 : 1 (approx.)
Height of ornament:	0.5 - 3.0μ

Specimens measured: 10

recorded: 25

Remarks: In some of the less well preserved specimens the processes are sharply folded. Several specimens have reduced surface ornament, but this is considered, at least in part, to be a preservational effect.

The species Baltisphaeridium echinulatum Burmann, 1970, is very similar in appearance to Astropheos celestum Martin, 1969, comb. nov., and is here considered a possible synonym. It may differ in having a more symmetrical arrangement of processes.

Comparison: Astropheos celestum Martin, 1969, comb. nov. differs from Astropheos sp. A by having fewer longer processes and a less regular body form.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Caernarvon, North Wales, U.K.; Early Llanvirnian. Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Samples H5, W1, C1, SAL 2778, SAL 2781.

Previous Records: Assise de Dave (upper), de Naninne, de Jonquoi, and de Thimensart, Belgium; Silurian (Martin). Basin d'Illizi, and Grand Erg Occidental, Algerian Sahara; Ordovician and Silurian (Jardine et al.). Possibly also, Aufschlusse A/7, G.D.R.; Late Llanvirnian (Burmann).

Astropheos sp. A

Pl. 23, fig. 7; pl. 26, fig. 6; pl. 33, fig. 8; pl. 35, fig. 6.

Description: The central body is sub-polygonal in outline and is formed from conical expansions of the process bases. The processes number approximately 15 in optical section, and attain, on average, a length equivalent to half the central body diameter. The body and process walls have a smooth or microgranulose surface texture. Additionally the processes carry an ornament of short lateral thorn-like projections, which are most conspicuous along the process stems, but may extend onto the central body in a reduced form. No definite excystment structure is present.

Dimensions:	Central body diameter:	30(36)42μ
	Length of processes:	12(18)25μ
	Width of processes proximally:	8μ (approx.)
	Ratio of central body diameter to process length:	2 : 1
	Number of processes in optical section:	15 (approx.)

Specimens measured: 7

recorded: 11

Remarks: All specimens are poorly preserved, being severely affected by the internal growth of pyrite.

Comparison: This species may be distinguished from Astrophaeos celestum Martin, 1969, comb. nov. by its shorter, and more numerous processes.

Occurrence: Hope Shales and Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Samples W1, W3, SAL 2778, SAL 2781.

Genus CULCITISPINA gen. nov.

Derivation of Name: Latin, culcita, cushion or pillow, referring to the pillow-like form, and spina, thorn referring to the ornament.

Diagnosis: Central body approximately rectangular, in the form of a semi-inflated pillow, drawn out at the corners into hollow tapering processes, which communicate with the central body cavity. Wall of moderate thickness and single layered. Body decorated by short spines or hairs, simple or branched, usually extending onto the processes. Excystment by the development of a slit along one side of the body.

Type Species: Culcitispina brevis sp. nov. Early Llanvirnian, Hope Shales, Shropshire, U.K.

Remarks: The genus Villosacapsula Loeblich and Tappan, 1976, is similar in concept but restricted to forms having triangular outlines. Veryhachium Deunff ex Downie, 1959, emend. differs in having a smooth or granular wall, while the genus Striatotheca Burmann, 1970, is distinguished by its striate wall.

Culcitispina brevis sp. nov.

Pl. 18, fig. 3; pl. 21, figs. 5, 8 (Hol.);
pl. 22, fig. 1; pl. 29, fig. 4(?)

Derivation of Name: Latin, brevis, short, referring to the short processes at the corners.

Diagnosis: Central body sub-rectangular to sub-circular in outline. Wall of moderate thickness, ornamented by numerous short irregular hairs which terminate simply or bifurcate. Processes similarly ornamented, short, approximately one-sixth to one-twelfth of the body diameter in length, blunt and conical.

Holotype: Slide reference: W1 20 2 0.2 989 493. Early Llanvirnian, Hope Shales, Whitsburn, Shropshire, U.K.; N.G.R. SJ32890194

Description: The body outline depends upon the angle of compression and degree of inflation. All the specimens have been compressed during preservation, and in most cases the body wall displays a series of folds. The ornament, although slender distally, generally develops curved contacts with the central body. Proximally therefore, the hairs are often quite robust.

Dimensions: Central body: 37(45.5)49 x 31(37.5)46μ

Length of processes: 1(2.5)6μ

Height of ornament: 1-5μ

Holotype: Central body: 47 x 45μ

Length of processes: 2-3μ

Height of ornament: 1 - 4.5μ

Specimens measured: 10

recorded: 32

Remarks: The specimens are moderately carbonised and the extent to which the body ornament is preserved varies considerably.

Comparison: Culcitispina fakira Martin, 1969, comb. nov. differs in having much longer processes. Veryhachium entrichos Loeblich, is similar to Culcitispina brevis sp. nov. but basically triangular in outline.

Occurrence: Hope Shales, Shropshire, and possible, Skiddaw Slates, Lake District, U.K.; Early Llanvirnian, Samples H5, W1, SAL 389.

Culcitispina fakira Martin, 1969, comb. nov.

1969 Veryhachium fakirum Martin, p. 93-4, pl. 2, figs. 109-10, pl. 6, fig. 256; text-figs. 42-3.

Original Diagnosis:

Central body: outline square or slightly rectangular; length of sides 20 to 50μ.

Appendages: 4 in number; projecting in the same plane as the central body. Length 13 to 22μ, being approximately half that of the sides of the central body. Form conical with narrow base, thinning progressively to a simple tip.

Ornamentation: the central body and appendage surfaces are covered by hairs having a robust base, of length possibly attaining 4μ.

Culcitispina cf. fakira Martin, 1969, comb. nov.

Pl. 24, fig. 2.

Description: (single specimen) The compressed central body is distorted by folding and the growth of pyrite. It is clear, however, that the original outline was approximately rectangular. The four corners extend into hollow, tapering processes which lie in the same plane as the central body, and terminate sharply. In length, they are approximately equivalent to the length of the central body. The process interiors communicate freely with the body cavity. The process stems merge with the central body at their proximal contact. The wall is fairly thin and decorated by cone-like tubercles bearing fine hairs. No definite excystment structure is present.

Dimensions:		
	Central body:	32(?) x 26μ
	Length of processes:	27.5μ approx.
	Height of ornament:	< 2μ

Remarks: Although having a similar body size to C. fakira Martin comb. nov. the processes are relatively long and have a broader base.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Culcitispina? sp. A

Pl. 35, fig. 7.

Description:: (single specimen) The central body is hollow, approximately square in outline, and slightly inflated. A hollow, tapering process extends from each corner of the body, and six similar, though less robust, processes are randomly arranged on the body surface. All processes communicate freely with the central body cavity, have a curving contact with the central body, terminate sharply, and are relatively short (generally less than half the central body diameter. Both body and processes have a fairly thin wall and are decorated by slender hairs less than 2μ in length. No definite excystment opening is present.

Dimensions:		
	Central body:	33 x 27.5μ
	Length of processes:	7 - 15μ
	Height of ornament:	< 2μ

Remarks: The specimen is only tentatively referred to Culcitispina gen. nov. owing to the presence of subsidiary processes on the surface of the central body.

Occurrence: Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Sample SAL 2781.

Genus FRANKEA Burmann, 1970

Type Species: Frankea hamata Burmann, 1970, p. 290, Late Llanvirnian, Aufschlusse B/85(1), G.D.R.

Original Diagnosis; The central body is triangular with a triradiate arrangement of processes, terminally divided into simple branches from a common origin. The number of terminal filaments (two or more) and the

ratio of process length to central body height are variable. (transl.)

Remarks: As some doubt has been expressed as to the usefulness of this genus (see Rauscher, 1974), the situation is briefly reviewed.

The genus was introduced by Burmann in 1970, who attributed four new species to it. In addition, the species Veryhachium sartbernardense Martin, was transferred and became Frankea sartbernardense (Martin) Burmann.

Rauscher (1974), suggested that Veryhachium sartbernardense Martin should not be generically reattributed until a full review of the genus Veryhachium Deunff ex Downie had been undertaken. Further, the species introduced by Burmann (1970) were rejected by Rauscher, who considered them to be variable forms of Veryhachium sartbernardense Martin.

Two separate issues therefore require consideration:

a) the acceptance or rejection of the genus Frankea Burmann, 1970,

and b) the acceptance or rejection of the species introduced to the genus by Burmann (1970)

a) It is acknowledged that certain species of Veryhachium Deunff Deunff ex Downie (e.g. V. trisulcum Deunff, V. reductum Deunff) show marked similarity to species assigned to the genus Frankea Burmann, in both body form and process arrangement. However, the distinctive style of process termination seen in species attributed to Frankea Burmann, is here considered to be a feature worthy of representation at generic level. It is thought that little would be gained by awaiting a future review of the genus Veryhachium Deunff ex Downie.

b) In the present study, approximately thirty specimens were recovered which, although fragmentary and carbonised, could be attributed to one or other of the following species: Frankea hamulata Burmann;

F. hamata Burmann, F. longiuscula Burmann, and F. sartbernardense (Martin) Burmann. A few additional specimens proved difficult to allocate because of their intermediate character, and because of morphographical similarities between F. hamulata Burmann, F. hamata Burmann and F. sartbernardense (Martin) Burmann.

In addition, the author examined a small number of specimens of F. breviuscula Burmann from a Moroccan sub-surface preparation. This species occupies a morphographically intermediate position between F. hamata Burmann and F. longiuscula Burmann, but has not yet been recorded from British material. Considerable variability in form was noted. Continuous variation therefore appears to exist between F. hamata Burmann and F. longiuscula Burmann, through F. breviuscula Burmann.

However, although likely intermediate forms ranging between the species Frankea hamata Burmann, F. sartbernardense (Martin) and F. hamulata Burmann, have been noted, and the morphological variation in F. breviuscula Burmann may be sufficient to link F. hamata Burmann and F. longiuscula Burmann, most of the observations were based upon poorly preserved material, and the author considers the evidence to date of continuous variation between all species of Frankea Burmann, to be inconclusive. Since it was possible to assign most specimens to one or other of the species of Frankea Burmann, without difficulty, it is preferred to retain all species of the genus at the present time

Frankea hamata Burmann, 1970

Pl. 8, fig. 10; pl. 16, fig. 16(?); pl. 30, fig. 7(?)

1970 Frankea hamata Burmann, p. 290–1, pl. 2, figs. 7, 9–10.

1976 Multiplicisphaeridium hamatum (Burmann) Eisenack et al., p. 459.

Original Diagnosis: Central body triangular with a triradiate arrangement of medium-length processes, the terminations dividing into a pair of simple filaments, of medium length, in the form of a barb. The ratio of process length to central body height is approximately 0.3 - 0.5 : 1, the relatively long process filaments to process stem, approximately 1 : 1. Process robustness varies slightly. The central spaces of the processes are in communication. (transl.)

Description: The specimens conform closely to the above diagnosis, although interpretation is made difficult by their fragmentary and carbonised condition. In addition it should be emphasised that the central body is flattened and pillow-like, that no surface ornament is apparent, and that no excystment structures or characteristic patterns of fragmentation were observed.

Dimensions:		
	Central body height:	14.5(18)22μ
	Length of processes:	6(9)11μ
	Width of processes:	1(1.5)2μ
	Length of process filaments:	6(8)9μ
	Ratio of process length tol central body height:	0.5 : 1

Specimens measured: 2

recorded: 4(?)

Remarks: Though of similar relative proportion to the holotype, the specimens are, on average, 15% smaller.

Comparison: Frankea hamata Burmann differs from Frankea sartbernardense (Martin) Burmann in having bifurcate process terminations, supported by relatively slender process stems.

Occurrence: Caernarvon(?) and Menai, N. Wales, U.K.; (?)Skiddaw Slates, Lake District, U.K.; (?)Arenigian and Early Llanvirnian. Samples C1, M3(?), SAL 389(?).

Previous Records: Aufschlusse B/85(1),G.D.R.; Late Llanvirnian; (Burmann).

Frankea hamulata Burmann, 1970

Pl. 35; fig. 10.

1970 Frankea hamulata Burmann, p. 291, pl. 2, figs. 5-6.

1976 Multiplicisphaeridium hamulatum (Burmann) Eisenack et al., p. 461-2.

Original Diagnosis: Central body triangular, with, in general, slightly convex sides, and with a triradiate arrangement of processes. The relatively short and slender processes (ratio of process length to central body height approximately 1 : 4) are terminated by a small compressed head and divide into several quite short, thorn-like filaments. (transl.)

Description: The few specimens recovered agree with the above diagnosis. Two specimens are relatively complete, but a third is much fragmented. All are carbonised, but not totally opaque. The specimens are compressed, and the processes lie within this plane of flattening. No excystment structures or fragmentation patterns are evident, and the vesicle surface is apparently without ornament.

Dimensions:

Central body height:	24(24.5)25μ
Length of processes:	3.5(5)6μ
Process breadth:	1(1.5)2μ

Ratio of process length to process breadth: 3: 1

Ratio of central-body height to process length: 5 :1

Specimens measured: 2

recorded: 3

Remarks: The specimens are approximately 20% smaller than the holotype of Burmann (1970).

Comparison: The swollen process terminations, dividing into several short, thorn-like projections, distinguish this species from Frankea sartbernardense (Martin).

Occurrence: Skiddaw Slate, Lake District, U.K.; Late Llanvirnian. Sample SAL 2781.

Previous Records: Aufschlusse A/15b, G.D.R.: Late Llanvirnian; (Burmann).

Frankea longiuscula Burmann, 1970

Pl. 20, fig. 1; pl. 22, fig. 10; pl. 32, fig. 1; pl. 35, fig. 2.

1970 Baltisphaeridium sartbernardense Cramer, p. 157-8, pl. 17, figs. 249-50 (pars.)

1970 Frankea longiuscula Burmann, p. 291-2, pl. 2, figs. 4, 12; pl. 3, figs. 1-2.

1976 Multiplicisphaeridium longiusculum (Burmann) Eisenack et al. p. 467-8.

Original Diagnosis: Central body triangular with slightly convex sides and a triradiate arrangement of long slender processes (Ratio of process

length to central body height approximately 2 : 1). The termination at each point of division splits into several (about 12) simple, relatively short filaments. The transition from the central body occurs gradually through a slightly conical enlarged base, which lacks a distinct basal constriction. (transl.)

Description: Although the specimens are incomplete and usually strongly carbonised, it is clear that the central body is compressed, with the processes lying in the same plane of flattening. Process length ranges between one and two times the central body height, and the processes divide terminally into five to seven relatively short, simple, tapering filaments. A possible slit-like opening is present along one edge of the body in two of the specimens. The test surface is without ornament.

Dimensions:

Central body height:	33(39)44µ
Length of processes:	36(53)64µ
Process breadth:	1.5(2)3µ
Ratio of process length to process breadth:	26 : 1
Ratio of process length to central body height:	1.4 : 1

Specimens measured: 5

recorded: 6

Remarks: The specimens differ from those described by Burmann (1970) in having a somewhat lower ratio of process length to central body height. In addition, there are fewer terminal filaments.

Comparison: Frankea longiuscula Burmann is distinguished from F. breviuscula Burmann by its longer processes.

Occurrence: Hope Shales, Shropshire; Skiddaw Slates, Lake District, U.K.; Llanvirnian. Samples W1, SAL 2778, SAL 2781.

Previous Records: Aufschlusse A/19, G.D.R.; Late Llanvirnian; (Burmann). Unknown location (Cramer).

Frankea sartbernardense (Martin, 1966b) Burmann, 1970

Pl. 3, fig. 9; pl. 4, fig. 12; pl. 6, fig. 13; pl. 13, fig. 12; pl. 30, fig. 5; pl. 32, fig. 4.

1964 Veryhachium sp. in Wray, p. 94, pl. 1, fig. 5.

1966b Veryhachium sartbernardense Martin, p. 12-3, figs. 11-3.

1967 Veryhachium sartbernardense Martin in Martin, p. 316.

1967 Evittia sartbernardense (Martin) Brito, p. 477.

1969 Veryhachium sartbernardense Martin in Martin, p. 103-4, pl. 1, figs. 53, 57; pl. 2, figs. 68-9, 105; pl. 5, fig. 220; pl. 6, fig. 263; text-figs. 53-5.

1970 Baltisphaeridium sartbernardense (Martin) Cramer, p. 157-8, pl. 17, figs. 246, 248; text-fig. 4-6d. (pars.)

1970 Veryhachium sartbernardense Martin in Paris and Deunff, p. 28, pl. 1, fig. 7.

1970 Frankea sartbernardense (Martin) Burmann, p. 291, pl. 2, figs. 1, 3, 8, 11.

1971c Baltisphaeridium sartbernardense (Martin) Cramer in Cramer, pl. 2, fig. 10.

1973 Multiplicisphaeridium sartbernardense (Martin) Eisenack et al., p. 791-2.

1974 Veryhachium sartbernardense Martin in Rauscher, p. 101-2, pl. 5, fig. 18.

Original Diagnosis: The central body is an equilateral or slightly isoceles triangle. The length of the sides is from 20-38μ. Each apex is prolonged into a generally stout appendage (length 4-10μ) the extremity of which carries a plume of 3-6 filaments. The latter, which can attain a length of 10μ thin progressively to a fragile tip.

Two examples of the 18 observed carry on the central body, a fourth appendage of the same type. (transl.)

Description: The specimens agree with the above diagnosis except that the size of the central body ranges between 17.5 and 33μ (12-43% smaller). In addition, occasional specimens have been noted which apparently possess only two filaments in the terminal plume, although the other process terminations in the same specimen possess three or more. The central body surface is unornamented, and no excystment structures or fragmentation patterns were observed.

Dimensions:	Central body height:	17.5(20)23μ
	Length of processes:	3.5(5)6.5μ
	Process breadth:	1(2.3)4μ
	Ratio of process length to process breadth:	2 : 1
	Ratio of process length to central body height:	1 : 4

Specimens measured: 9
recorded: 18(?)

Remarks: The material is carbonised and fragmentary. Specimens carrying an additional fourth appendage were not encountered.

Brito (1967) considered the genus Evittia Brito to be closely related to Veryhachium Deunff ex Downie and to Wilsonastrum Jansonius. Loeblich

(1970), opposed this view, maintaining the lenticular form of Evittia sommeri Brito to be a secondary feature due to compression, and considering this feature in Veryhachium Deunff ex Downie and Wilsonastrum to be original. The author agrees with this latter view, and hence believes the attribution by Brito (1967) of Veryhachium sartbernardense Martin to Evittia Brito to be erroneous.

The S.E.M. study of surface sculpture by Tappan and Loeblich (1971), led them to propose the genus Dacteriocradus for forms with subtriangular outline, distally dividing processes, and smooth wall surface. They considered Veryhachium sartbernardense Martin to possibly belong to Dacteriocradus. As scanning electron microscopy has not been used in the present study it is not possible to comment further on this proposal.

Cramer (1970) transferred Veryhachium sartbernardense Martin to be the genus Baltisphaeridium (Eisenack), while Eisenack et al. (1973) attributed it to Multiplicisphaeridium (Staplin). In view of the flattened lenticular form, and processes which lie in the plane of the central body, the affinities of the species are here considered to be more inclined towards Veryhachium Deunff ex Downie, and the sub-group Polygonomorphitae. Hence, the proposals of Cramer (1970) and Eisenack et al. (1973) are not accepted.

The diagnosis of Frankea sartbernardense (Martin was emended by implication, when Burmann (1970) introduced the species F. hamulata Burmann, for forms having bulbous process terminations dividing into several short thorn-like filaments.

Comparison: See Frankea hamata Burmann, in this study.

Occurrence: Menai and Caernarvon, North Wales, U.K.; Arenigian. Samples M2, C4, C5, C6

Previous Records: Libya; Lower Palaeozoic (Wray). Sart-Bernard, Belgium; Ordovician (Martin). Brittany, France; Llanvirnian (Paris and Deunff). G.D.R.; Late Llanvirnian (Burmann). Normandy, France; Llanvirnian (Rauscher).

Genus POLYGONIUM Vavrdova, 1966, emend

Type Species: Polygonium gracile Vavrdova, 1966, p. 413, pl. 1, fig. 1; text-fig. 36; Arenigian, Central Bohemia.

Emended Diagnosis: Central body hollow, having a polygonal or sub-polygonal outline, and eight or more regularly arranged, tapering processes, which normally exceed one-third of the central body diameter in length. Body wall apparently single layered, either thin or moderate in thickness, Process stems hollow, smooth or granulose, simple or rarely branching, with closed acuminate tips, and a curving contact with the central body. Process interiors communicating freely with the central body cavity.

Remarks: The diagnosis is emended to include sub-polygonal forms, and forms having somewhat shorter processes. Vavrdova (1966) does not refer to excystment in this genus, nor have definite excystment structures been observed in the genus in this study. Occasional

specimens show an irregular rupture of the central body wall, but this appears to be associated with poor preservation.

Comparison: The genus Veryhachium Deunff ex Downie emend. differs in that all major processes are confined to a single plane. Micrhystridium Deflandre, 1937, may be distinguished by its circular or sub-circular outline, and the genus Solisphaeridium Staplin et al., 1965, by its circular outline and thick wall. Recavisentis gen. nov. differs in having prominent process decoration, while the genus Tectitheca Burmann 1968, is characterised by distinct conical and cylindrical parts to the central body. (see, however, T. contracta Burmann). Goniosphaeridium Eisenack, 1969a, is here restricted to large, thin-walled forms with broad processes, similar to the type species G. polygonale Eisenack. The latter differs markedly from the type species of Polygonium Vavrdova emend.

Polygonium gracile Vavrdova, 1966, emend.

Pl. 2, figs. 2-3; pl. 11, fig. 3, pl. 13. fig. 4; pl. 15, fig. 10, pl. 31, fig. 5.

1966 Polygonium gracilis Vavrdova, p. 413, pl. 1, fig. 3; pl. 3, fig. 1; text-figs. 3b and 4b.

1971 Polygonium gracilis Vavrdova in Rasul (MS.)

1973 Polygonium sp. A in Vanguestaine (MS.), p. 183, pl. 11, fig. 7, text-fig. 59b (pars.)

1974 Polygonium gracile Vavrdova in Rauscher, p. 75, pl. 3, fig. 1.

Original Diagnosis: Shells with hexagonal or pentagonal outline, provided with long, usually simple smooth processes, communicating with the inner cavity. Processes are regularly arranged in circles after the following pattern 1; 5' (6'); 5" (6'"); (3'"); 1"".

Emended Diagnosis: Central body with a pentagonal or hexagonal outline. Body and process wall apparently single layered and smooth. Processes moderately long, tapering, acuminate, simple, and arranged regularly on the central body.

Description: The specimens agree with the emended diagnosis. Although compressed, the central body is generally straight sided in outline.

Dimensions:

Central body:	18(21)24 x 16(19)22μ
Length of processes:	8(?) - 20(?)μ (broken)
Width of processes proximally:	1 - 2μ
Ratio of central body diameter to process length:	1.3 - 1.5(?)
Approximate number of processes in optical section:	6 - 11

Specimens measured: 10

recorded: 30

Remarks: The diagnosis is emended to exclude reference to a specific pattern of process arrangement. Process length has been difficult to assess due to breakage. The specimens are at the lower end of size-range quoted by Vavrdova (1966) for this species, and occasional specimens with central body diameters less than 20μ are included.

Comparison: Polygonium gracile Vavrdova emend. may be distinguished from P. tener Timofeev comb. nov., P. cf. tener Timofeev comb. nov., and

P. pungens Timofeev comb. nov. by possession of a central body with a distinct polygonal (hexagonal or pentagonal) outline.

Occurrence: Caernarvon, Menai and Bangor, North Wales, U.K.; Early Arenigian. Samples B1, M 2, M3 and C6. Also Skiddaw Slates, Lake District, U.K.; Early Llanvirnian. Sample SAL 390 (single specimen, reworked?).

Previous Records: Klabava Shales, Central Bohemia; Arenigian (Vavrdova). Shineton Shales, Shropshire, U.K.; Tremadocian (Rasul, MS.). Montagne Noir, France; Arenigian; (Rauscher) Massif de Stavelot, Belgium; Middle Revinien (Vanguestaine, MS.).

Polygonium pungens Timofeev, 1959. comb. nov.

1959 Archaeohystrichosphaeridium pungens Timofeev,p. 39, pl. 3, fig. 33 (invalid, I.C.B.N. Arts. 37 and 43).

1969 Baltisphaeridium pungens (Timofeev) Martin, p. 60, pl. 1, figs. 16, 23, 24, 34; text-fig. 14.

?1969 Archaeohystrichosphaeridium pungens Timofeev in Lister et al. p. 98.

1974 Goniosphaeridium pungens (Timofeev) Rauscher, p. 62, pl. 1, figs. 7-8.

Original Diagnosis: Outline circular, membrane dense, with 12 to 20 pointed, long spines. Spines with expanded bases, their length equal to half the vesicle diameter. Sculpture of the background shagreen, colour pale yellow-grey. (transl.)

Remarks: Timofeev (1959) describes this species as being 'circular' in outline, but appears to have used the term loosely, as the specimen he

illustrates is sub-polygonal in appearance. The species is here re-attributed to the genus Polygonium Vavrdova emend. because of its sub-polygonal outline, process arrangement, process style, and body form.

Polygonium cf. pungens Timofeev, 1959 comb. nov.

Pl. 3, fig. 5; pl. 10, figs. 8, 10; pl. 31, fig. 6.

Description: The central body is sub-polygonal in outline and marked by infolds of the body wall. The processes are slender, tapering, distally acuminate or occasionally evexate, with widely curved proximal contacts, which may impart a concavity to the body wall between adjacent process bases. The wall of both body and processes appears similar, and is apparently single layered. The surface texture is smooth or microgranulate.

Dimensions:	Central body:	25(28)32μ
	Length of processes:	8(11.5)15μ
	Width of processes proximally:	1 - 3μ
	Ratio of central body diameter to process length:	2.4 : 1
	Approximate number of processes in optical section:	15
Specimens measured:		7
	recorded:	12?

Remarks: The specimens differ from Polygonium pungens Timofeev, 1959, comb. nov. by having a predominently smooth wall and by the occurrence of occasional processes with evexate terminations. However, the specimens are both carbonised and corroded and the differences may

result from the poor state of preservation. The Lake District specimens are particularly badly preserved and are only doubtfully attributed to this species. No definite excystment structures were observed.

Comparison: Polygonium cf. pungens Timofeev, comb. nov., may be distinguished from P. tener Timofeev, comb. nov., and P. cf. tener Timofeev, comb. nov., by its more numerous processes which have a less widely curving proximal contact with the central body.

Occurrence: Bangor and Caernarvon, N. Wales, U.K.; Early Arenigian; Skiddaw Slates, Lake District, U.K.; Early Llanvirnian. Samples B1, C6, SAL 390.

Polygonium tener Timofeev, 1959, comb. nov.

1959 Archaeohystrichosphaeridium tener Timofeev, p. 40, pl. 3, fig. 39; invalid name, I.C.B.N, Arts. 37 and 43.

Original Diagnosis: Outline round, membrane dense with 10 to 12 large spines, half the body diameter in length, with acute-angled bases. Sculpture of background shagreen. (transl.)

Remarks: Although Timofeev (1959) describes this species as rounded in outline, the specimen he figures has a sub-polygonal appearance. The species is re-attributed to the genus Polygonium Vavrdova emend. because of this, and because of process style, process arrangement, and body form; which are also characteristic of the genus.

Polygonium cf. tener Timofeev, 1959, comb. nov.

Pl. 4, fig. 11; pl. 5, fig. 10.

Description: The central body is sub-polygonal in outline with approximately 12 tapering, acuminate processes, which have widely curved proximal contacts. Both the body wall and processes appear to be smooth and single layered.

Dimensions:		
	Central body:	24(27.5)32μ
	Length of processes:	16(20)24μ
	Width of processes proximally:	3(6.5)10μ
	Ratio of process length to central body diameter:	0.7 : 1 (av.)
	Approximate number of processes in optical section:	10
Specimens measured:	9	
recorded:	14	

Remarks: The examples described above apparently lack surface ornament and have processes which often exceed half the central body diameter. However, the specimens are strongly carbonised and fine surface detail is difficult to detect. They otherwise closely resemble the type figured by Timofeev (1959).

Comparison: Polygonium cf. pungens Timofeev, 1959, comb. nov. differs by possession of more numerous processes, which have a less widely curving proximal contact. Polygonium gracile Vavrdova, 1966, may be distinguished by its distinct polygonal outline.

Occurrence: Caernarvon, N. Wales, U.K.; Late Arenigian. Samples C4, C5.

Polygonium div. spp.

A single specimen (pl. 28, fig. 4) recovered from sample R1 (Late Llanvirnian) is also tentatively referred to this genus on account of its distinctly polygonal outline.

Many other specimens were encountered during the course of this investigation, which although broken and carbonised, still displayed a more or less polygonal central body outline, with simple tapering processes. They were not attributable to previously described species, and their generally poor state of preservation, and the occurrence of numerous gradational forms, made effective subdivision of the group impossible. They are neither described nor illustrated in this work, but are referred to in the range charts under Polygonium div. spp.

Genus STRIATOTHECA Burmann, 1970

1974a Rugulidium Cramer, Kanes, Diez and Christopher, p. 60 (pars.).

Type Species: Striatotheca principalis Burmann, 1970, var. principalis nom. nov. = Striatotheca principalis Burmann, 1970, p. 300, pl. 11; fig. 1; Late Arenigian - Early Llanvirnian, Griffesschiefer, Vogtland, G.D.R.

Original Diagnosis: Central body tetragonal or polygonal in outline, passing into a limited number of gradually tapering, hollow processes at the corners, without basal constrictions. The processes and/or central body are provided with striate sculpture composed of rib-like elements in fan-like arrangement. The four sided basic form may be altered by incurving of the outer edges, through continuation of the basal curvature of the processes, which as a rule pass into the central body gradually. There may be further deviation from the basic form through shortening of the sides,

process reduction, unequal process development, and the development of additional processes.

The comparatively closely spaced striations may be limited to the processes or may run onto the central body in a fan-shaped pattern. The ribs have a sub-parallel attitude to the sides. The centrally placed ribs display a more marked curvature in relation to the edges. In the middle part of the central body the ribbing of each fan system diverges strongly, and, in the intervening space, the ribs of adjoining fan systems can merge into one another or overlap. (transl.)

Remarks: The genus Rugulidium Cramer et al., 1974, was proposed for quadrate and triangular striate forms. It is in part, therefore, a junior synonym of Striatotheca Burmann, 1970.

Striatotheca frequens Burmann, 1970

Pl. 17, fig. 3; pl. 23, fig. 3; pl. 28, fig.5(?);
pl. 29, fig. 7; pl. 31, fig. 12; pl. 34, fig. 1.

1970 Striatotheca frequens Burmann, p. 303, pl. 10, figs. 4-5, 7.

1970 Striatotheca sp., in Burmann, p. 303-4, pl. 10, figs. 3, 6.

1974 Rugulidium quietum (Martin) Cramer et al., p. 60, pl. 25, fig. 12; pl. 26, figs. 16-7 (pars.)

1976 Striatotheca frequens Burmann in Eisenack et al., p. 761.

Diagnosis: Central body quadrate, straight sided, the corners all gradually merging into processes, each having a relatively wide base and gradually tapering. The longitudinal striation of the processes extends over the entire central body in fan-like patterns which intermesh. The species is characterised not only by the length-breadth

ratio, but also by the relative constancy of the absolute size. (transl.)

Description: The central body is more or less rectangular, and strongly compressed. The processes lie in the same plane, and extend from the corners of the central body. They are hollow and communicate freely with the central body cavity. The conical processes are rather variable in form and size. The process sides may be straight, slightly convex, or slightly concave. When slightly concave the junction between process and central body is gradual, and distal termination acuminate. When straight or slightly convex, the process is usually broad, blunt, and more sharply defined from the central body. The process bases carry a longitudinal striation which diverges proximally onto the central body, generating a pattern of fine striations over the majority of the surface. The striae parallel the outer margin when close to the edge, but incurve when close to the centre.

Dimensions:	Central body:	33(36)40 x 28.5(32)39µ
	Length of processes:	8(12)20µ
	Density of striation:	approximately 20–30 striae across the full width of the central body

Specimens measured: 12

recorded: 21

Remarks: The range of variability within this species is apparently greater than that expressed in the diagnosis. A relatively constant feature, however, is the pattern of fine sub-parallel striations which ornament the test surface. Cramer et al. (1974) illustrate two specimens under the name Rugulidium quietum (Martin), which are here considered to belong to Striatotheca frequens Burmann, because of process length and fineness of striation.

Comparison: Striatotheca frequens Burmann, may be distinguished from S. rarirrugulatum (Cramer et al.), S. principalis Burmann var. principalis nom. nov., and S. principalis parva Burmann, by the fineness and regularity of its sub-parallel striation. S. quieta (Martin) may be distinguished by its very short processes (see also S. quieta (Martin)).

Occurrence: Caernarvon, N. Wales, U.K.; Hope Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K.; Llanvirnian. Samples H5, W1, R1(?), SAL 389, SAL 390, SAL 2781.

Previous Records: Vogtland, G.D.R.; Late Llanvirnian; (Burmann). Sub-surface material Tadla Basin, Morocco, Late Arenigian - Early Lanvirnian; (Cramer et al.).

Striatotheca principalis parva Burmann 1970

Pl. 10, fig. 7; pl. 13, fig. 8.

1970 Striatotheca principalis var. parva Burmann, p. 300, pl. 8, fig. 6.

1972 Veryhachium microrugulatum Vavrdova, p. 81-2, pl. 2, figs. 3-4, text-fig. 2.

1976 Striatotheca principalis parva Burmann, in Eisenack et al., p. 771-2.

Original Diagnosis: Central body quadrate, approximately straight sided, each corner passing into a gradually tapering process. A fan-like ribbing spreads over the central body from the corners. The processes are comparatively slender and carry little ribbing. The ribbing of the central body is relatively wide-spaced (width of ribbing 2μ, about eight sub-parallel ribs may be counted. (transl.)

Description: The central body is strongly compressed and ornamented by a rather coarse, irregular series of sub-parallel striations. A gradually tapering, apparently hollow process extends from each corner and joins the central body proximally without angular discordance. The processes lie in the same plane of compression as the central body, and communicate freely with the body cavity.

Dimensions: Central body: 26(31)35 x 19(21)22μ

Length of processes: 13μ (broken)

Density of striation: approximately 12 striae across the full width of the central body.

Specimens measured: 2

recorded: 2

Remarks: Eisenack et al. (1976) noted a discrepancy in size between the illustration of Striatotheca principalis parva Burmann and the dimensions given in the description by Burmann (1970). The specimens described here correspond more closely in size to the illustration.

Vavrdova (1972) introduced under the name Veryhachium microrugulatum a species which is here considered synonymous with Striatotheca principalis parva Burmann.

Comparison: Striatotheca principalis parva Burmann may be distinguished from S. rarirrugulata (Cramer et al.) Eisenack et al., by its generally larger size and a greater number of sculptural elements on the central body. S. principalis principalis Burmann nom. nov. differs in possessing strongly developed ornament and a larger central body.

Occurrence: Menai and Bangor, N. Wales, U.K.; Lower Arenigian. M2, B1.

Previous Records: Griffelschiefer, Vogtland, G.D.R.; Late Arenigian - Early Llanvirnian (Burmann). Klabava and Sarka Shales, Bohemia; Arenigian - Llanvirnian (Vavrdova).

Striatotheca principalis Burmann, 1970, var. principalis nom. nov.

Pl. 31, fig. 10.

1970 Striatotheca principalis Burmann, p. 300, pl. 11, fig. 1.

1974 Striatotheca principalis Burmann in Rauscher, p. 75, pl. 3, fig. 23.

1976 Striatotheca principalis Burmann in Eisenack et al., p. 769-70.

Diagnosis: Central body quadrate in outline, more or less straight sided, elongate, passing at the corners into gradually tapering, hollow, pointed processes. From the longitudinally striate processes, the closely spaced ribbing extends in four fan systems over the entire central body. The outermost ribs lie sub-parallel to the edges, while the central ribs curve strongly and either diverge of disappear. About sixteen sub-parallel ribs can be counted. (transl.)

Description: (based on a single fragmentary specimen). The central body is rectangular with slightly incurving sides, and is strongly compressed. The processes pass smoothly into the central body outline and lie in the same plane of compression. They are hollow and communicate freely with the cavity of the central body. The sub-parallel striation is strongly developed.

Dimensions:	Central body:	38.5 x 33μ
	Length of processes:	15+μ
	Density of striation:	10–16 striae across the width of the central body

Remarks: The specimen is 20–25% smaller than the holotype of *Striatotheca principalis* Burmann var. *principalis* nom. nov., but is similar in all other respects. The test is moderately carbonised.

In accord with Article 26 of I.C.B.N. the name of this taxon has been changed to *Striatotheca principalis* Burmann var. *principalis*, in order to distinguish it from *S. principalis* var. *parva* Burmann.

Comparison: *Striatotheca principalis* Burmann var. *principalis* nom. nov. is sometimes difficult to distinguish from *S. frequens* Burmann, and it is usually necessary to use more than one morphological feature. Generally, in *S. principalis* Burmann var. *principalis* nom. nov. the body

is larger and less variable in form, and bears more coarsely developed and widely spaced striations. S. principalis var. parva Burmann is smaller, with less coarsely developed striation.

Occurrence: Skiddaw Slates, Lake District, U.K.; Early Llanvirnian. Sample SAL 390.

Previous Records: Griffelscheifer, Vogtland, G.D.R.; Late Arenigian - Early Llanvirnian (Burmann). Montagne Noire, France; Arenigian (Rauscher).

Striatotheca quieta (Martin, 1969) Rauscher, 1974

Pl. 7, fig. 7; pl. 17, fig. 8; pl. 23, fig. 4; pl. 26, figs. 1-2; pl. 29, fig. 5, 6(?); pl. 31, fig. 11; pl. 33, fig.11; pl. 34, fig. 2.

1969 Veryhachium quietum Martin, p. 100-1, pl. 5, fig. 226; pl. 6, fig. 290; text-fig. 48.

1970 Striatotheca acutiuscula Burmann, p. 303, pl. 8, figs. 3, 4.

?1974 Striatotheca quieta (Martin) Rauscher, p. 76, pl. 3, fig. 12.

1974 Rugulidium quietum (Martin) Cramer et al., p. 60, pl. 26, fig. 15 (pars.)

1976 Striatotheca quieta (Martin) in Eisenack et al., p. 773-4.

Original Diagnosis:

Central Body: outline square to slightly rectangular; length of sides 25 to 45μ; the ratio of a long side to a short side is from 1.1 to 1.2.

Appendages: 4 in number; they project in the same plane, and without precise limits, from the angles of the central body. Length,

from 2 to 6μ; form conical, very short, with an obtuse tip.

Ornament: the surface of the central body and processes is ornamented with a dense network of fine wrinkles, sub-parallel to the sides of the body and incurving towards the central part, sometimes the wrinkles show a slight anastomosing pattern. (transl.)

Description: The central body is strongly compressed, with a square to rectangular outline, and straight or slightly incurving sides. Short, conical, hollow processes extend from each corner. Rarely, a fifth process is developed between edge and centre of the body. Occasional specimens have a slit and flap along one edge of the central body, which is presumed to be an excystment opening. The sub-parallel striation is fine and closely spaced.

Dimensions: Central body: 20(28)35 x 19(26)35μ

Length of processes: 3(4)6μ

Density of striation: 1–2μ approx.

Specimens measured: 6

recorded: 21

Remarks: Most specimens are carbonised and affected by the growth of pyrite. Occasionally the body wall is thinner (perhaps as a result of natural oxidation), and the striation is difficult to detect except under the highest magnification.

Comparison: Striatotheca quieta (Martin) is readily distinguished from S. rarirrugulatum (Cramer et al.), S. principalis Burmann principalis, and S. principalis parva Burmann, by the fineness of its striate ornament. S. frequens Burmann has processes which are longer and more robust, but has a similar striate ornament. Occasional

forms intermediate between S. frequens Burmann and S. quieta (Martin) have been recorded, and it is possible that future investigations may show the two taxa to be conspecific.

Occurrence: Caernarvon, N. Wales, U.K.; Hope Shales and Stapeley Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K.; Llanvirnian. Samples C1, H5, W1, W3, SAL 389, SAL 390, SAL 2778, SAL 2781.

Previous Records: Jonquoi and Thimensart, Belgium; Wenlock(?) - Ludlow (Martin, reworked?). Aufschlüsse B/89, G.D.R.; Late Llanvirnian (Burmann). Sub-surface material, Tadla Bain, Morocco; Late Arenigian - Early Llanvirnian (Cramer et al.). (?) Montagne Noir, France; Arenigian (Rauscher).

Striatotheca rarirrugulata (Cramer, Kanes, Diez and Christopher, 1974b) Eisenack, Cramer and Diez, 1976.

Pl. 3, figs. 7-8; pl. 4, fig. 13; pl. 6, fig. 18; pl. 10, fig. 5; pl. 14, figs. 5-7; pl. 16, figs. 6-7.

?1967 Veryhachium lairdi (Deflandre) Deunff in Combax, pl. 3, fig. 90.

?1974 Striatotheca principalis var. parva Burmann in Rauscher, p. 75-76, pl. 3, figs. 13-4.

1974b Rugulidium rarirrugulatum Cramer et al., p. 61, pl. 25, figs. 19, 21, 23; pl. 26, fig. 24.

1976 Striatotheca rarirrugulata (Cramer et al.) Eisenack et al., p. 775-6.

Original Diagnosis: Central body square to rectangular, dorsoventrally compressed, pillow-shaped. Each corner bears one veryhachid, moderately broad-based process, hollow at the base and solid distally. The processes are about equally as long as, or slightly longer than the long edge of the

body and vesicle wall. A few coarse rugulate sculptural elements are present on the central body; they are arranged in an open, uncrowded pattern of side-parallel to diagonally aligned ridges. Disregarding the coarse rugulae, the processes and central body are psilate. The coarse rugulate elements are up to about two microns wide and high and are six to ten microns apart.

No endodermal structures observed; opening through a straight slit-pylome situated at a long edge of the central body.

Description: The central body is always strongly compressed and more or less rectangular in outline. The four tapering processes lie in the plane of compression. Proximally, the processes gradually merge with the central body outline. Distally, their terminations are acuminate. The coarse striations either sub-parallel the outer edges, or, if more centrally placed, incurve towards the centre of the test, where they intersect.

Dimensions:	Central body:	14(18)23 x 10(15)20μ
	Length of processes:	8(11)17μ
	Density of striation:	usually 4-8 striae across the full width of the central body.

Specimens measured: 17

recorded: 35.

Remarks: None of the specimens are complete, and, depending upon the sample from which they were derived, all are carbonised to some degree. The processes appear to be hollow along the whole of their length, but in some cases this is difficult to verify, because of the opacity of the specimens. Although no straight-slit pylomes were observed, the tests of many specimens are ruptured.

Comparison: This species differs from Striatotheca principalis var. parva Burmann, in having only a few coarse striations, and perhaps also, a smaller central body (there is some discrepancy between the central body sizes quoted by Burmann (1970) and the specimen she illustrates). The Silurian species Neoveryhachium carminae Cramer is similar in overall appearance, but has a larger central body and is considered by Cramer (1970) and Cramer et al. (1974) to possess a periderm and muri.

Occurrence: Menai, Bangor, and Caernarvon, N. Wales, U.K.; Arenigian. Samples M2, M3, B1, C4, C5, C6.

Previous Records: (?) Sub-surface material, Aassi-Messaoud, Sahara; Tremadocian; (Combaz). Sub-surface material Tadla Basin and sediments in Spain, Saudi Arabia, Libya, Tunisia and Algeria; Late Arenigian - Early Llanvirnian; (Cramer et al. 1974a). (?) Montagne Noir, France; Arenigian; (Rauscher).

Striatotheca trigonia Burmann 1978

1970 Striatotheca trigonia Burmann, p. 302, pl. 9, fig. 2.

1976 Striatotheca trigonia Burmann in Eisenack et al., p. 791-2..

Original Diagnosis: Central body triangular in outline, developed from the four sided basic form by the complete reduction of one side. On the short side arise two processes, the bases of which touch each other. The remaining two processes arise gradually from the central body in normal positions. The processes on the short side are not so strongly conical at their bases as those of the long side. The processes bear a coarse longitudinal ribbing which is hardly visible in the middle part of the central body. (transl.)

Striatotheca cf. trigonia Burmann, 1970.

Pl. 32, fig. 10.

Description: (based on a single fragmentary specimen). Central body strongly compressed, trapezoidal in form, with a hollow process developed at each corner. The two processes separated by the side of reduced length are themselves greatly reduced relative to the opposing processes. The two larger processes merge into the central body without angular contact, and are ornamented by a longitudinal striation which diverges proximally onto the central body. The two smaller processes join the central body more abruptly and apparently lack ornament. The central part of the body also appears to be unornamented.

Dimensions:	Central body:	34 x 13–31μ
	Length of processes:	17 and 7μ
	Density of striation:	not possible to assess due to poor preservation.

Remarks: The specimen is damaged and rather strongly carbonised. Consequently certain details, including the precise form of the central body, and extent of the ornament are not clear.

Comparison: Striatotheca cf. trigonia Burmann, differs from S. trigonia Burmann, primarily in overall size, being 25–35% smaller than the holotype.

Occurrence: Skiddaw Slates, Lake District, U.K.; Late Llanvirnian. Sample SAL 2778.

Genus VERYHACHIUM Deunff ex Downie, 1959, emend.

1966 Hystrichotriangulatum Andreeva, p. 132.

Type Species: Veryhachium trisulcum (Deunff) ex Deunff 1959, p. 27, pl. 1, figs. 4, 13 = Veryhachium trisulcum Deunff, 1954c, p. 306 (nomen

nudum) = Hystrichosphaeridium trisculum Deunff, 1951, p. 323, text-fig. 3 (nomen nudum).

Emended Diagnosis: Central body hollow, thin walled, polygonal or sub-polygonal, usually bearing three or four simple, hollow, processes with closed acuminate tips. Processes lying in a single plane, emerging from the angles and forming an integral part of the central body. Surface smooth or ornamented by grana. Excystment by epityche.

Remarks: Some disagreement has existed over the correct author citation of this genus, due, primarily to uncertainty as to whether it should be considered under the terms of the I.C.Z.N. or I.C.B.N.

Loeblich and Tappan (1976) noted that Deunff (1954) originally included the genus in the family Hystrichosphaeridiae, a family name with a zoological termination, and argued that it was therefore necessary to apply the I.C.Z.N. rules. Under the zoological code Deunff's original description of the genus (1954c) and designation of type species is invalid, as the type species was not described (I.C.Z.N. Art. 13(a) (i)). Nor had this species been earlier described when first cited by Deunff in 1951 as Hystrichosphaeridium trisulcum. Furthermore, the generic diagnosis cannot be considered a combined generic-specific one, covering the type species also, as nine other species are also included in the genus (see Loeblich and Tappan (1969) p. 55).

Deunff described Veryhachium trisulcum Deunff, 1954c (nom. nud.) and several other forms in 1959, but unfortunately failed to indicate the type species. Under strict appliction of the zoological code (I.C.Z.N. Art. 13 (6)) the genus remained invalid until the type species was stated by Downie in 1959.

The genus was redefined by Staplin (1961) and later emended by Downie and Sarjeant (1963) and by Loeblich and Tappan (1969). The emended diagnosis presented here is essentially that of Loeblich and Tappan (1969), but differs in that reference to an ornament of prickles and small spines is excluded.

Comparison: The genus Impluviculus Loeblich and Tappan, 1969, differs in that excystment is via a centrally located quadrangular or rounded pylome. Ecmelostoiba Wicander, 1974, is similar, but the major processes are not confined to a single plane. The genera Villosacapsula Loeblich and Tappan, 1976, and Culcitispina gen. nov. differ in that an ornament of small spines or irregular hairs is present.

Veryhachium abortivum sp. nov.

Pl. 24, figs. 7(Hol.),8-9; pl. 27, fig. 5.

Derivation of Name: Latin, abortivus, prematurely born or terminated, referring to the processes.

Diagnosis: Central body triangular in outline, slightly inflated, with sides generally a little convex. Wall firm, yet relatively thin, smooth or slightly gramulose in surface texture. Angles rounded or extending into very short conical processes.

Holotype: Slide reference: W1 <20 4 0.1 1033 251. Early Llanvirnian, Hope Shales, Whitsburn, Shropshire, U.K. N.G.R. SJ 32890194

Description: The specimens agree with the above diagnosis. The processes, if present, are never clearly differentiated from the central body. The body wall is usually darker towards the angles suggesting a possible thickening of the wall in these regions.

Dimensions: Central body side length: 22(32)40μ

Central body height: 24(33.5)41μ

Length of processes: 0 - 4μ

Holotype:

Central body side length: 30μ (average)

Central body height: 29μ (average)

Length of processes: 2 - 3μ

Specimens measured: 12

recorded: 15

Remarks: Apart from obvious morphographical differences, this species is usually distinguishable from other trispinose forms in the same assemblage by a darker colouration of the wall.

Comparison: Veryhachium brevitrispinum Staplin, 1961, is similar in form, but has a rather more convex outline and processes whcih are clearly differentiated from the central body.

Occurrence: Hope Shales and Stapeley Shales, Shropshire, U.K.; Early Llanvirnian. Samples W1, W3.

Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959

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.

?1862 Xanthidium sp. in White, p. 386, fig. 5.

1935 Xanthidium sp. in Laird, p. 255, fig. 7b.

1946 Hystrichosphaeridium lairdi Deflandre, Index Card 1112, 2 figs. (nomen nudum).

1954c Hystrichosphaeridium lairdi Deflandre in Deunff, p. 306, (invalid)

1959 Veryhachium lairdi (Deflandre) ex Deunff, p. 28, pl. 8, figs. 75–9.

1963 Veryhachium lairdi (Deflandre) in Stockmans and Williere, p. 454–5, pl. 3, fig. 5; text fig. 7.

1964a Veryhachium valiente Cramer, p. 34 (nomen nudum).

1964b Veryhachium lairdi (Deflandre) Deunff in Cramer, p. 309, pl. 11, fig. 16; pl. 12, figs. 1–2; text-fig. 27: 10–11.

1964b Veryhachium valiente Cramer, p. 311, pl. 12, figs. 3–4, 6; text-fig. 28: 7–9.

1965 Veryhachium lairdi Deflandre in Rauscher et al., p. 311, pl. 4, figs. 1–3.

1966b Veryhachium lairdi (Deflandre) in Martin, p.435–6, figs. 14–5.

1966b Veryhachium valiente Cramer in Martin, p.436–7, fig. 16.

1966a Veryhachium lairdi (Deflandre) in Martin, p. 376.

1966a Veryhachium valiente Cramer in Martin, p. 376–7; text-fig. 23.

non 1967 Veryhachium lairdi (Deflandre) Deunff in Combaz, pl. 3, figs. 89–91

1967 Acritarch 3364 in Magloire, p. 491, pl. 9, fig. 12.

1968a Veryhachium valiente Cramer in Cramer, p. 64.

1969a Veryhachium valiente complex in Cramer, p. 486.

1969 Veryhachium lairdi (Deflandre) Deunff in Martin, p. 95, pl. 2, figs. 75–81, 83; pl. 6, fig. 258.

1969 Veryhachium valiente Cramer in Konzalova-Mazancova, p. 90, pl. 16, fig. 2.

1969 Veryhachium lairdi (Deflandre) Deunff in Konzalova-Mazancova, p. 89–90, pl. 16, fig. 1.

1969 Veryhachium cf. lairdi (Deflandre) Deunff in Konzalova-Mazancova, p. 89-90, pl. 16, fig. 3.

1969 Veryhachium lairdi (Deflandre) Deunff in Stockmans and Willière, p. 9-10, pl. 1, figs. 15-6.

1969 Veryhachium lairdi (Deflandre) in Henry, p. 76, pl. 1, fig. 7.

1969 Veryhachium lairdi (Deflandre) in Le Corre and Deunff, p. 46, fig. 11.

1969 Veryhachium lairdi (Deflandre) Deunff in Lister et al., p. 98.

1969 Veryhachium valiente Cramer in Lister et al., p. 98.

1970 Veryhachium lairdi Deflandre in Paris and Deunff, p. 27, pl. 1, figs. 1, 13.

1970 Veryhachium lairdi (Deflandre) Deunff in Burmann, p. 304, pl. 11, figs. 4-5.

1970 Veryhachium lairdi (Deflandre) Deunff in Cramer, p. 97-8, fig. 28.

1970 Veryhachium valiente Cramer in Cramer, p. 100, fig. 28.

1970 Veryhachium valiente Cramer in Cramer, p. 746.

1970 Veryhachium valiente Cramer in Cramer and Diez de Cramer, p. 1079.

1970 Veryhachium lairdii (Deflandre) ex Deunff in Loeblich, p. 741-2.

1970 Veryhachium valiente Cramer in Loeblich, p. 744, fig. 36C-E.

1971 Veryhachium cf. lairdi (Deflandre) in Downie et al., pl. 2, fig. 3.

1972 Veryhachium cf. lairdi Deflandre in Combaz and Peniguel, p. 130, pl. 1, figs. 17-8.

1973 Veryhachium cf. V. lairdi (Deflandre) Deunff in Legault, p. 53, pl. 12, figs. 3, 6-7, 11.

1974 Veryhachium lairdi (Deflandre) in Martin, p. 28, 43.

1974 Veryhachium lairdi (Deflandre) Deunff in Rauscher, p. 77, pl. 3, fig. 8.

1974 Veryhachium valiente Cramer in Rauscher, p. 77, pl. 3, fig. 9.

1974 Veryhachium valiente Cramer in Stockmans and Willière, p. 9, pl. 2, fig. 10.

?1974 Veryhachium cf. valiente (Cramer) in Lefort and Deunff, fig. 8.

?1974 Veryhachium cf. valiente Cramer in Pothe de Baldis, p. 372, pl. 1, fig. 12.

1974 Veryhachium valiente Cramer in Hill, (MS.).

Original Diagnosis: The shell, pale brown, light brown or bright orange, measures 10–30μ in width. The overall size of the specimens observed in the formations of Veryhac'h, ranges between 55 and 100μ.

The general form of the shell corresponds to that of a cushion, more or less inflated, carrying a spine at each angle. The shell may be diagramatically square, rectangular or lozenge–shaped. (transl.)

Description: The central body is compressed, and has a rectangular outline. The body sides are either incurving, straight or a little convex. The wall is thin or of only moderate thickness, and smooth or microgranulose in surface texture. The angles of the central body extend into hollow, usually long, flexible, tapering processes, with acuminate tips, which lie in the same plane as the central body. Proximally, the process stems vary in width, and either completely merge with the central body, or have a more distinct, but still curving contact. Internally communication between the central body cavity and process interiors, is unrestricted. Excystment is by a slit–like opening along one side of the central body.

Dimensions:		
	Central body:	26.5(31)36 x 17.5(27)36μ
	Length of processes:	up to 22μ (broken)
	Width of processes proximally:	2 - 10μ

Ratio of central body length to process length: 1.2 - 1.7 : 1 (approx.)

Specimens measured: 26

recorded: 83

Remarks: The body outline is greatly influenced by the degree of inflation, folding of the body wall, and other preservational details.

The species was introduced by Deflandre (1946), under the zoological code and named Hystrichosphaeridium lairdi, but it was not described and was therefore invalid (I.C.Z.N. Art. 13(a) (1)). Upon establishing the genus Veryhachium, Deunff (1954c), recommended that H. lairdi Deflandre, 1946 (nomen nudum) be transferred to it, but he did not actually state the new combination. Later, Deunff (1959), under the Zoological Code (see Veryhachium Deunff ex Downie, 1959, in this study), validated the species by describing it and stating the new combination. However, a holotype was not designated. Loeblich (1970), designated a lectotype from the available syntypes, and transferred the species from the animal to the plant kingdom.

Since the introduction of Veryhachium valiente by Cramer (1964) authors have experienced difficulty in differentiating Veryhachium lairdii Deflandre ex Deunff, 1959, from V. valiente Cramer, 1964. Cramer (1964) claimed V. valiente Cramer, 1964, to have straight body sides and V. lairdii Deflandre ex Deunff, 1959, to have generally concave sides. Subsequent study (see Martin, 1969), involving the examination of large numbers of specimens, has shown body outline to be a most unsatisfactory criterion for separating the two species.

Loeblich (1970), considered the specimens attributed to V. valiente Cramer, 1964b, and V. lairdii Deflandre ex Deunff, 1959, by

Cramer (1964b), to be con-specific, but restricted usage of V. valiente Cramer, 1964b, to Silurian forms, and V. lairdii Deflandre ex Deunff, 1959, to Ordovician forms, 'resembling the lectotype'.

Martin (1969) illustrated several straight-sided specimens from the Llanvirn (pl. 2, figs. 75-6, 83), which are similar to specimens recovered in this study. They were accompanied, as in this study, by forms having concave or slightly convex sides, with all grades of variation between the two. The situation, therefore, is one in which straight sided specimens occur with others having incurving or slightly convex sides in material of both the Ordovician and Silurian age.

It is clear that body outline cannot be used as a reliable basis for separation of the two species. In this study, Veryhachium lairdii Deflandre ex Deunff, 1959, is considered to be the same species as V. valiente Cramer, 1964b, the name V. lairdii Deflandre ex Deunff, 1959, taking precedence as senior synonym.

Forms having an additional, centrally placed, process attributed to V. valiente Cramer, by Cramer (1964b), are here excluded from V. lairdii Deflandre ex Deunff, 1959, and attributed to "V." rhomboidium Downie.

Occurrence: (?) Caernarvon, N. Wales, U.K.; Hope Shales and Stapeley Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K.; Arenigian(?) and Llanvirnian. Samples C1(?), C4(?), C6(?), W1, W3, SAL 2778.

Selected Previous Records: Presqu'ile de Crozon, Brittany, France; Caradoc Deunff, 1959, V. lairdii). Hassi-Messaoud sub-surface; N. Africa, Tremadoc (Combaz, 1967, V. lairdii). Huy, Sart Bernard, Naninne, Jonquoi, and other localities, Belgium; Ordovician-Silurian (Martin, 1969, V. lairdii). Montagne Noire, France; Arenig, Llanvirn and Caradoc (Rauscher, 1974, V. lairdii). Province of Leon, N.W. Spain; Upper Ludlovian - Emsian (Cramer 1964b, V. valiente). Montagne Noire and Cotentin, France; Arenig-Llanvirn, and Silurian - Devonian (Rauscher, 1974, V. valiente).

Veryhachium minutum Downie, 1958

Pl. 4, fig. 15; pl. 6, fig. 19; pl. 16, fig. 5(?)

p. 30, fig. 13(?); pl. 32, fig. 5(?); pl. 34, fig. 11.

1958 Veryhachium minutum Downie, p. 344, pl. 17, fig. 4; text-fig. 3c.

?1967 Veryhachium lairdi (Deflandre) Deunff in Combaz, p. 17, pl. 3, figs. 89, 91 (pars.)

1969 Veryhachium minutum Downie in Martin, p. 97, pl. 1, figs. 12(?), 14, 18, 31, 35-9, 55(?), 60, 61(?), 62-3; text-figs. 45-6.

?1969 Veryhachium lairdi (Deflandre) Deunff in Martin, p. 95, pl. 2, fig. 79.

?1970 Veryhachium minutum Downie in Martin et al., p. 344, pl. 1, fig. 8.

1971 Veryhachium minutum Downie in Rasul (MS.)

1972 Veryhachium minutum Downie in Martin, p. 27, pl. 5, fig. 5.

1973 Impluviculus milonii (Deunff) Loeblich and Tappan in Vanguestaine, (MS. pars.)

1974 Veryhachium minutum Downie in Rauscher, p. 63, pl. 1, fig. 11.

1974 Veryhachium minutum Downie in Potter (MS.)

1974 Veryhachium minutum Downie in Hill (MS.)

1974 Veryhachium minutum Downie in Stockmans and Willière, p. 7, pl. 2, figs. 8-9.

Original Diagnosis: Test small, about 3-15μ, formed by the united bases of the processes; test wall thin, colourless, transparent; processes conical; length 80-200% of the test diamter, but difficult to distinguish test from processes; number 4-6.

Description: The central body is hollow, compressed, and basically rectangular in outline with sides, straight, incurving, or convex, depending upon the degree of inflation, and/or preservational state.

The wall is thin, single layered, and has a smooth or microgranulose surface texture. The processes are slender, hollow, tapering extensions of the body angles, which open freely into the body cavity. Distally the process stems are closed and have acuminate tips. One or two additional processes may occasionally arise from the body centre. No definite excystment structure is present.

Dimensions:	Central body sides:	5.5(10.5)15 x 5(9)12μ
	Length of processes:	up to 10μ (broken)
	Ratio of central body length to process length:	0.5 - 1.5 : 1

Specimens measured: 10

recorded: 19

Remarks: The specimens differ in preservation according to the sample from which they were recovered. Some have been strongly carbonised and are totally opaque, whilst others have suffered very little carbonisation and have transparent walls.

The holotype of this species (Downie (1958), pl. 17, fig. 4)) has a much wrinkled test and an approximately rectangular outline. Although several examples conform closely to this specimen, also here attributed to the same species are a number of specimens (notably from sample C6) which have more inflated tests with convex sides and few minor folds.

Potter (1974, MS.) has discussed the difficulties in distinguishing this species from Impluviculus milonii (Deunff) Loeblich and Tappan, 1969 and I. multiangularis Umnova, 1971, comb. nov. Vanguestaine, 1973, (MS.). Impluviculus Loeblich and Tappan 1969, is a genus, in which the test is flattened, of sub-quadrate outline, and marked by an opening, situated at the centre of the body surface. Vanguestaine (1973, MS.) emended the

diagnosis to include 'quadrangular, polygonal, or sub-circular' outlines.

The essential difference between species of Impluviculus Loeblich and Tappan, 1969, and Veryhachium minutum Downie, 1958 is therefore the presence in the former of a centrally situated opening. However, as indicated by Potter (1974, MS.), in poorly preserved material, accidental ruptures, deformation attributable to the internal growth of pyrite crystals, and the presence of folds, extra processes and debris, can mimic the genuine occurrence of an opening.

Occasional specimens have been recovered in which a more or less centrally placed opening was observed, but in all cases the structure is irregular and indefinite, and the specimens have been attributed to Veryhachium minutum Downie, 1958.

In order to distinguish between Veryhachium minutum Downie, 1958, and Impluviculus multiangularis Umnova, 1971, comb. nov. Vanguestaine (1973, MS.), Potter (1974, MS.) restricted V. minutum Downie, 1958 to forms having only four processes. In the present study several specimens with five or, in some cases, six processes were encountered, but they have not been attributed to I. multiangularis Umnova 1971, comb. nov. Vanguestaine (1973, MS.) as the specimens display a basic rectangular form with the additional process, or processes, extending from a central position on the central body. Species attributable to Impluviculus Loeblich and Tappan, 1969, must, according to the emended diagnosis of Vanguestaine (1973, M.S.) have processes which arise close to, or at the outer edge of the body ('equatorial or sub-equatorial' position).

Comparison: In well preserved specimens, both Impluviculus milonii (Deunff) Loeblich and Tappan, 1969, and I. multiangularis Umnova, 1971, comb. nov. Vanguestaine 1973, (MS.), may be distinguished from

Veryhachium minutum Downie, 1958, by the presence of a centrally located opening on the central body. Veryhachium lairdii (Deflandre) ex Deunff, 1959, differs in being larger in size.

Occurrence: Caernarvon and Menai (?), N. Wales, U.K.; Skiddaw Slates, L.District, U.K.; Arenig-Llanvirn. Samples C4, C5, M3(?), SAL 2781, SAL 2778(?), SAL 390(?).

Previous Records: Shineton Shales, Shropshire, U.K.; Tremadocian; (Downie). N. Africa; Tremadocian; (Combaz, Veryhachium lairdi). Chevlipont Wepion, Rigenée and Sart Bernard, Belgium; Tremadocian, Arenigian(?), and Llanvirnian; (Martin, 1969). Shineton Shales - Dictyonema flabelliforme zone and Arenaceous Beds, Shropshire, U.K.; Tremadocian; (Rasul, M.S.). Montagne Noire, France; Tremadocian; (Martin, 1972). Ombret, Belgium; Caradocian; (Martin et al.). Stavelot, Belgium; Tremadocian - Lower Salmian; (Vanguestaine, MS., Impluviculus milonii, pars.). Montagne Noire, France; Tremadocian; (Rauscher). Ffestiniog Beds, N. Wales, U.K.; Shoot Rough Road Shale, Shropshire, U.K.; Upper Cambrian (Potter, MS.).

'Veryhachium' rhomboidium Downie, 1959.

1959 Veryhachium rhomboidium Downie, p. 62-3, pl. 12, fig. 10.

Original Diagnosis: Test rhomboidal, surface smooth, walls moderately thick, test size 16 to 23μ; processes, four or six, arising at the corners of the test, simple spines, length 50 to 100 per cent. of test size.

'Veryhachium' cf. rhomboidium Downie, 1959.

Pl. 21, fig. 6.

Description: (based on a single specimen) The central body is hollow, compressed, approximately square in outline, with a smooth or slightly

granulose wall of moderate thickness. The processes are hollow, tapering, and have acuminate tips. They are arranged one at each corner of the central body, with two others arising from the body surface. The central body cavity and process cavities communicate freely. The contact between the process stem and central body is curved. No excystment structure is present.

Dimensions:	Central body:	33 x 30μ
	Length of processes:	23μ (broken)
	Width of processes proximally:	2–4μ

Remarks: The original three dimensional form is difficult to assess, but the regularity of the outline suggests that the specimen may have been pillow-shaped with three or four processes lying in the same plane. The specimen is similar to '*Veryhachium*' *rhomboidium* Downie, but differs in that the central body is larger and possibly slightly granulose in texture.

Occurrence: Hope Shales, Shropshire, U.K.; Early Llanvirnian. Sample W1.

Veryhachium trispinosum Formgroup, Cramer, 1964b

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.

Included species: *Veryhachium reductum* (Deunff, 1959) Jekhowsky, 1961.
Veryhachium downiei Stockmans and Willière, 1962
Veryhachium trisculcum (Deunff, 1951) ex Deunff, 1959.
Veryhachium trispinosum (Eisenack, 1938) Deunff, 1959.
Veryhachium geometricum (Deflandre, 1945) Stockmans and Willière, 1963.

1938 Hystrichosphaeridium trispinosum Eisenack, p. 16, fig. 2.

1940 Hystrichosphaeridium trispinosum Eisenack in Lewis, p.34, pl. 3, fig.8.

1942 Hystrichosphaeridium geometricum Deflandre, p. 476, fig. 9, (nom. nud.).

1945 Hystrichosphaeridium geometricum Deflandre ex Deflandre, p. 64-5, pl. 2, figs. 2-5.

1945 Hystrichosphaeridium trispinosum Eisenack in Deflandre, pl. 2, fig. 1.

1951 Hystrichosphaeridium trisulcum Deunff, p. 323, fig. (nom. nud.)

1953 ?Hystrichosphaeridium geometricum Deflandre in Fisher, p. 16, pl. 7, fig. 9.

1954a Hystrichosphaeridium trispinosum Eisenack in Deunff, p. 240, fig. 2 (nom. nud.)

1954c Veryhachium trisulcum (Deunff) in Deunff, p. 306.

1954c Hystrichosphaeridium geometricum (Deflandre) in Deunff, p. 306.

1954c Hystrichosphaeridium trispinosum (Eisenack) in Deunff, p. 307.

?1956 Veryhachium trisulcum (Eisenack) in Deunff, fig. 8.

1959 Veryhachium cf. trispinosum (Eisenack) in Deunff, pl. 1, figs.5-7, 9.

1959 Veryhachium trisulcum Deunff var. reductum Deunff, p. 27, pl. 1, figs. 1, 3, 8, 10-12, 14, 16-7, 22-3.

1959 Veryhachium trisulcum Deunff in Deunff, p. 27, pl. 1, figs. 4, 13.

1959 Veryhachium trisulcum Deunff var. venetum Deunff, p. 27-8, pl. 1, figs. 2, 20.

1959 Veryhachium trispinosum (Eisenack) in Downie, p. 68-9, pl. 12, fig. 7.

1960 Veryhachium trispinosum (Eisenack) in Stockmans and Willière, p. 2, pl. 1, figs. 1-2, pl. 2, figs. 21-2, 24.

1961 Veryhachium sp. cf. H. trispinosum Eisenack in Staplin, p. 413, pl. 49, fig. 5.

1961 Veryhachium reductum (Deunff) Jekhowsky, p. 210-2, pl. 2, figs. 22-24.

1962a Veryhachium trispinosum Eisenack in Stockmans and Willière, p. 46-7, pl. 2, figs. 25-6, text-fig. 1.

1962a Veryhachium downiei Stockmans and Willière, p. 47-8, pl. 2, figs. 20-2; text-fig. 2.

1962b Veryhachium downiei Stockmans and Willière in Stockmans and Williere, p. 84, pl. 1, figs. 2-4; text-fig. 2.

1963 Veryhachium downiei Stockmans and Willière in Stockmans and Willière, p. 451-2, pl. 1, figs. 9-10; pl. 3, figs. 1-2; text-figs. 1-3.

1963 Veryhachium downiei var. haumanni Stockmans and Willière, p. 452, pl. 1, fig. 9; pl. 3, figs. 1-2; text-figs. 1-3.

1963 Veryhachium geometricum Deflandre in Stockmans and Willière, p. 452, pl. 1, fig. 18; text-fig. 4.

1963 Veryhachium reductum Deunff in Stockmans and Willière, p. 455-6, pl. 1, fig. 16, pl. 3-4; text-figs. 8, 9?.

1963 Veryhachium trispinosum (Eisenack) in Downie, p. 636.

1963 Veryhachium geometricum (Deflandre) Deunff, in Downie and Sarjeant, p. 94.

1963 Veryhachium reductum (Deunff) Jekhowsky in Downie and Sarjeant, p. 94.

1963 Veryhachium trispinosum (Eisenack) Deunff in Downie and Sarjeant, p. 94.

1963 Veryhachium trisulcum Deunff var. venetum Deunff in Downie and Sarjeant, p. 94.

1964b Veryhachium trispinosum Formgroup Cramer, p. 305-6, pl. 8, text-fig. 26.

1965 Veryhachium trispinosum Eisenack in Bain and Doubinger, p. 21, pl. 2, figs. 1-2.

1965 Veryhachium reductum Deunff forma reductum de Jekhowsky in Bain and Doubinger, p. 20, pl. 1, fig. 10.

1965 Veryhachium trispinosum Eisenack in Rauscher et al., p. 311.

1965 Veryhachium downiei Stockmans and Willière in Rauscher et al., p. 310.

1965 Veryhachium trisulcum Deunff in Vavrdova, p. 351, pl. 2, fig. 3.

non 1965 Veryhachium cf. trispinosum Eisenack in Vavrdova, p. 354-5.

1966a Veryhachium downiei var. haumanni Stockmans and Willière in Martin, p. 374.

1966a Veryhachium reductum (Deunff) forma breve de Jekhowsky in Martin, p. 374-5.

1966a Veryhachium downiei Stockmans and Willière in Martin, p. 374.

1966a Veryhachium trispinosum (Eisenack) in Martin, p. 373, fig. 20.

1966b Veryhachium trispinosum (Eisenack) in Martin, p. 431-2, text-fig. 8.

1966b Veryhachium reductum (Deunff) in Martin, p. 433-2; text-fig. 10.

1966 Veryhachium downiei Stockmans and Willière in Stockmans and Willière, p. 234, pl. 1, figs. 1-7.

1967 Veryhachium downiei Stockmans and Willière in Stockmans and Willière, p. 234, pl. 1, figs. 1-7.

1967 Veryhachium downiei Stockmans and Willière in Martin, p. 328.

1967 Veryhachium reductum (Deunff) in Martin, p. 328.

1967 Veryhachium trispinosum (Eisenack) in Martin, p. 328.

1967 Veryhachium trispinosum (Eisenack) in Lister and Downie, p. 173.

1967 Veryhachium trispinosum (Eisenack) in Martinez-Machiavello, p. 79-80, pl. 1, figs. 4-6; text-figs. 4-6.

1968b Veryhachium trispinosum Eisenack in Cramer, p. 127.

1968 Veryhachium trispinosum Formgroup in Lister (MS.), p. 109-11, pl. 13, figs. 1-9, 11.

1969 Veryhachium downiei Stockmans and Willière in Martin, p. 91-2, pl. 1, fig. 65; pl. 2, figs. 85, 102; pl. 6, fig. 253; pl. 7, fig. 345, 348-9; text-fig. 40.

1969 Veryhachium trispinosum (Eisenack) Deunff in Martin, p. 106-7, pl. 1, fig. 56; pl. 2, figs. 66, 82, 84, 93, 97, 101, 106; pl. 3, fig. 130; pl. 6, fig. 262; pl. 7, figs. 350-1.

1969 Veryhachium reductum Deunff in Stockmans and Willière, p. 11-2, pl. 2, figs. 14-6.

1969 Veryhachium reductum Deunff in Henry, p. 88, pl. 6, figs. 41, 47, 49.

1969 Veryhachium reductum (Deunff) de Jekhowsky in Konzalova-Mazancova, p. 87-8, pl. 16, figs. 4, 8.

1969 Veryhachium downiei Stockmans and Willière in Stockmans and Willière, p. 7-8, pl. 1, figs. 18-21.

1969 Veryhachium cf. trispinosum (Eisenack) in Henry, p. 76, pl. 1, figs. 3, 5.

1969 Veryhachium trispinosum (Eisenack) in Le Corré and Deunff, p. 46, fig. 2.

1969 Veryhachium cf. trisulcum venetum Deunff in Le Corré and Deunff, p. 46, figs. 5-7.

1969 Veryhachium trispinosum (Eisenack) Deunff in Konzalova-Mazancova, p. 88-9, pl. 16, figs. 6-7, text-fig. 4.

1969 Veryhachium trisulcum Deunff in Le Corré and Deunff, p. 46, figs. 1, 3-4.

1969 Veryhachium trisulcum (Deunff) in Henry, p. 76, pl. 1, figs. 1-2, 4, 6.

1969 Veryhachium trisculcum Deunff var. venetum Deunff in Konzalova-Mazancova, p. 88, pl. 16, fig. 5.

1970 Veryhachium trispinosum (Eisenack) Deunff in Cramer, 99-100, fig. 28.

1970 Veryhachium downiei Stockmans and Willière in Cramer, p. 95, fig. 28.

1970 Veryhachium geometricum (Deflandre) Deunff in Cramer, p. 97, fig. 28.

1970 Veryhachium reductum (Deunff) de Jekhowsky in Cramer, p. 98, fig. 28.

1970 Veryhachium trisulcum (Deunff) Deunff in Cramer, p. 100, fig. 28.

1970 Veryhachium trispinosum (Eisenack) Deunff in Cramer and Diez, p. 1078.

1970 Veryhachium trispinosum (Eisenack) Deunff in Lister and Holliday, p. 454, pl. 19, figs. 14, 18.

1970 Veryhachium reductum (Deunff) Jekhowsky in Paris and Deunff, p. 28, pl. 1, figs. 3, 5, 4.

1970 Veryhachium trispinosum Eisenack in Paris and Deunff, p. 29, pl. 1, figs. 15, 17.

1970 Veryhachium cf. trisulcum (Deunff) in Paris and Deunff, p. 29, pl. 1, fig. 2.

1971 Veryhachium downiei Stockmans and Willière in Deunff et al., p. 14, pl. 2, figs. 7-8.

1971 Veryhachium cf. trispinosum (Eisenack) in Henry and Thadeu, p. 1, pl. 1, fig. 11.

1971 Veryhachium trisculum Deunff in Henry and Thadeu, p. 1, pl. 1, figs. 3, 8, 13.

1971 Veryhachium trisulcum var. venetum Deunff in Henry and Thadeu, p. 1, pl. 1, fig. 10.

1971 Veryhachium reductum Deunff in Henry and Thadeu, p. 1, pl. 1, figs. 2, 9.

1971 Veryhachium cf. downiei Stockmans and Willière in Henry and Thaden, p. 1, pl. 1, figs. 4, 12.

1971 Veryhachium cf. trispinosum (Eisenack) in Rauscher, pl. 1, fig. 14.

1972 Veryhachium cf. trispinosum Eisenack in Combaz and Peniguel, p. 129-30, pl. 1, fig. 16.

1972 Veryhachium trispinosum (Eisenack) Deunff in Martin, p. 28.

1973 Veryhachium trispinosum Eisenack in Thusu, p. 138, pl. 2, fig. 8.

1974 Veryhachium trispinosum (Eisenack) in Pothe de Baldis, p. 372, pl. 1, fig. 11.

1974 Veryhachium trispinosum (Eisenack) Deunff in Stockmans and Willière p. 8, pl. 1, fig. 13; pl. 3, figs. 1-4; pl. 4, fig. 14.

1974 Veryhachium downiei Stockmans and Willière in Stockmans and Willière p. 5-6, pl. 1, figs. 12, 14, 16-7; pl. 2, figs. 2, 4-5, 7, 13-4; pl. 3, figs. 5-7.

1974 Veryhachium reductum (Deunff) de Jekhowsky in Stockmans and Willière, p. 8.

1974 Veryhachium trisulcum Deunff var. venetum Deunff in Stockmans and Willière, p. 8-9.

1974 Veryhachium trispinosum (Eisenack) Deunff in Gorka, p. 230-1, pl. 10, figs. 4-7.

1974 Veryhachium downiei Stockmans and Williere in Gorka, p. 229-30, pl. 11, figs. 4-5.

1974 Veryhachium geometricum (Deflandre) Deunff in Gorka, p. 230-1, pl. 11, figs. 1ab, 2ab.

1974 Veryhachium trispinosum (Eisenack) Deunff in Rauscher, p. 99, pl. 5, fig. 20.

1974 Veryhachium trisulcum (Deunff) in Rauscher, p. 99, pl. 5, figs. 19, 21.

1974 Veryhachium downiei Stockmans and Willière in Rauscher, p. 76, pl. 3, fig. 7.

1974 Veryhachium trispinosum Formgroup in Hill (MS.)

1974 Veryhachium trispinosum (Eisenack) in Martin, p. 28, 43, 44, 46, 47.

1974 Veryhachium downiei Stockmans and Willière in Martin, p. 28, 46, 47.

Description: The central body is hollow, pillow-like, and has a triangular outline with straight, convex or concave sides. Each body angle is drawn out into a simple tapering process, lying in the same plane as the central body. The stems are hollow with closed acuminate tips, and free communication with the central body interior. The wall is smooth or granulose. Excystment is by an arched slit between two of the processes (epityche).

Dimensions: Central body height: 15–40μ

Length of processes: 10–100μ

Specimens measured: 100

recorded: 695

Remarks: In order to accomodate interesting transitional forms, Cramer (1964b), initiated the use of Formgroups. The system is not recognised by either the I.C.B.N. or I.C.Z.N. and cannot therefore be considered valid under their rules. It is nevertheless adopted here in preference to widening the definitions of previously described species which would inevitably result in greater overlap and confusion.

Cramer (1964b) included five species in the Veryhachium trispinosum Formgroup. A sixth species, V. trispinosoides Stockmans and Willière, 1966, was added by Hill (1974, MS.). The scheme of Cramer (1964) is followed here.

A large number of trispinose forms were recovered from the Lower Ordovician material investigated in this study, but in general the specimens were poorly preserved, and very few have complete processes. Such specimens are difficult, if not impossible to separate from damaged specimens attributable to three other Ordovician genera viz: Frankea Burmann, 1970, Vogtlandia Burmann, 1970, and Lusatia Burmann, 1970, which may also have triangular outlines, and are normally distinguishable by differentitation of the process tips.

A specimen with a triangular body outline may not therefore belong to one or other of the six species which constitute the Veryhachium trispinosum Formgroup as defined above.

The genera Frankea Burmann and Vogtlandia Burmann are known to occur in the material examined by the presence of a small number of fairly complete specimens, the genus Lusatia Burmann was not recorded. However, the number of specimens attributable to Frankea Burmann and Vogtlandia Burmann, from amongst the large number of trispinose forms recorded without process tips, is not thought to be large. To have restricted consideration to the better preserved specimens would have eliminated 90-95% of the trispinose assemblage, probably giving a false impression of the abundance of trispinose veryhachids relative to other species. The specimen total recorded here, therefore includes all forms having a triangular body outline, with simple or broken process tips, and must consequently be regarded as an approximation.

Occurrence: Menai, Bangor and Caernarvon, N. Wales, U.K.; Hope Shales and Stapeley Shales, Shropshire, U.K.; Skiddaw Slates, Lake District, U.K. Early Arenigian - Late Llanvirnian. Samples B1, M2, C1, C6, H5, W1, W3, SAL 389, SAL 390, SAL 2778, SAL 2781.

Selected Previous Records: Presqu'ile de Crozon, Brittany, France; Caradocian (Deunff, 1959, Veryhachium trisulcum var. reductum). Sondage de l'Asile d'aliénés, Tournai, Belgium; Devonian (Frasnian) Stockmans and Willière, 1962a, V. downiei). Finistere, Brittany, France; Ordovician (Deunff, 1951, Hystrichosphaeridium trisulcum) Baltic provinces; Silurian (Eisenack, 1938, Hystrichosphaeridium trispinosum). Montagne Noire, France; Silurian (Deflandre, 1942, H. geometricum).

'Veryhachium' sp. A.

Pl. 21, fig. 7.

Description: The central body is compressed, hollow, thin walled, and has an approximately quadrate outline. The angles are drawn out into single hollow, tapering processes, which lie in the same plane as the central body. In length, they do not exceed the central body diameter. Five shorter, though similar, processes are arranged on the body surface. Process tips are acuminate. Stem contact with the central body is curved. The wall is ruptured along one edge, between two of the principle processes. The surface of the wall appears to be smooth.

Dimensions: Central body: 29 x 26.5μ

Length of processes: 12-20μ

Remarks: The diagnosis of 'Veryhachium' rhomboidium Downie, 1959, as emended by Hill (1974, MS.) included forms with up to nine processes.

However, the specimen considered here also differs from the holotype in other ways. The outline is less rectangular, and, relative to body side-length the processes are shorter. It is therefore considered too far removed from 'V. 'rhomboidium Downie, as originally diagnosed, to be attributable to it.

Occurrence: Hope Shales, Shropshire; Early Llanvirnian. Sample W1.

Genus VILLOSACAPSULA Loeblich and Tappan, 1976

Type Species: Villosacapsula setosapellicula (Loeblich) Loeblich and Tappan, 1976 = Veryhachium setosapelliculum Loeblich, 1970, p. 743, figs. 36A-B, 37A-B. Upper Ordovician, Sylvan Shale, Lawrence Quarry, Pontotoc County, Oklahoma, U.S.A.

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 the processes with short scattered microspines, excystment by an eiptyche.

Remarks: Veryhachium Deunff ex Downie, 1959, differs in possessing a laevigate or gramulate wall.

Villosacapsula piliferum Martin, 1966, comb. nov.

1965 Veryhachium cf. trispinosum Eisenack in Vavrdova, p. 354-5.

1966b Veryhachium piliferum Martin, p. 432; text-fig. 9.

1969 Veryhachium piliferum Martin in Martin, p. 99-100, pl. 2, fig. 86; text-fig. 47.

1972 Veryhachium piliferum Martin in Martin, p. 27.

1973 Goniosphaeridium piliferum (Martin) Eisenack et al., p. 495.

1974 Veryhachium piliferum Martin in Martin, p. 28, 43, 45.

Original Diagnosis:

Central body: outline triangular, more or less equilateral; length of sides 25 to 30μ.

Appendages: 3 in number; projecting in the same plane and the central body angles. Length generally equal to that of the central body sides.

Ornamentation: the surface of the central body and of the appendages is covered in hairs, with robust base, and length about 1μ.

Villosacapsula cf. piliferum Martin, 1966, comb. nov.

Pl. 33, fig. 12.

Description: (single specimen) The central body is pillow-like with a triangular outline. A simple tapering process extends from each body angle. All three processes lie in the same plane as the central body, and their hollow stems communicate freely with the central body cavity. The body wall carries one or two folds and appears to be single layered and relatively thin. The surfaces of both body and processes are ornamented by minute hairs, generally less than 0.5μ in length. No excystment structure is present.

Dimensions:		
	Central body side length:	22-25μ
	Length of processes:	18μ (broken)
	Height of ornament:	< 0.5μ

Remarks: The surface ornament appears to be more delicate than in Villosacapsula piliferum Martin comb. nov. The specimen is carbonised though the wall has remained relatively transparent.

Comparison: Villoscapsula setosapellicula (Loeblich) Loeblich and Tappan differs from V. cf. piliferum Martin comb. nov. in having a thicker wall and an ornament of microspines 1-2μ in length.

Occurrence: Skiddaw Slates, Lake District, U.K., Late Llanvirnian. Sample SAL 2778.

Subgroup Uncertain

Genus NOTHOOIDIUM Loeblich and Tappan, 1976

Type Species: Nothooidium morbidum (Cramer et al.) Loeblich and Tappan, 1976 = Ooidium morbidum Cramer et al., 1974b, p. 186, pl. 28, figs. 21-2, 24-9. Late Arenigian - Early Llanvirnian, Moroccan sub-surface.

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 morbidum (Cramer et al.) Loeblich and Tappan, was attributed by Cramer et al. (1974), to the genus Ooidium Timofeev, 1957. Loeblich and Tappan (1976) recognised that the species had little in common with Ooidium Timofeev or any other published genus They therefore proposed Nothooidium to accomodate the taxon.

Nothooidium sp. A.

Pl. 32, fig. 11; pl. 34, fig. 6.

Description: (based on two specimens) The central body is compressed, hollow, and has an approximately pear-shaped outline. The body wall is moderately thin, and marked by crescentic folds. Numerous short, blunt spines ornament the surface. They are slightly swollen distally, often flat crested, and regularly distributed over the surface. In one specimen there is a large opening at one pole.

Dimensions:		
	Central body:	40–43 x 38–39μ
	Height of ornament:	1–2μ
	Diameter of opening:	20μ (approx)

Remarks: Both specimens are moderately carbonised, the (solid?) spines being silhouetted against the body wall which is relatively transparent.

Comparison: Nothooidium sp. A differs from Nothooidium morbidum (Cramer et al.) Loeblich and Tappan in surface ornament, which in the latter takes the form of flat crested verrucae approximately two microns high and three to five microns in diameter.

Occurrence: Skiddaw Slates, Lake District, U.K.; Late Llanvirnian, Samples SAL 2778, SAL 2781.

CHAPTER 5 STRATIGRAPHIC PALYNOLOGY

5.1. BIOSTRATIGRAPHIC ZONATION

There have been few previous attempts to produce a microfloral subdivision of Lower Ordovician strata. Lister (I.G.S. unpublished report, PDL/68/98), in a study of Skiddaw Slates exposed in the Cross Fell Inlier (see also Chapter 6), proposed three 'Assemblage Types' which he believed characteristic of Arenig and Lower Llanvirn strata. Jardine et al. (1974), attempted a biostratigraphic zonation of Palaeozoic rocks (Tremadocian to Devonian) from the Algerian Sahara, based on acritarchs, chitinozoa and sporomorphs. They defined twenty three palynological zones and presented range charts, showing the distribution of typical acritarch species. An approximate correlation between the 'Assemblage Types' of Lister and zones of Jardine et al. is given in Table 9.

Other authors have recorded acritarch species obtained from localities dated by graptolites and/or trilobites. However, these datings have often been of a tentative nature, and not specific beyond 'Arenigian' or 'Llanvirnian'. In addition, the relative position of samples within these intervals was often unknown.

This latter observation is also applicable to some of the samples examined in this study (from the Tarn Moor and Tailbert-Llanshaw tunnel sections). The samples from Caernarvon, however, were collected from an almost continuously exposed, well dated, graptolite-yielding section, not apparently disrupted by faulting. Relative sample positions from this section are known with a high degree of certainty. Samples from Shropshire, whilst not from continuously exposed sections

Series		This Study	Lister	Jardine et al.
Llanvirn	m	?---?---? 5		E
	b	4	1	
Arenig	h	3	2	?---?---?
	e	b 2 a	3	D C$_2$
		1 ?---?---?		

Table 9 Approximate correlation between the biozones proposed in this study, and those of Lister (unpublished report), and Jardine et al., (1974).

were from particularly well dated trilobite localities and referrable to either the upper or lower part of the Didymograptus bifidus Zone. The relative position of samples within the D. bifidus Zone is therefore known. The assemblages yielded by the samples from Caernarvon and Shropshire form the basis of the proposed zonal scheme in this study.

Based on the assemblages recovered from sixteen samples, a scheme of five microfloral zones is proposed, which partially span the Arenig and Llanvirn Series. It must be appreciated, however, that because of the low frequency of sampling, poor preservation, and consequent uncertainty as to the true ranges of species, the absolute minimum of information was available for the creation of the biozonation. Hence, it cannot be regarded as more than a first step in the palynological subdivision of Lower Ordovician sediments. The scheme is certain to require adjustment and amendment as additional data become available.

The biostratigraphical unit which most suitably takes account of the type of information available is the Oppel Zone, defined by

Hedberg (1976) as 'a zone characterised by an association or aggregation of selected taxons of restricted and largely concurrent range, chosen as indicative of approximate contemporaneity'. Not all taxa considered diagnostic of the zone need be present, and interpretation is sufficiently flexible to allow the inclusion of biostratigraphic criteria other than range concurrence.

Zone 1 (based on the assemblages from samples B1 and B2)

Zone 1 approximately corresponds to the lower part of the Zone of Didymograptus extensus. The top of the zone coincides with the base of Zone 2. The base of the zone is undefined. Zone 1 is characterised by the presence of Cymatiogalea cuvillieri (Deunff), (r), Acanthodiacrodium cf. simplex Combaz, (r/c), Multiplicisphaeridium sp. D, (c), Striatotheca rarirrugulatum (Cramer et al.), (r/c), Coryphidium bohemicum Vavrdova, (c), Peteinosphaeridium lepton sp. nov. (r/c), and Stelliferidium striatulum (Vavrdova), (c). A major part of the assemblage is composed of less diagnostic species including Polygonium gracile Vavrdova, (c), P. cf. pungens Timofeev comb. nov., (c), and morphographically similar intermediate types, (a). Micrhystridium aremoricanum Paris and Deunff comb. nov. is also of common occurrence, but specimens attributable to the Veryhachium trispinosum Form group are rare. In addition occur species belonging to the genera Elektoriskos? (r/c), and Poikilofusa (r), and further species attributable to the genera Acanthodiacrodium (r), Multiplicisphaeridium (r/c), Micrhystridium (c), Stelliferidium (r), and Striatotheca (r).

Zone 2

Zone 2 is subdivided into two subzones.

Subzone 2a (based on the assemblages from samples M2, M3 and C6)

approximately corresponds to the upper part of the Zone of Didymograptus extensus. The base of the subzone is at present taken at the first occurrence of Micrhystridium cf. cleae Martin. The top of the subzone is more or less coincident with the base of the Zone of Didymograptus hirundo. Species which characterise Subzone 2a include Micrhystridium cf. cleae Martin, (r/c), Frankea sartbernardense (Martin), (r/c), Micrhystridium subtile sp. nov., (c), Peteinosphaeridium sp. C, (c), P. cf. paucifurcatum (Eisenack), (r), and Schizodiacrodium sp. B, (r). Specimens attributable to the genus Baltisphaeridium (r) make their first appearance within Subzone 2a. The genus Polygonium, as in the underlying zone, is well represented through Polygonium gracile Vavrdova, (c), P. cf. pungens Timofeev comb. nov., (r/c), and associated intermediate types, (a). Micrhystridium aremoricanum Paris and Deunff comb. nov. is common, and specimens attributable to the Veryhachium trispinosum Formgroup are more frequently encountered. Important species present in Zone 1 which continue into this subzone include Peteinosphaeridium lepton sp. nov., Coryphidium bohemicum Vavrdova, and Striatotheca rarirrugulatum (Cramer et al.). C. bohemicum Vavrdova continues as a common species, but both P. lepton sp. nov. and S. rarirrugulatum (Cramer et al.) occur more frequently, reaching their acme in Subzone 2a.

Subzone 2b (based on the assemblages from samples C4 and C5)

This subzone, which approximately corresponds to the Zone of Didymograptus hirundo, is, on present evidence, rather difficult to define palynologically. A single specimen of Cymatiogalea cf. gramulata Vavrdova was recorded, and Micrhystridium crispum sp. nov. appears to be confined to it, but is not a common species. Other features include the frequent occurrence of Micrhystridium subtile sp. nov., (c/a),

Peteinosphaeridium sp. C, (c/a), and the first definite occurrences of Multiplicisphaeridium maroquense (Cramer et al.). The genus Polygonium is represented by P. cf. tener Timofeev comb. nov., (r/c), and associated types (c). Specimens attributable to the Veryhachium trispinosum Formgroup, and to Micrhystridium aremoricanum Paris and Deunff comb. nov., are of generally common occurrence. Notable species occurring in Subzone 2a, still present in Subzone 2b, include Corphidium bohemicum Vavrdova, (r/c-c), Striatotheca rarirrugulatum (Cramer et al.), (c - r/c), Peteinosphaeridium lepton sp. nov., (r/c), Frankea sartbernardense (Martin), (r/c), and Schizodiacrodium sp. B, (r).

The species Marrocanium simplex Cramer et al. was not recorded from the two samples used to characterise Subzone 2b, but was recorded from better preserved material of probable Didymograptus hirundo zone age from the Lake District. Marrocanium simplex Cramer et al., is morphographically similar to Veryhachium lairdii (Deflandre) ex Deunff, but differs in that the four processes support a thin membrane. The material recovered from samples C4 and C5 was strongly carbonised and it is unlikely that delicate membrane structures would have survived. The apparent absence of the species from these samples is therefore not surprising. The Lake District records suggest that it occurs regularly in Subzone 2b. Its base occurrence may be within the lowermost part of Subzone 2b or within the uppermost part of Subzone 2a.

Zone 3 (based on the assemblages from samples H5, C1, SAL 389, and SAL 390)

This zone approximately corresponds to the lower part of the Zone of Didymograptus bifidus. Its base is at present taken as coinciding with the base of the Zone of D. bifidus, and the top is defined by the base of Zone 4. Zone 3 is characterised by the occurrence of Arkonia virgata

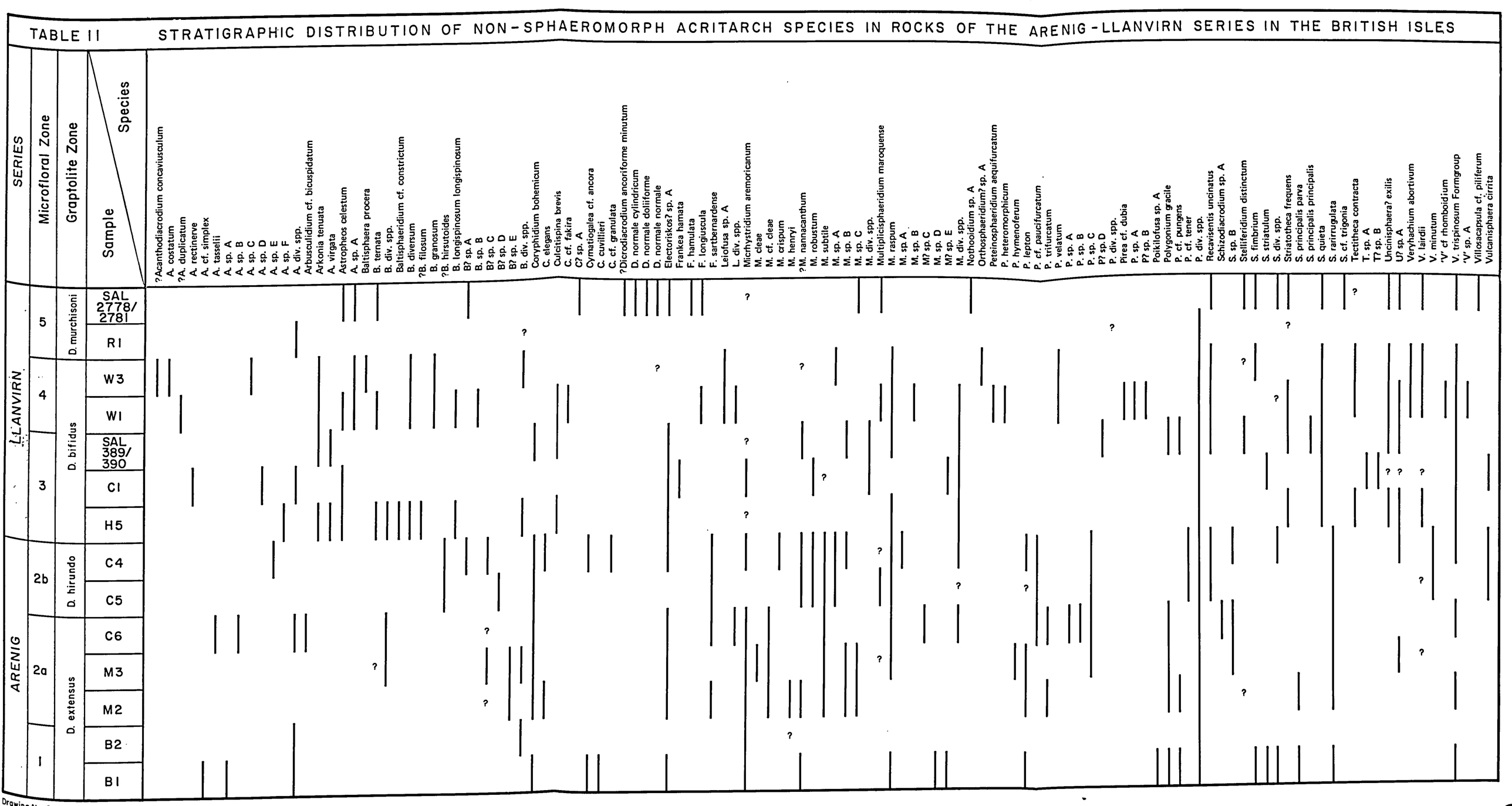
Burmann (c), A. tenuata Burmann, (r - c), Striatotheca quieta (Martin), (r), S. frequens Burmann, (r/c), Astropheos celestum (Martin) comb. nov., (c), Baltisphaeridium diversum sp. nov., (r), Culcitispina brevis gen. et sp. nov., (r - r/c), and Uncinisphaera? exilis sp. nov., (r - c). The base occurrences of these species do not necessarily coincide with the base of Zone 3. Additional occurrences include several species of Baltisphaeridium Eisenack, though generally represented by few specimens. The Veryhachium trispinosum Formgroup is abundantly represented for the first time, and there are rare occurrences of Tectitheca contracta Burmann.

Peteinosphaeridium lepton sp. nov. and Striatotheca rarirrugulatum (Cramer et al.) are now absent. Coryphidium bohemicum Vavrdova may continue into the lower part of the zone in low numbers.

Zone 4 (based on the assemblages from samples W1 and W3)

Zone 4 approximately corresponds to the upper part of the Zone of Didymograptus bifidus. Its base is at present placed at the appearance of Frankea longiuscula Burmann. The top is defined by the base of Zone 5. Species which characterise Zone 4 include Peteinosphaeridium velatum Kjellström, (r/c), P. aequifurcatum Kjellström, (r), Veryhachium abortivum sp. nov., (r/c), Astropheos sp. A, (r - r/c), Baltisphaeridium diversum sp. nov., (r/c - c), Tectitheca contracta Burmann, (c/a), Culcitispina brevis gen. et sp. nov., (r - c), and probably Dicrodiacrodium normale Burmann var. normale. (inconclusive occurrence in sample W3). Most of the important species occurring in Zone 3 also occur in Zone 4 (Arkonia virgata Burmann is a possible exception). Specimens attributable to the Veryhachium trispinosum Formgroup are particularly abundant in this zone.

TABLE II STRATIGRAPHIC DISTRIBUTION OF NON-SPHAEROMORPH ACRITARCH SPECIES IN ROCKS OF THE ARENIG-LLANVIRN SERIES IN THE BRITISH ISLES



Drawing No. 21501

TABLE 12

FREQUENCY OF OCCURRENCE OF ACRITARCH SPECIES IN ROCKS OF THE BRITISH ARENIG-LLANVIRN SERIES

r = rare : < 1% r/c = 1 - 3% c = common : 3 - 8% c/a = 8 - 20% a = abundant : > 20%

| SERIES | Microfloral Zone | Graptolite Zone | Sample | ?Acanthodiacrodium concaviusculum | A. costatum | ?A. duplicatum | A. rectinerve | A. cf. simplex | A. tasselii | A. sp. A | A. sp. B | A. sp. C | A. sp. D | A. sp. E | A. sp. F | A. div. spp. | Arbusculidium cf. bicuspidatum | Arkonia tenuata | A. virgata | Astropheos celestum | A. sp. A | Baltisphaera procera | B. ternata | B. div. spp. | Baltisphaeridium cf. constrictum | B. diversum | ?B. filosum | B. granosum | ?B. hirsutoides | B. longispinosum longispinosum | B? sp. A | B. sp. B | B? sp. C | B? sp. D | B? sp. E | B. div. spp. | Coryphidium bohemicum | C. elegans | Culcitispina brevis | C. cf. fakira | C? sp. A | Cymatiogalea cf. ancora | C. cuvillieri | C. cf. granulata | ?Dicrodiacrodium ancoriforme minutum | D. normale cylindricum | D. normale doliiforme | D. normale normale | Electoriskos? sp. A | Frankea hamata | F. hamulata | F. longuscula | F. sartbernardense | Leiofusa sp. A | L. div. spp. | Micrhystridium aremoricanum | M. cleae | M. cf. cleae | M. crispum | M. henryi | ?M. nannacanthum | M. robustum | M. subtilis | M. sp. A | M. sp. B | M. sp. C | M. div. spp. | Multiplicisphaeridium maroquense | M. raspum | M. sp. A | M. sp. B | M? sp. C | M. sp. D | M? sp. E | M. div. spp. | Nothoidium sp. A | Orthosphaeridium? sp. A | Peteinosphaeridium aequifurcatum | P. heteromorphicum • | P. hymenoferum | P. lepton | P. cf. paucifurcatum | P. trifurcatum | P. velatum | P. sp. A | P. sp. B | P. sp. C | P? sp. D | P. div. spp. | Pirea cf. dubia | P. sp. A | P? sp. B | Poikilofusa sp. A | Polygonium gracile | P. cf. pungens | P. cf. tener | P. div. spp. | Recavisentis uncinatus | Schizodiacrodium sp. A | S. sp. B | Stelliferidium distinctum | S. fimbrium | S. striatulum | S. div. spp. | Striatotheca frequens | S. principalis parva | S. principalis principalis | S. quieta | S. rarirrugulata | S. cf. trigonia | Tectitheca contracta | T. sp. A | T? sp. B | Uncinisphaera? exilis | U? sp. A | Veryhachium abortivum | V. lairdii | V. minutum | 'V.' cf rhomboidium | V. trispinosum Formgroup | 'V.' sp. A | Villosacapsula cf. piliferum | Vulcanisphaera cirrita |
|---|---|---

Drawing No. 21474

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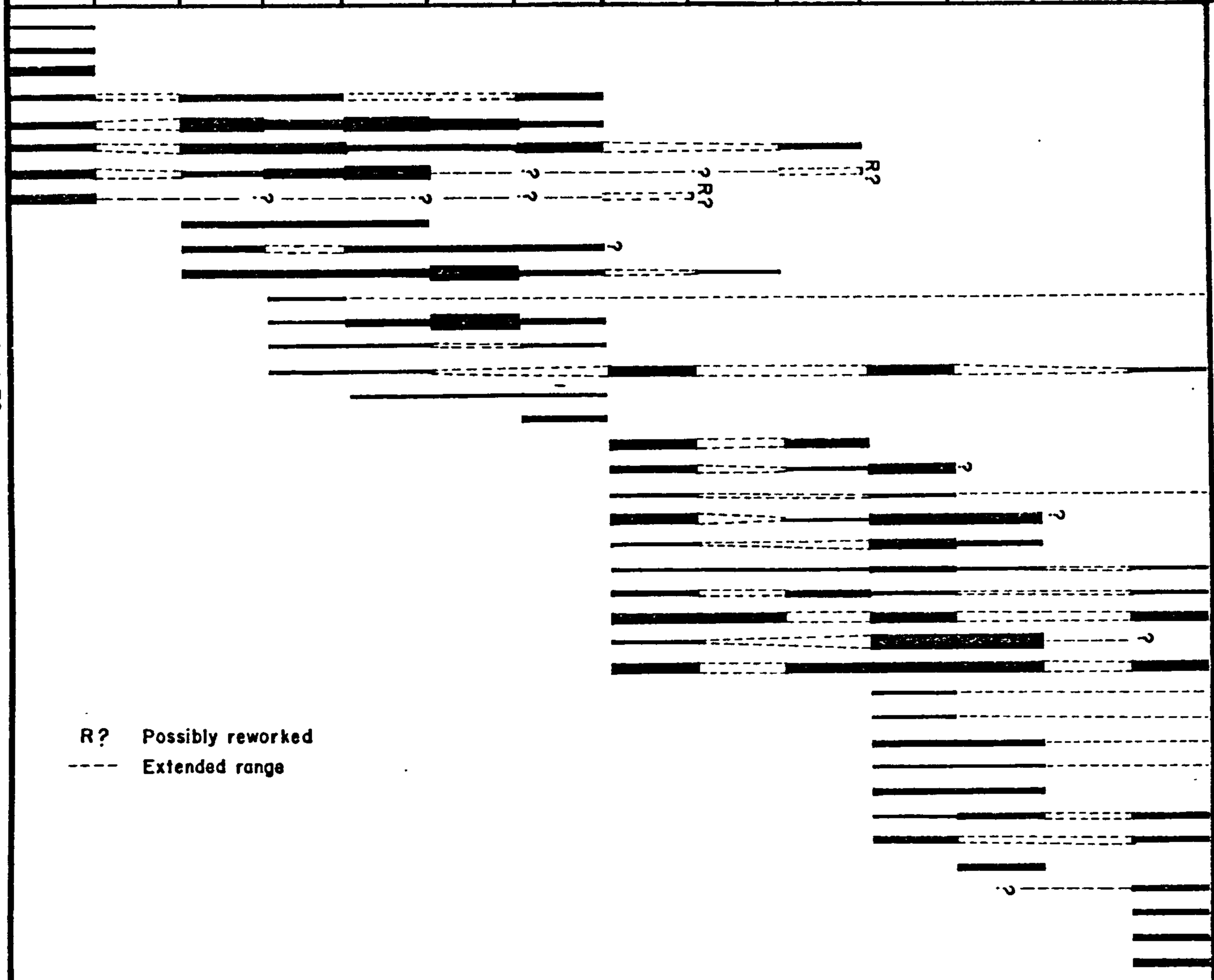
TABLE 13 STRATIGRAPHIC DISTRIBUTION OF SELECTED SPECIES

ARENIG							LLANVIRN						
1	2a				2b		3			4		5	
D. extensus					D. hirundo		D. bifidus					D. murchisoni	
B1	B2	M2	M3	C6	C5	C4	H5	C1	SAL 389/390	W1	W3	R1	SAL 2776/2781



R? Possibly reworked

---- Extended range

SERIES
Microfloral Zone
Graptolite Zone
Sample / Species
Cymatiogalea cuvillieri
Acanthodiacrodium cf. simplex
Multiplicisphaeridium sp. D
Peteinosphaeridium lepton
Striatotheca rarirrugulata
Coryphidium bohemicum
Polygonium gracile
Stelliferidium striatulum
Micrhystridium cf. cleae
Frankea sartbernardense
Micrhystridium subtile
Peteinosphaeridium hymenoferum
P. sp. C
Schizodiacrodium sp. B
Baltisphaera spp.
Peteinosphaeridium cf. paucifurcatum
Micrhystridium crispum
Arkonia virgata
Culcitispina brevis
Baltisphaeridium longispinosum longispinosum
Arkonia tenuata
Baltisphaeridium diversum
Striatotheca quieta
S. frequens
Astropheos celestum
Tectitheca contracta
Uncinisphaera ? exilis
Peteinosphaeridium aequifurcatum
P. heteromorphicum
P. velatum
Baltisphaeridium granosum
Veryhachium abortivum
Astropheos sp. A
Frankea longiuscula
Orthosphaeridium sp. A
Dicrodiacrodium normale normale
D. normale doliiforme
Nothooidium sp. A
Frankea hamulata

Zone 5 (based on the assemblages from samples SAL 2778 and SAL 2781)

Zone 5 approximately corresponds to the lower part of the Zone of Didymograptus murchisoni. The base of the zone coincides with the base of the D. murchisoni zone. The top of the zone is undefined. Species which appear to characterise Zone 5 include Dicrodiacrodium normale doliiforme Burmann, (r), Villosacapsula cf. piliferum Martin comb. nov., (r), Nothoodium sp. A, (r), and Frankea hamulata Burmann, (r). Species present in Zone 4, also occurring in Zone 5, include Frankea longiuscula Burmann, (r/c), Astropheos sp. A, (r/c), and Dicrodiacrodium normale Burmann var. normale, (r/c). Baltisphaeridium diversum sp. nov., Culcitispina brevis gen. et sp. nov., and Arkonia tenuata Burmann, present in both Zones 3 and 4, have so far not been recorded from Zone 5. Specimens attributable to the Veryhachium trispinosum Formgroup are rather less abundant than in Zone 4.

5.2. COMPARISON WITH PREVIOUSLY RECORDED ASSEMBLAGES IN EUROPE AND NORTH AFRICA

The stratigraphic intervals investigated by previous authors, discussed in this part of Chapter 5, are compared in Table 10.

German Democratic Republic

Lower Ordovician microplancton has been described from the G.D.R. by Burmann (1968, 1970). Seventy-six species were recorded from borehole (Arkona 101, Rugen 3h) and surface outcrop material (Aufschlusse A and B), dated as Late Llanvirnian on graptolite evidence. A further twenty-two species were described from the Griffelschiefer (pencil slate). However, these slates are not accurately dated. The trilobite and graptolite

evidence is conflicting, the trilobites suggesting that the age is Llanvirnian, and the graptolites that it is Arenigian. According to Burmann(1968, 1970), the organic microplankton yielded by the Griffelschiefer indicates an age which is clearly older than Late Llanvirnian. Furthermore, comparison with assemblages from the Klabava Shales (Czechoslovakia), suggests that it may be Late Arenigian. Burmann, however, considers the present evidence to be insufficient for positive dating, and proposes that the Griffelschiefer should be regarded as Arenigian - Early Llanvirnian until a closer examination of the Czechoslovakian material is possible.

Of the twenty-two species described from the Griffelschiefer, only one, Striatotheca principalis parva Burmann, is present in the U.K. Arenigian (microfloral Zones 1 - 2a, b). Additionally, specimens have been compared with Dicrodiacrodium bicuspidatum Burmann (= Arbusculidium bicuspidatum Burmann comb. nov.), and the genus Vogtlandia Burmann may be represented by Multiplicisphaeridium sp. A, and possibly also by Multiplicisphaeridium maroquense Cramer et al. Vogtlandia Burmann is considered by Burmann (1968, 1970) to be a characteristic genus of the Griffelschiefer.

Of the seventy-six species recorded by Burmann from the Late Llanvirnian, the following three are present in the U.K. Arenigian (microfloral Zones 1 - 2a, b).

Baltisphaeridium uncinatum (Downie)

= Recavisentis uncinatus Downie comb. nov.

Frankea sartbernardense (Martin)

Veryhachium lairdii (Deflandre)

Baltisphaera ternata Burmann may also be present.

Seventeen of the seventy-six species recorded from the Late Llanvirnian by Burmann are certainly present in the U.K. Llanvirnian (microfossils Zones 3-5). They are as follows:

Acanthodiacrodium costatum Burmann

A. rectinerve Burmann

Arkonia tenuata Burmann

A. virgata Burmann

Baltisphaeridium procera Burmann

B. ternata Burmann

Baltisphaeridium uncinatum (Downie)

= Recavisentis uncinatus Downie comb. nov.

Dicrodiacrodium normale cylindricum Burmann

D. normale doliiforme Burmann

D. normale Burmann = D. normale Burmann var. normale nom. nov.

Frankea hamata Burmann

F. hamulata Burmann

F. longiuscula Burmann

F. sartbernardense (Martin)

Striatotheca acutiuscula Burmann = S. quieta (Martin)

S. frequens Burmann

Tectitheca contracta Burmann

Veryhachium lairdii (Deflandre)

Dicrodiacrodium ancoriforme minutum Burmann, Acanthodiacrodium duplicatum Burmann, A. concaviusculum Burmann, and Baltisphaeridium echinulatum Burmann (as Astropheos celestum (Martin)), may also be present. In addition, a species has been compared with Striatotheca trigonia Burmann.

The species Dicrodiacrodium normale doliiforme Burmann, and Frankea hamulata Burmann were not recorded in this study from rocks older than Late Llanvirnian, and hence agree biostratigraphically with the occurrences of Burmann (1968, 1970). However, it is quite clear, from the U.K. material that many of the species recorded by Burmann (1968, 1970) from the Late Llanvirnian range down into the Early Llanvirnian in the U.K.

The absence of Arkonia virgata Burmann, A. tenuata Burmann, Striatotheca quieta (Martin), and S. frequens Burmann, in the pencil slates, lends support to Burmann's view that these rocks are older than Llanvirnian.

Morocco

Cramer et al., (1974a and b) have described seventeen species from the core material of well BJ 109, Tadla Basin, Morocco. In addition they illustrate four other species (non Polygonium gracile Vavrdova, Schizodiacrodium sp., Acanthodiacrodium sp., and an 'unedited' acritarch), which, presumably, are also from the same core material. Of these twenty one species, seven are present in the Late Arenigian - Early Llanvirnian of the U.K. (microfloral Zones 2a, 2b, 3 and 4). They are:

Coryphidium elegans Cramer et al.

Dicrodiacrodium ancoriforme Burmann (pars.)

= D. normale Burmann var. normale (uncertain record in microfloral Zone 4)

Multiplicisphaeridium maroquense Cramer et al.

Rugulidium quietum (Martin) = Striatotheca quieta (Martin)

Rugulidium rarirrugulatum Cramer et al.

= Striatotheca rarirrugulata (Cramer et al.)

Rugulidium triangulatum Cramer et al.

= Arkonia temuata Burmann

Schizodiacrodium sp. = Schizodiacrodium sp. B

A species similar to Pirea dubia Vavrdova was also recorded from microfloral Zone 4.

In microfloral Zone 5 (Late Llanvirnian) the genus Nothooidium Loeblich and Tappan is present (Ooidium mordidum Cramer et al. = Nothooidium mordidum (Cramer et al.) Loeblich and Tappan), and Dicrodiacrodium Burmann is well represented. Under Dicrodiacrodium ancoriforme Burmann, Cramer et al. (1974b), include all other species of Dicrodiacrodium Burmann, introduced by Burmann (1968). Cramer et al. (1974b) were unable to distinguish the individual taxa due to the presence of transitional forms. In this study, however, the various species of Dicrodiacrodium Burmann have been maintained.

Of the remaining fourteen species recorded by Cramer et al. (1974a and b) the following three were noted in Lake District samples, not used in the compilation of the proposed microfloral zones:

Marrocanium simplex Cramer et al.

Multiplicisphaeridium hoffmanensis Cramer et al., 1974b, pl. 24, fig. 10.

Unedited acritarch of Cramer et al. 1974b, pl. 24.

Poland

Ordovician sediments are not exposed in the western part of the east European Platform, and are known only from borehole material, where they are often represented by a thinly developed calcareous facies. Dating has been with the aid of trilobite faunas, or by graptolites, or by brachiopods. In the region of Bialowieza, Lower Ordovician sediments (Late Arenigian) were penetrated by the borehole Podborowisko IG 1.

A sample from Podborowisko IG 1 (392.40 - 393 m.) was examined palynologically by Gorka (1969) who described from it twenty three acritarch species. None of these species is certainly present in the U.K. Late Arenigian (microfloral Zone 2b), although Baltisphaeridium hirsutoides (Eisenack) may be represented. Peteinosphaeridium trifurcatum Eisenack (= Baltisphaeridium trifurcatum (Eisenack) subsp. breviradiatum Eisenack) is, however, present in microfloral Zone 2a (Early Arenigian) and Baltisphaeridium longispinosum (Eisenack) forma longispinosum in microfloral Zones 3-4 (Early Llanvirnian). In addition, certain specimens attributed by Gorka (1969) to Baltisphaeridium multipilosum (Eisenack) may belong to B. diversum sp. nov.

Sweden

The Grotlingbo No. 1 borehole, drilled for the Geological Survey of Sweden, penetrated a condensed sequence of Ordovician limestones and shales. The acritarchs yielded by these beds were subsequently investigated by Kjellström (1971a and b). Kjellström described sixty-five species. Many were new and apparently short ranging. In his 1971a paper he distinguished four baltisphaerid assemblages. Assemblage I was characterised by five species obtained from, and restricted to, a stratigraphic horizon corresponding

to the uppermost part of the Zone of Didymograptus hirundo and the very lowest part of the Zone of Didymograptus bifidus. None of the five species are present in microfloral zones 2b and 3, but two, Baltisphaeridium granosum Kjellström and Peteinosphaeridium velatum Kjellström, are present in microfloral Zone 4 of this study (upper part of the Zone of Didymograptus bifidus).

Assemblage II was composed of ten species, none of which ranged lower than the middle part of the Zone of Didymograptus murchisoni. Of the ten species forming Assemblage II, Baltisphaeridium longispinosum (Eisenack) longispinosum was recorded from microfloral Zones 3 and 4, Peteinosphaeridium heteromorphicum Kjellström from microfloral Zone 4, and specimens similar to Baltisphaeridium constrictum Kjellström from microfloral Zone 3, where, also, B. filosum Kjellström may occur. From Assemblage IV Kjellström records Peteinosphaeridium aequifurcatum Kjellström which is present in microfloral Zone 4.

It is clear from the foregoing comparison that several species recorded from the Middle Ordovician by Kjellström range much lower.

Belgium

Microplankton yielded by the Lower Palaeozoic rocks of Belgium has been principally investigated by Martin (1966a and b, 1967, 1969). The Lower Ordovician is represented by the Huy and Sart-Bernard formations, dated by Bulman (1950) as Late Arenigian and Llanvirnian respectively.

The Huy formation outcrops at the type locality of Huy and at Puagne, Fosse, Malonne and Sart-Bernard. From four samples Martin records twenty seven species, of which the following eight are present in the U.K. Arenigian (microfloral Zones 1, 2a, 2b).

Baltisphaeridium striatulum Vavrdova

= Stelliferidium striatulum (Vavrdova)

Baltisphaeridium uncinatum

= Recavisentis uncinatus Downie comb. nov.

Micrhystridium nannacanthum Deflandre

M. raspa = Multiplicisphaeridium raspum (Cramer)

M. robustum Downie

Veryhachium lairdi (Deflandre)

V. sartbernardense Martin = Frankea sartbernardense (Martin

V. trispinosum (Eisenack) = V. trispinosum Formgroup (pars.)

The Sart-Bernard formation outcrops at Dave, Arville, Puagne and at the type locality of Sart-Bernard. Borehole material from Sart-Bernard and Wepion was also used. From eight samples Martin records twenty-nine species, of which the following six are present in the U.K. Llanvirnian (microfloral Zones 3, 4 and 5).

Baltisphaeridium striatulum Vavrdova

= Stelliferidium striatulum (Vavrdova)

Micrhystridium nannacanthum Deflandre

Micrhystridium raspa (Cramer)

= Multiplicisphaeridium raspum (Cramer)

M. robustum Downie

Veryhachium lairdi (Deflandre)

V. trispinosum (Eisenack) = V. trispinosum Formgroup (pars.)

In addition Martin (1969) records Veryhachium fakirum Martin and V. piliferum Martin, with which specimens from the U.K. Llanvirnian (microfloral Zones 3, 4 and 5) have been compared.

England

In order to assess the compositional differences between Tremadocian and Arenigian microfloral assemblages, a comparison was made with the species recorded by Rasul (1971, MS.) in his comprehensive study of acritarchs from the Wrekin district of Shropshire. The Tremadocian sequence there is unfortunately incomplete. The basal beds are unexposed, and the uppermost beds eroded and unconformably overlain by Silurian strata.

In most, if not all, areas of the U.K., Arenigian deposition was preceded by a period of erosion. The extent of the hiatus, and the evolutionary development of microfloras during this period is unknown. It is clear, however, that Tremadocian and Arenigian microfloral assemblages differ markedly in composition. Several genera, commonly recorded by Rasul (1971, MS.) in the Tremadocian, do not appear to be present in the U.K. Arenigian (for example, Impluviculus Loeblich and Tappan, Priscotheca Deunff). Others, while ranging up into the Arenigian, are not well represented (Acanthodiacrodium Timofeev ex Deflandre and Deflandre-Rigaud, Cymatiogalea Deunff). In the Arenigian, also, several new genera make

their appearance (Baltisphaeridium Eisenack, Peteinosphaeridium Staplin et al., Coryphidium Vavrdova, Striatotheca Burmann).

Only nine of the one hundred and sixty three species recorded from the Shropshire Tremadocian by Rasul (1971, MS.) have been recorded in this study in the Arenigian (microfloral Zones 1, 2a and 2b). They are as follows:

Cymatiogalea cuvillieri Deunff

Micrhystridium robustum Downie

Priscogalea distincta Rasul

= Stelliferidium distinctum Rasul comb. nov.

Priscogalea fimbria Rasul

= Stelliferidium fimbrium Rasul comb. nov.

Polygonium gracile Vavrdova

Schizodiacrodium sp. A = Schizodiacrodium sp. A

Tectitheca uncinatum (Downie)

= Recavisentis uncinatus (Downie) comb. nov.

Veryhachium minutum Downie

Vulcanisphaera cirrita Rasul

In addition specimens have been compared with Polygonium pungens Timofeev, comb. nov. (= Archeohystrichosphaeridium pungens Timofeev, nom illegit.)

Certain Lower Ordovician assemblages from the U.K. are discussed in Chapter 6 (p.333).

France

There have been a number of studies dealing with Ordovician acritarchs from France. In general, interest has centred on two regions, the Massif Amoricain, and the Montagne Noire. The studies considered here are those of Rauscher (1974) and Paris and Deunff (1970).

a) Rauscher (1974)

In his thesis, Rauscher (1974) describes assemblages ranging from Cambrian (Tremadocian) to Silurian in age. Of relevance for comparison with the assemblages described in this study are the Lower Ordovician assemblages he recorded from the Montagne Noire, and the syncline of May-Sur-Orne.

Arenigian rocks outcrop in the Roquebrun and Minervois regions of the Montagne Noire. Two sections were studied by Rauscher south of Roquebrun. The first, a succession of schistose sandstones and grits outcropping along the Roquebrun valley, was considered to be of Early Arenigian age by Thoral (1935), and, according to Rauscher (1974), more recent work confirms this dating. The second, a series of slates and sandstones, outcropping in the Landegran valley, is also now considered to be of Early Arenigian age (Dean, 1966), although some earlier workers believed it to be Middle Arenigian or younger.

In the Minervois region the Lower Ordovician is represented by psammitic sandstones and quartzites. These deposits are attributed in part to the Early Arenigian, on evidence from fossiliferous nodules (Rauscher, 1974) p. 58).

From these Arenigian localities Rauscher (1974) describes thirty-nine species, of which the following seven have been recorded from the U.K. sections: (microfloral Zones 1 - 2a and b).

Baltisphaeridium hirsutoides (Eisenack)

Coryphidium bohemicum Vavrdova

Micrhystridium robustum Downie

Peteinospháeridium breviradiata Eisenack = P. trifurcatum Eisenack

Polygonium gracile Vavrdova

Striatotheca principalis parva Burmann

Veryhachium minutum Downie

In Normandy, west of May-sur-Orne, lies a NW - SE trending syncline, in which is preserved a sequence of Cambrian, Ordovician and Silurian rocks. The Ordovician is partly represented by slates with Calymene and an underlying ironstone, which develops a lateral speckled facies. A Llanvirnian age is attributed to these beds. Rauscher describes twenty-two species from them. Seven of these species are recorded from the U.K. Llanvirnian sections studied (microfloral Zones 3-5). They are as follows:

Baltisphaeridium longispinosum (Eisenack) longispinosum

Baltisphaeridium ternatum (Burmann) - (in part equivalent to Baltisphaera ternata Burmann and B. procera Burmann)

Goniosphaeridium uncinatum (Downie) = Recavisentis uncinatus Downie comb. nov.

Micrhystridium nannacanthum Deflandre

Veryhachium trispinosum Eisenack = V. trispinosum Formgroup (pars.)

V. trisculcum Deunff

Cymatiogalea striatulum (Vavrdova)

= Stelliferidium striatulum

(Vavrdova)

In addition Rauscher (1974) records the presence of Veryhachium horridum Paris and Deunff. This species, as described by Paris and Deunff (1970), is partly diagnosed by its rectangular outline. Otherwise it is very similar to Astropheos celestum Martin comb. nov., and may in fact be the same species. Rauscher (1974) also records three species which are absent in the U.K. Llanvirnian, but present in the U.K. Arenigian. They are: Micrhystridium henryi Paris and Deunff, Peteinosphaeridium breviradiatum Eisenack (= P. trifurcatum Eisenack), and Veryhachium sartbernardense Martin (= Frankea sartbernardense (Martin)).

(b) Paris and Deunff (1970)

An assemblage of acritarchs, chitinozoa, and scolecodonts was described by Paris and Deunff (1970), from the locality Vieux-Vy-sur-Couesnon, Ille-et-Vilaine (Brittany). The ferruginous beds from which they were obtained are considered to be of Llanvirnian age. Thirty-three species of acritarch were recorded, of which the following five species were recorded from the U.K. Llanvirnian = (microfloral Zones 3 - 5).

Micrhystridium inconspicuum aremoricanum Paris and Deunff

= M. aremoricanum Paris and Deunff comb. nov.

Priscogalea striatula (Vavrdova)

= Stelliferidium striatulum

(Vavrdova)

Veryhachium lairdi Deflandre

V. sartbernardense Martin

= Frankea sartbernardense (Martin)

V. trispinosum Eisenack = V. trispinosum Formgroup (pars.)

Paris and Deunff (1970), also record Veryhachium horridum Paris and Deunff, which may be the same species as Astropheos celestum Martin comb. nov., and, in addition, Cymatiogalea ancora Paris and Deunff (to which a number of specimens from the U.K. Arenigian have been compared) and Micrhystridium henryi Paris and Deunff (which also occurs in the U.K. Arenigian.

Czechoslovakia

Vavrdova has been primarily responsible for investigations into the acritarch assemblages yielded by the Cambro-Ordovician rocks of Czechoslovakia.

Contributions have also been made by Eisenack (1948), who described a poorly preserved assemblage from the Sarka Shales (Llanvirnian), and by Mazancova (1969) who described an assemblage from the Kralav Dvur Shales (Early Ashgillian).

Vavrdova has presented the results of her studies in a series of short papers (1965, 1966, 1972, 1973, 1974, 1976). In total she records sixty-three species from the Klabava Shales (Arenigian). Eight of these species are present in one or other of the assemblages used to formulate microfloral Zones 1 and 2 in this study. The eight species are as follows:

Coryphidium bohemicum Vavrodva

Baltisphaeridium uncinatum (Downie) = Recavisentus uncinatus comb. nov.

Polygonium gracile Vavrdova

Stelliferidium striatulum (Vavrdova)

Veryhachium lairdii (Deflandre)

V. minutum Downie

V. microrugulatum Vavrdova = Striatotheca principalis parva Burmann

V. trisculcum Deunff = V. trispinosum Formgroup (pars.)

Also present in microfloral Zone 2 is a species which has been compared with Cymatiogalea granulata Vavrdova and which has also been described from the Klabava Shales by Vavrdova.

Of the remaining species reported from the Bohemian Arenigian, Baltisphaeridium longispinosum (Eisenack) is present in the Hope Shales of Shropshire (earliest Llanvirnian). The long, slender processes of this species are particularly susceptible to breakage after carbonisation, and its apparent absence from the Arenigian samples examined in this study may be due to this factor.

From the Llanvirnian of Czechoslovakia, Vavrdova records a total of twenty-three species. Of these, the following six are present in one or other of the Llanvirnian assemblages used to formulate microfloral Zones 4, 5 and 6 in this study:

Acanthodiacrodium costatum Burmann

Baltisphaera ternata Burmann

Coryphidium bohemicum Vavrdova

Polygonium spinosum Jardine et al.

= Astropheos celestum Martin comb. nov.

Striatotheca principalis Burmann

Veryhachium trispinosum Deunff

Vavrdova (1972) also records Frankea sartbernardense (Martin), (as Evittia sartbernardense (Martin)). This species occurs in the U.K. Arenigian, (microfloral Zones 1 and 2), but was not recorded from the Llanvirnian assemblages.

Estonia

Since 1931, Eisenack has published the results of many micro-palaeontological investigations of the Ordovician and Silurian deposits in the Baltic region. In his papers of 1958a and 1962c Eisenack summarised much of his earlier work on the Ordovician deposits. It is with these two accounts that comparisons with the present study have been made.

The samples from which Eisenack obtained his microfossil assemblages were correlated lithologically or palaeontologically to the Estonian Ordovician succession. Eisenack (1958a) recorded a total of nine non-spheromorph acritarch species from the Glaukonitsand (B1) and Glaukonitkalk (B2). These deposits are of uppermost Tremadocian to Late Arenigian age. Of the nine species, the following three were recorded from British material of Arenigian age (microfloral Zones 1, 2a, 2b):

Baltisphaeridium hirsutoides Eisenack

= Baltisphaeridium hirsutoides (Eisenack)

Baltisphaeridium hymenoferum (Eisenack)

= Peteinosphaeridium hymenoferum (Eisenack)

Baltisphaeridium trifurcatum (Eisenack) (pars)

= Peteinosphaeridium trifurcatum Eisenack (al. breviradiata Eisenack)

In addition, specimens were compared with Baltisphaeridium trifurcatum paucifurcatum Eisenack = Peteinosphaeridium paucifurcatum Eisenack.

Eisenack (1962c) recorded fifteen species or subspecies of non-spheromorph acritarch from the Vaginatenkalk B3 and Revaler Stufe (C1). These deposits are attributed to the upper part of the Arenig the Llanvirn and Llandeilo Series. Of these fifteen species or subspecies only Baltisphaeridium longispinosum (Eisenack) longispinosum (al. filifera) has been recorded from British material of Llanvirnian age (microfloral Zones 3, 4), during the present study.

Evaluated Comparison

To enable further comparison of the Arenig/Llanvirn assemblages described in this study with those reported by previous authors, each assemblage has been evaluated as follows:

$$\frac{\text{Number of species also occurring in British material studied}}{\text{Total number of species present}}$$

For example, of the twenty nine species recorded from the Sart Bernard Formation (Llanvirn) by Martin (1969), six are also present in the studied British Llanvirn material. The numerical value given to Martin's assemblage is therefore $6/29 = 0.21$.

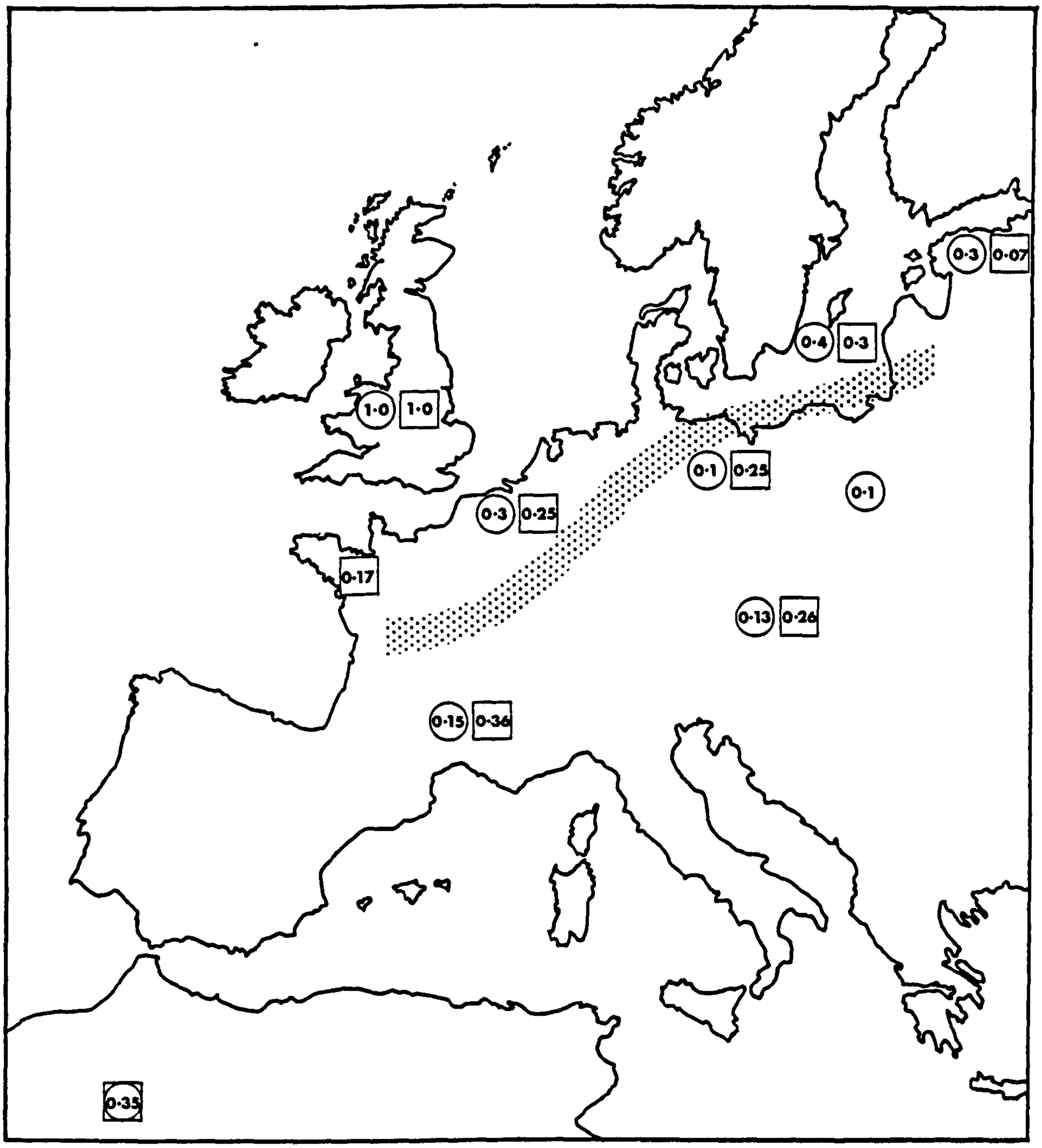
The maximum score of 1.0 is attained when all the species recorded from a particular assemblage are also present in the studied British material. The evaluation does not take account of assemblage size, preparation methods, or lithology of the studied sections. Nor are exactly equivalent stratigraphic horizons compared. Consequently

any conclusions drawn from the comparisons must be regarded as very tentative. The results are presented in Text-fig. 30.

What apparently is indicated, is the probable separation of the British, Belgian and Baltic region from more southerly areas during most of the Arenigian. During the Llanvirnian, the most marked contrast is between the British province and the Baltic province. However, the Baltic Llanvirnian assemblages, with which comparison is made, are composed of only a few species derived from carbonate lithologies. The indication should therefore be treated with caution.

Table 10 Stratigraphic Intervals investigated by previous authors, with which comparisons are made in this study

SYSTEM	SERIES \ AUTHOR	This study	Burmann 1968,1970	Cramer et al. 1974 a,b	Eisenack 1958a 1962c	Gorka 1969 (pars)	Kjellström 1971 a,b	Martin 1969 (pars)	Paris & Deunff 1970	Rasul 1971 (MS)	Rauscher 1974 (pars)	Vavrdova 1965-76
ORDOVICIAN	ASHGILL											
	CARADOC						?--? Assemb. 4 ?--? Assemb. 3 ?--? Assemb. 2					
	LLANDEILO											
	LLANVIRN (5 m, 4 b, 3)		ENGLAND AND WALES: composite section	GDR: unnamed fm	Revaler Stufe		SWEDEN	BELGIUM: Sart Bernard Fm	FRANCE: unnamed fm		FRANCE	CZECHOSLOVAKIA: Klabava Shales
	ARENIG (2 h, b, pr2, 1 e)			GDR: Pencil Slates	Vaginatenkalk. Glaukonitkalk Glaukonitsand	MOROCCO: Well BJ 109	POLAND: Podborowisko IGI Assemb. 1	BELGIUM: Huy Fm		ENGLAND: Shineton Shales	FRANCE	
CAMBRIAN	TREMADOC											



Text-fig. 30

◯ Arenig assemblage ▭ Llanvirn assemblage ◯ Arenig·Llanvirn boundary assemblage

⁘ Possible barrier during Arenigian time

Comparison of British Arenig and Llanvirn acritarch assemblages with those reported from the Continent and North Africa.

CHAPTER 6 APPLICATION OF THE ZONAL SCHEME TO MICROFLORAL ASSEMBLAGES FROM THE LAKE DISTRICT

In Chapter 1 of this study it was stated that the samples collected from a large number of Lake District localities were either barren of recognisable organic remains or contained only rare, fragmented and strongly carbonised acritarchs and chitinozoa. Two samples, however, contained more numerous less fragmentary, but still strongly carbonised, acritarchs. The biostratigraphic information they provided was not used to characterise the Arenig and Llanvirn stages microflorally, as the ages that had been assigned to them (based on their graptolite content) were questionable. The acritarch species present in these samples are listed and discussed below. Also discussed are the assemblages from five other Lake District localities.

A microfloral assemblage from siltstones of the Skiddaw Group at Outerside

Locality: 90 m. N. of Outerside summit, Derwent Fells

Sample: L 31 (see Text-fig. 6)

Age: ? Zone of *Didymograptus hirundo*

Species present:

Acanthodiacrodium sp.

Baltisphaera ternata Burmann

Coryphidium bohemicum Vavrdova

C. elegans Cramer et al.

Cymatiogalea sp.

Frankea sartbernardense (Martin)

Micrhystridium cf. *nannacanthum* Deflandre

Multiplicisphaeridium cf. maroquense Cramer et al.

?M. hoffmanensis Cramer et al.

Marrocanium simplex Cramer et al.

?Peteinosphaeridium heteromorphicum Kjellström

P. nudum (Eisenack)

P. trifurcatum Eisenack (al breviradiata Eisenack)

Polygonium sp.

?Recavisentis uncinatus (Downie)

Stelliferidium cf. striatulum (Vavrdova)

S. cf. furcatum (Deunff)

Striatotheca quieta (Martin)

S. frequens Burmann

S. rarirrugulatum (Cramer et al.)

?Uncinisphaera sp.

Veryhachium downiei Stockmans and Williere

V. lairdii (Deflandre) ex Deunff

V. trispinosum Formgroup

unedited acritarch of Cramer et al. (1974b)

The microfloral assemblage recovered from this sample corresponds to Zone 2b in the proposed microfloral scheme. The possible Didymograptus hirundo Zone age, indicated by the graptolites at this locality (Jackson, 1956 MS.), is thus confirmed.

However, the co-occurrence of Striatotheca rarirrugulatum (Cramer et al.), S. frequens Burmann, and S. quieta (Martin), suggest a position in the uppermost part of the zone. The assemblage is similar to those recorded by Cramer et al. (1974a and b) from the Tadla Basin, Morocco, considered to be Arenigian - Llanvirnian in age. In this respect the

most significant species are Marrocanium simplex Cramer et al., Multiplicisphaeridium cf. maroquense Cramer et al., ?M. hoffmanensis Cramer et al., Striatotheca quieta (Martin), S. rarirrugulatum (Cramer et al.), and the unedited acritarch of Cramer et al., 1974b.

A microfloral assemblage from slatey shales of the Skiddaw Group at Mungrisdale

Locality: Raven Crags, 135m W. of Undercrag.

Sample: L 21 (see Text-fig. 7)

Age: ? Subzone of Didymograptus deflexus

Species present:

?Baltisphaeridium hirsutoides (Eisenack)

Coryphidium bohemicum Vavrdova

?Cymatiogalea sp.

Multiplicisphaeridium sp.

M. sp. D.

Peteinosphaeridium lepton sp. nov.

Polygonium sp.

?Recavisentis uncinatus (Downie)

?Stelliferidium distinctum (Rasul)

S. furcatum (Deunff)

?S. striatulum (Vavrdova)

S. sp.

Striatotheca principalis parva Burmann

?Uncinisphaera sp.

?Veryhachium lairdii (Deflandre) ex Deunff

V. trispinosum Formgroup

Vulcanisphaera cirrita Rasul

The microfloral assemblage recovered from this sample is composed of rather poorly preserved, strongly carbonised, acritarchs. Process terminations are usually absent, and the identification of certain species is made difficult because of this.

The occurrence of Peteinosphaeridium lepton sp. nov. and Coryphidium bohemicum Vavrdova, suggests an Arenigian age. Of the remaining species the occurrence of Multiplicisphaeridium sp. D is especially significant. Taken in conjunction with the frequent occurrence of a form closely resembling Stelliferidium striatulum (Vavrdova), (positive identification is prevented by the poor preservation), and the presence of many simple spined acritarchs, possibly attributable to the genus Polygonium Vavrdova, the sample can, with a moderate degree of confidence, be assigned to Zone 1 of the proposed microfloral scheme. Zone 1 corresponds to the lower part of the Zone of Didymograptus extensus. Consequently it is probable that it includes part, if not all, of the Subzone of Didymograptus deflexus. Hence the D. deflexus Subzone age reported for this locality is supported.

A microfloral assemblage from a pelitic horizon within the Borrowdale Volcanic Group at Holehouse Gill

Locality: Holehouse Gill (NGR SO 185 925)

Samples: 5942, 5942(B), 5943, 5943(B) (Sheffield Univ.)

The pelites were located and mapped by Numan (1974 MS.), and two samples were subsequently prepared and examined by Downie (pers. comm.). The samples were later reprepared and the earlier preparations re-examined by the author in an attempt to gain additional information.

The organic material obtained was strongly carbonised, fragmented and very limited in quantity. All specimens were broken and many were completely opaque. In view of the low yield and strong carbonisation, oxidation was not attempted.

The following list is of species recorded both during re-examination of preparations 5942 and 5943 and in the examination of preparations 5942(B) and 5943(B). Because of poor preservation, many of the identifications are uncertain.

Species present:

Astropheos sp.

Baltisphaera sp.

Baltisphaeridium sp.

Coryphidium bohemicum Vavrdova

Frankea sartbernardense (Martin)

Leiofusa sp.

Micrhystridium nannacanthum Deflandre

Micrhystridium sp.

?Peteinosphaeridium trifurcatum Eisenack (al. breviradiata).

P. sp.

Polygonium gracile Vavrdova

P. sp.

P. sp.

Stelliferidium cf. distinctum (Rasul)

S. sp.

Striatotheca cf. principalis parva Burmann

?S. rarirrugulatum (Cramer et al.)

S. cf. rarirrugulatum (Cramer et al.)

Villosacapsula cf. piliferum Martin comb. nov.

Spp. indet.

Except for the occurrence of Astropheos sp. and Villosacapsula cf. piliferum Martin comb. nov., the assemblage is definitely Arenigian in character. The specimens of ?Striatotheca rarirrugulatum (Cramer et al.) cannot be positively identified, because of their highly carbonised, and fragmented state, but the occurrence of Coryphidium bohemicum Vavrdova, Frankea sartbernardense (Martin) and Polygonium gracile Vavrdova is certain.

Coryphidium bohemicum Vavrdova is a typical Arenigian species present in microfloral Zones 1 - 2, ranging into Zone 3 (Llanvirnian). Polygonium gracile Vavrdova is present in microfloral Zones 1 and 2 (Arenigian), with a single (reworked ?) occurrence in Zone 3 (Llanvirnian). Frankea sartbernardense (Martin) was recorded from Zone 2 (Arenigian), although it is likely that it ranges higher (see, for example, Rauscher, 1974; Burmann, 1970). None of these species can therefore be said to be confined to the Arenigian, but their co-occurrence with the typical Arenigian genera Peteinosphaeridium and Stelliferidium, suggests that most of the assemblage is Arenigian in age.

The exceptions are the single occurrence of Villosacapsula cf. piliferum Martin comb. nov., and of a specimen attributed to the genus Astropheos gen. nov. Villosacapsula cf. piliferum Martin comb. nov. was recorded from a sample of Didymograptus murchisoni Zone age, and Astropheos gen. nov. has so far only been recorded from rocks of Llanvirnian and younger age. These two specimens may therefore indicate an age younger than Arenigian.

If the occurrence of Villosacapsula cf. piliferum (Martin) is accepted as an indication of Late Llanvirnian strata then the typical Arenigian species would probably have to be considered reworked.

Comments on the palynological assemblages reported from pelitic shales of the Skiddaw Group in the Cross Fell inlier

Prior to the work of Lister (I.G.S. unpublished report PDL/68/98) the Lower Ordovician sedimentary sequence in the Cross Fell Inlier was considered to be as follows:

Lower Llanvirn	Milburn Beds
	Ellergill Beds
Arenig?	Slates of Brownber and Murton Pike
	Shales and sandstones of Hungrigg Sike and Meikle Awfell

Graptolites indicative of the Zone of Didymograptus bifidus had been recorded from the Milburn and Ellergill Beds, but the Milburn Beds were given a higher stratigraphic position because of the presence of interbedded lavas and tuffs. The Milburn Beds were viewed as a transition group to the overlying Borrowdale Volcanic Group.

No fossil evidence existed as to the age of the Hungrigg Sike and Meikle Awfell shales/sandstones, or as to the age of the Brownber and Murton Pike Slates, except for a 'lost' Glyptograptus (Shotton, 1935, p. 648). Consequently, their stratigraphic position was largely a matter of conjecture.

Palynological investigation of the Lower Ordovician sediments in the Cross Fell inlier was begun by Downie (in Wadge et al. 1967). A rich microfossil assemblage was obtained from the Milburn and Ellergill Beds. This preliminary work was followed by a more prolonged investigation undertaken by Lister. Based on the acritarchs he recorded, Lister

devised a stratigraphic scheme of 'Assemblage - Types', and proposed that the stratigraphy of the Skiddaw Slate Group should be modified as follows:

	Ellergill Beds	=	Assemblage Type 1
Lower Llanvirn	Milburn Beds	=	Assemblage Type 2
Upper Arenig	Undifferentiated Skiddaw Slates	=	Assemblage Type 3

An approximate correlation between the Assemblage Types and the zonal scheme proposed in this study is as follows:

Assemblage Type 1	=	Zone 4
Assemblage Type 2	=	Zone 3
Assemblage Type 3	=	Zones 1, 2a, b.

It is difficult to compare the assemblages recorded by Lister with those recorded during the course of this study, as Lister's investigation was carried out before the introduction of several important Lower Ordovician genera and species. A preliminary re-examination of the material prepared by Lister was undertaken by the author in order to establish whether or not the new genera and species were present. Although the re-examination was restricted to a very brief survey of eight of the original sixty-five samples, the following species were identified.

Coryphidium bohemicum Vavrdova

C. elegans Cramer et al.

Frankea longiuscula Burmann

Striatotheca frequens Burmann

S. principalis Burmann var. principalis

S. principalis parva Burmann

S. quieta (Martin)

The occurrence in sample SAL 356 (Ellergill Beds) of Frankea longiuscula Burmann probably indicates an age not older than microfloral Zone 4 and is an indication that this sample may be younger than SAL 235 (Millburn Beds), from which Frankea longiuscula Burmann was not recorded, but which contained several specimens of Arkonia tenuata Burmann, A. virgata Burmann, and Striatotheca frequens Burmann. Arenigian indications were found in SAL 500 (Undifferentiated Skiddaw Slate Group). These observations agree with the interpretation of Lister who placed SAL 356, SAL 235 and SAL 500 into Assemblage - Types 1, 2 and 3 respectively.

It must be emphasised that the agreement rests on a very limited amount of observation, and further work is needed before firm conclusions can be drawn.

An assemblage of Arenigian - Llanvirnian age from shales of the Skiddaw Group near Scalegill

Shales of the Skiddaw Group are exposed at several localities along the banks of the small stream of Scalegill, in the northern Lake District. A rich acritarch assemblage was obtained from the dark grey shales outcropping in the south bank, approximately 100m. upstream from the farm track. (NGR NY 200356).

The following species were noted:

?Arbusculidium bicuspidatum Burmann comb. nov.

Arkonia tenuata Burmann

Astropheos celestum Martin comb. nov.

Baltisphaera sp.

?Baltisphaeridium klabavense Vavrdova

B. sp. A.

?B. sp. C.

Marrocanium simplex Cramer et al.

?Multisphaeridium maroquense Cramer et al.

M. sp.

Peteinosphaeridium cf. bergstromii Staplin et al.

?P. nudum (Eisenack)

?P. sp. C.

P. sp.

Schizodiacrodium sp. B.

Striatotheca frequens Burmann

S. principalis parva Burmann

S. principalis Burmann var. principalis

The assemblage is intermediate in character between those of microfloral Zones 2b and 3. This indicates an age either high in the Zone of Didymograptus hirundo or low in the Zone of D. bifidus. A D. hirundo Zone age has been suggested for a locality situated further to the east.

A Didymograptus hirundo zone age for pelitic shales of the Skiddaw Group exposed at Causeway Foot

Shales of the Skiddaw Group outcrop to the west of the road at Causeway Foot, approximately two miles south of Keswick (NGR 291 220). A sample from this locality yielded a moderately rich assemblage of acritarchs. The following species were noted:

Coryphidium bohemicum Vavrdova

Dasydiacrodium sp.

Frankea sartbernardense (Martin)

Marrocanium simplex Cramer et al.

?Multiplicisphaeridium maroquense Cramer et al.

?Stelliferidium distinctum Rasul comb. nov.

Striatotheca principalis parva Burmann

Striatotheca principalis Burmann var. principalis

Striatotheca rarirrugulatum (Cramer et al.)

The assemblage corresponds to microfloral Zone 2b, and is therefore of Didymograptus hirundo Zone age. The frequent occurrence of Coryphidium bohemicum Vavrdova and Striatotheca rarirrugulatum (Cramer et al.) may however, indicate a position fairly low in the zone.

A re-examination of the microfossil assemblage from intercalated sediments at the base of the Eycott Volcanic Group

The northern limb of the Lake District anticline is marked by the outcrop of a thick series of lavas, with subordinate tuffs, ashes and agglomerates. Two divisions were recognised by Eastwood et al. (1968), the Binsey Group and the High Ireby Group. Formation status was proposed for both groups by Downie and Soper (1972).

The lowest strata of the Binsey Formation include lavas of the 'Eycott' type (from their occurrence on Eycott Hill), interbedded with fine grained sediments. The sediments (pelites, tuffaceous pelites, and tuffaceous mudstones) yielded an assemblage of acritarchs and chitinozoa dated by Downie (in Downie and Soper, 1972) as of early Llanvirnian age. Downie and Soper (1972) were thus able to conclude that in the northern Lake District there existed conformable passage from Skiddaw Slate sedimentation into the volcanic sequence.

The acritarch assemblage has been re-examined by the author. Sample details are as follows (from Downie and Soper, 1972).

Sample No.	Locality and Description
119	Small quarry immediately N. of Whitfield Cottage (2377.3486). Tuffaceous pelite from horizon 2, above lower lava flow of the Binsey sequence.
120	Quarry behind bungalow immediately E. of Whitfield Cottage. Black pelite, same horizon as 119.
122	Spillway from Over Water reservoir (2590.3551). Tuffaceous mudstone, horizon 3, above lava flow a of the Binsey sequence.

Horizon index numbers refer to successions listed in the Cockermouth Memoir, p. 66.

The following is a composite list of species from all three samples.

Acanthodiacrodium cf. duplicatum Burmann

A. hirsutum Gorka

A. cf. ignoratum (Deunff)

A. rectinerve Burmann

A. simplex Combaz

A. spp.

Arbusculidium filamentosum (Vavrdova)

Arkonia cf. tenuata Burmann

Baltisphaera ternata Burmann

Baltisphaeridium sp.

Coryphidium bohemicum Vavrdova

C. elegans Cramer et al.

Cymatiogalea cf. ancora Paris and Deunff

?C. cuvillieri Deunff

C. spp.

Frankea sartbernardense (Martin)

Impluviculus sp.

Marrocanium simplex Cramer et al.

Micrhystridium cf. cleae Martin

M. spp.

Multiplicisphaeridium maroquense Cramer et al.

M. raspum (Cramer)

M. spp.

Peteinosphaeridium cf. bergstromii Staplin et al.

Pirea ornata Burmann comb. nov.

Polygonium cf. elongatum Rasul (MS.)

'Polygonium' spp.

?Priscotheca complanata Deunff

?Priscotheca prismatica Deunff

Recavisentis uncinatus (Downie)

Schizodiacrodium sp.

Stelliferidium cf. striatulum (Vavrdova)

S. spp

Striatotheca frequens Burmann

S. principalis parva Burmann

S. principalis Burmann var. principalis

S. rarirrugulatum (Cramer et al.)

Vavrodella spp.

Veryhachium lairdii (Deflandre) ex Deunff

V. minutum Downie

V. trispinosum Formgroup

The co-occurrence of Arkonia cf. tenuata Burmann, Marrocanium simplex Cramer et al., and Striatotheca frequens Burmanns, is indicative of a position either high in the Zone of Didymograptus hirundo or low in the Zone of D. bifidus. Pirea ornata Burmann comb. nov. has previously been recorded only from localities in East Gremany, credited with an Late Llanvirnian age by Burmann (1970). However, as so little information is available about this species its range cannot be reliably taken as restricted to the Late Llanvirnian.

A most interesting aspect of the assemblage is the high number of specimens present, generally associated with the Tremadocian or Arenigian. This is clearly seen in a percentage comparison of key genera which for sample 119 is as follows:

Acanthodiacrodium	13%
Coryphidium	8%
Cymatiogalea	15%
'Polygonium'	31%
Stelliferidium	12%
Striatotheca	4%
Veryhachium	3%
Others	14%

Such high percentages of Acanthodiacrodium, Cymatiogalea, Coryphidium, 'Polygonium', and Stelliferidium, are untypical of the Arenig - Llanvirn boundary, and it seems probable that many of the specimens present are reworked from Tremadoc and Lower Arenig strata. This possibly is supported by the following observations:

1) Other cases of Tremadocian (and possibly Arenigian) reworking occur in the area, e.g. at Scalegill, near Sunderland. (Downie pers.

comm. and the author's own observations).

2) After allowing for the differing response of species to metamorphism, two general grades of carbonisation appear to be present (particularly noticeable in sample 119).

The alternative explanation, that certain genera continued to flourish locally in the Lake District area, after extinction elsewhere, is considered less plausible.

CHAPTER 7 FACTORS AFFECTING THE PRESERVATION OF ACRITARCHS

In preceding chapters it has frequently been necessary to draw attention to the poor state of preservation of the material studied. Although most of the prepared samples yielded an organic residue, only a small number contained acritarchs sufficiently well preserved to allow positive identification of a useful number of specimens. Often, the majority of specimens, because of their degraded state, were either unidentifiable or could only be tentatively udentified.

The processes which alone or in combination can reduce fossil microplankton to an unidentifiable state are as follows:

a) thermal alteration
b) fracturing (shearing, compression, crystal growth)
c) corrosion (biodegredation and oxidation)

Although here considered separately these phenomena are sometimes directly related to each other. Thermally affected microplankton, for example, is more brittle and therefore more liable to fracture.

Thermal alteration

For many years it has been appreciated that thermal energy can induce changes in the colour and translucency of spores and organic walled microplankton (see Gutjahr, 1966, and earlier references quoted by him; Correia, 1967). The colour changes are progressive with increasing temperature, and are due to chemical alteration of the wall material, leading to a higher amount of fixed carbon. The process is referred to in this study and 'carbonisation' although some authors, dealing specifically with this topic, have recently distinguished between 'carbonisation' and 'coalification' (Gray and Boucot, 1975).

The starting point (a low carbon substance) and end point (a high carbon substance) are the same in both processes, but intermediate products of reaction may differ (Gray and Boucot, 1975).

Changes in the translucency of thermally affected pollen grains and spores were correlated to light-absorption values by Gutjahr (1966). The light absorption equipment he used removed some of the subjectivity associated with the direct judgement of colour changes, As similar equipment was not available, the author prepared a comparative table (Table 14 part A) on similar lines to that produced by Correia (1967). This permitted the comparison of the acritarch assemblages studied, with regard to their degree of carbonisation. Parts B and C of Table 14 are attempts to classify the extent of fragmentation, and degree of corrosion respectively. The table was compiled with reference to preservation only in acritarchs. It is not applicable to other organic-walled microfossils and organic debris, which may respond differently to the effects of thermal energy and other degrading processes.

Where the grade of carbonisation is quoted for an assemblage in this study, it is with reference to Table 14 part A. For example, grade 5 indicates grey or totally opaque specimens. Grade 4/5 indicates the occurrence of dark brown specimens together with grey or totally opaque forms.

It is clear from most assemblages examined in connection with this study that the colour and translucency of specimens is largely dependant upon wall thickness. Wall composition may also play a part, but this unfortunately is a little researched topic. In thermally unaffected sediments, organic-walled microplankton may range from being virtually colourless, to being a clear amber, according to wall thickness. With an increase in temperature (say to 120°C) the thicker walled specimens

Table 14

A		B		C	
Grade	Degree of carbonisation as indicated by colour	Grade	Degree of fragmentation	Grade	Degree of corrosion
1	clear yellow	A	none	a	unaffected
2	light brown	B	superficial		
3	mid (reddish) brown	C	central body with splits, but more or less complete, some processes damaged	b	superficial, small corrosion patches, but no perforations
4	dark brown	D	central body incomplete, but at least one process intact	c	general corrosion, with or without perforation
5	grey or black	E	central body incomplete, no processes intact		
6	black only	F	detached fragments only	d	severe general corrosion, and/or extensive perforation

Degrees of carbonisation, fragmentation and corrosion in acritarchs.

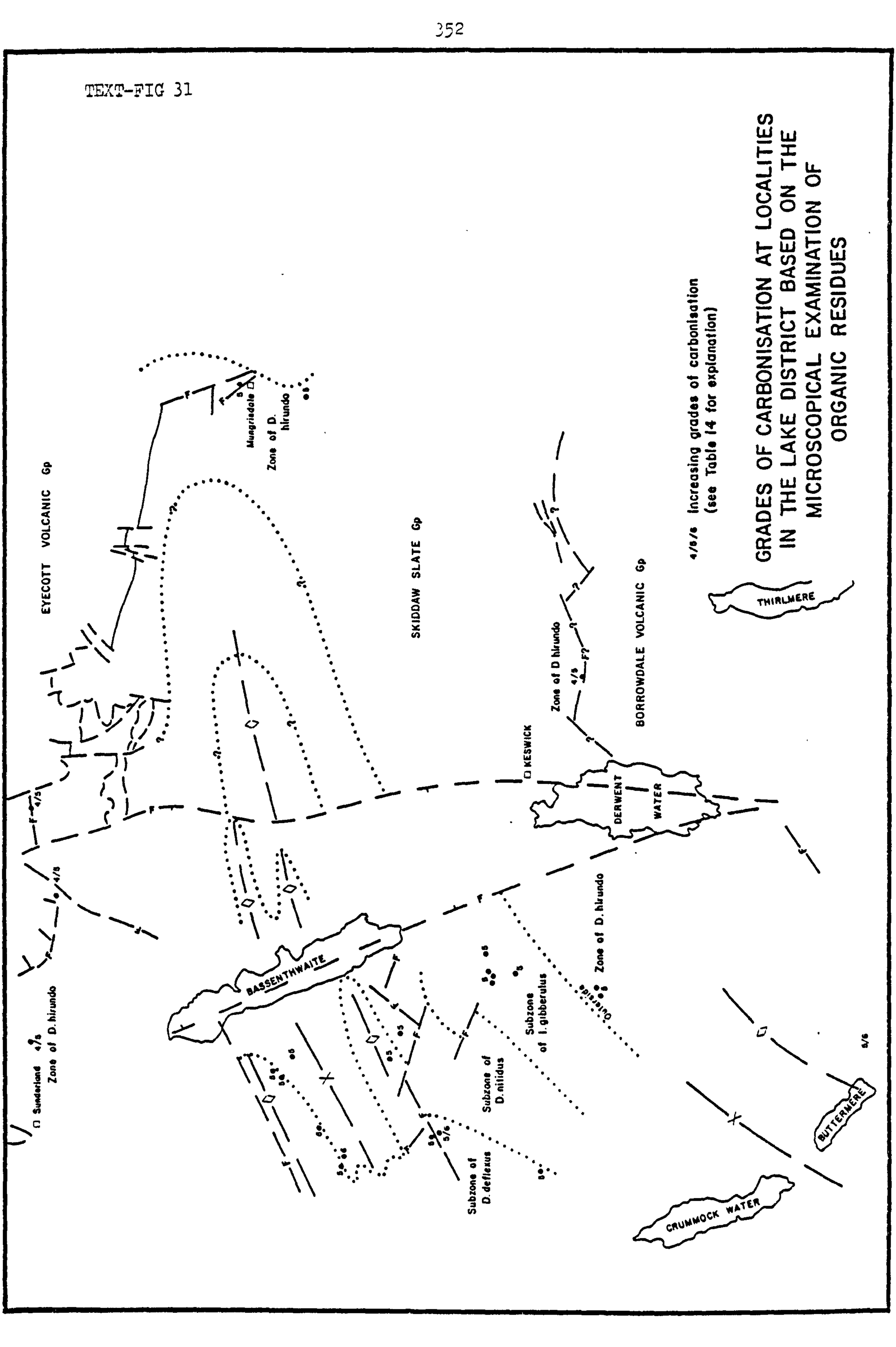
rapidly become opaque, while those having a thinner wall, though darkening, remain translucent. A range of translucencies therefore still remains, though with emphasis towards the darker end of the scale. Above approximately 180°C all organic material is reduced to amorphous carbon or crystalline graphite.

In sediments from the Tadla Basin, Morocco, for example, Cramer et al. (1974a and b) found species from the same horizon of variable translucency (compare Marrocanium simplex Cramer et al., 1974a, pl. 26, figs. 1 and 2, with Picostella perforata Cramer et al., 1974b, pl. 28, fig. 11). Material from the same general area, examined by the author, contained species of Cymatiogalea Deunff which were virtually opaque to transmitted light, together with relatively thin walled specimens of Striatotheca rarirrugulata (Cramer et al.) and Coryphidium elegans Cramer et al., which were transparent.

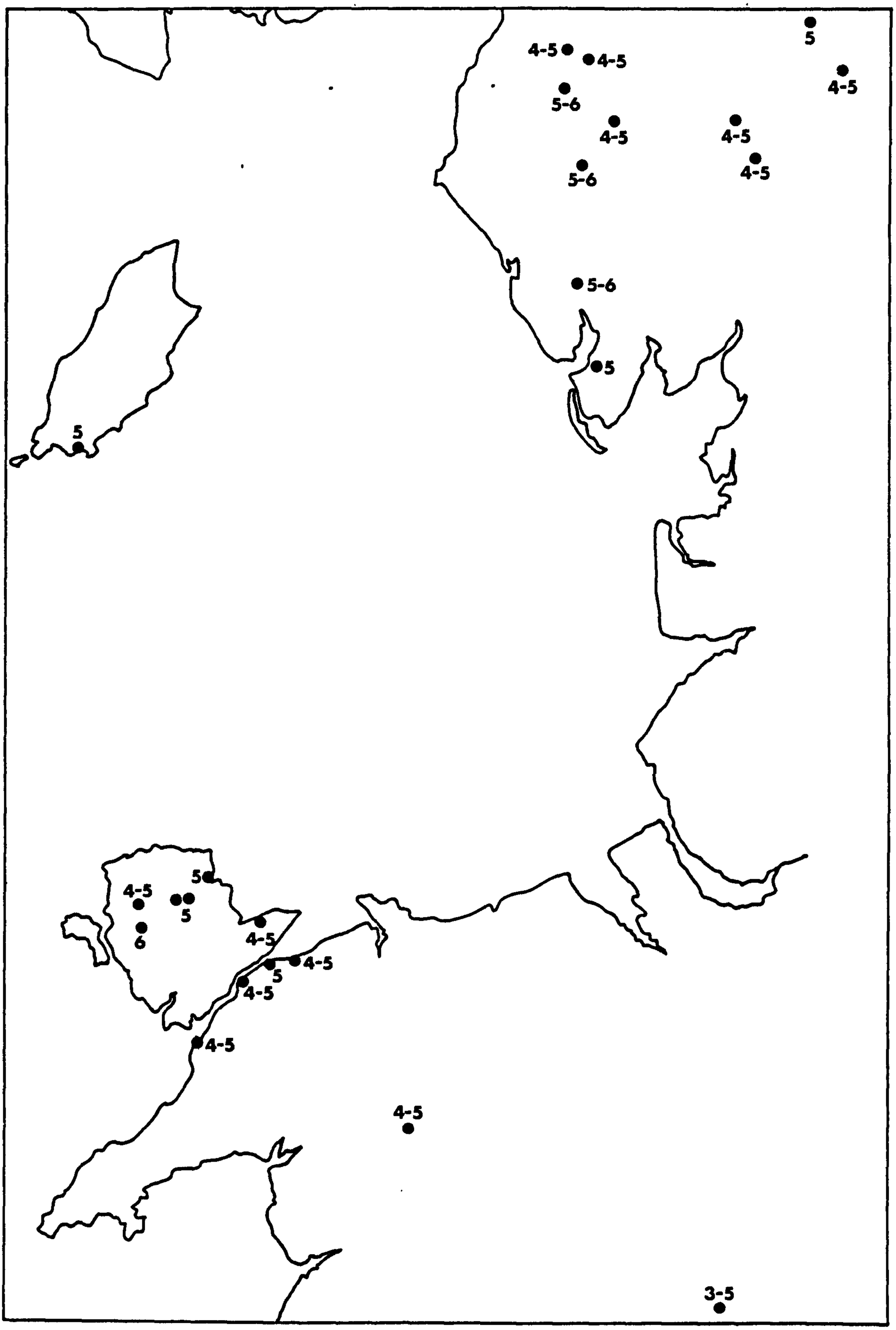
Grades of carbonisation of assemblages from principal localities in the Lake District are given in Text-fig. 31. It may be observed from these data that the assemblages are not all carbonised to the same degree. In addition, it is clear that assemblages from older horizons in the Skiddaw Slates (i.e. those occupying the core of the Lake District anticline) are more carbonised than those in younger rocks on the anticlinal flanks. An exception is an assemblage of Didymograptus hirundo Zone age from a locality south of Mungrisdale. However, the higher grade of carbonisation at this locality is explained by its close proximity to the Skiddaw granite metamorphic aureole.

Text fig. 32 is a comparison of the carbonisation grades of assemblages from principal localities in the North Wales, Shropshire, the Isle of Man and Lake District areas. There is considerable variation.

TEXT-FIG 31


GRADES OF CARBONISATION AT LOCALITIES IN THE LAKE DISTRICT BASED ON THE MICROSCOPICAL EXAMINATION OF ORGANIC RESIDUES
4/5/6 Increasing grades of carbonisation (see Table 14 for explanation)
THIRLMERE
EYECOTT VOLCANIC Gp
SKIDDAW SLATE Gp
BORROWDALE VOLCANIC Gp
Mungrisdale
Zone of D. hirundo
KESWICK
DERWENT WATER
BASSENTHWAITE
Sunderland
Zone of D. hirundo
Subzone of I. gibberulus
Subzone of D. nitidus
Subzone of D. deflexus
BUTTERMERE
CRUMMOCK WATER

Text-fig. 32



Grades of carbonisation at principal localities in Shropshire, North Wales, the Isle of Man, and the Lake District, based on the microscopical examination of organic residues.

In Anglesey the degree of carbonisation varies from grade 4 to 6, being least in dark-grey shales at Coch-y-meri (N.G.R. SH 5447 7954), and in the blue-grey graptolitic siltstones at Llanbabo (localities A2, A3). In Shropshire, samples from Hope, Lyde and Rorrington, yielded assemblages carbonised in the 3-5 range, while those from the Priestweston area were generally slightly more carbonised (4-5). At Arenig, samples N2 to N4 were collected from sites close (within 10m) to a dolerite dyke. However, the degree of carbonisation was apparently no greater in these samples than in others from the same section, at much greater distances (98m) away from the dyke.

The direct relationship between the colour of fossil microplankton and rock palaeotemperatures has been demonstrated and commented upon by various authors (see, for example, Karweil, 1966; Landes, 1967; Evans and Staplin, 1971). In the areas investigated in this study, the intensity of carbonisation does not generally exceed grade 5 (as defined in Table 14) and the maximum temperature attained was therefore probably less than 180°C. The carbonisation was therefore due to metamorphism of relatively low grade. At the present time it is not possible to distinguish the carbonising effects produced by dyamothermal metamorphism, from those produced by burial metamorphism and contact metamorphism. In the Lake District the assemblages from the anticlinal core, west of Bassenthwaite, have been subjected to a greater depth of burial than the younger assemblages from the anticlinal flanks. In this case, however, the higher degree of carbonisation in the anticlinal core may not be due to depth of burial alone, for it has been shown that the Skiddaw Slates in this area are underlain by a westerly extension of the Skiddaw granite (Bott, 1974).

The different grades of carbonisation in North Wales and Anglesey are difficult to explain precisely without additional data. At the

moment they may be attributed to local fluctuations of the metamorphic grade, due to geomorphological variations in the underlying basement.

At Arenig, the apparent absence of contact metamorphism in samples close to a thick dolerite dyke may be explained by the overprinting effect of low grade regional metamorphism.

Fracturing (compression, shearing, crystal growth)

With exception to the possible formation of shrinkage cracks, carbonisation does not in itself cause fragmentation of organic walled microfossils, which is primarily due to compression, crystal growth and shearing forces. However, as the temperature increases and volatile components are lost, plasticity of the wall is reduced, and organic walled microfossils are rendered far more susceptible to brittle fracture. The recovery of recognisable acritarchs by standard maceration techniques from sediments which have been thermally affected and later mechanically stressed is almost always low. In severe cases organic microplankton is reduced to a mosaic of carbonised fragments. This condition was demonstrated by Burmann (1969), in acritarchs and chitinozoa studied in thin section. Burmann concluded that disintegration began with the formation of fine fractures, sometimes orientated and related to the stress direction. Corroded and carbonised forms, possibly of chitinozoa, were observed by the author in Hope Beck Slates, sectioned parallel to the bedding plane. Disintegration was particularly advanced in this case, the forms being represented by twenty or so detached fragments. The fragments, nevertheless, still retained a correct positional relationship with each other.

Undoubtedly some disruption of hollow bodied forms also occurs as the overburden pressure increases and the sediment dewaters. At this

early stage microplankton is unlikely to have been thermally affected, and walls are therefore still likely to be in a fairly plastic condition. The initial response will probably be distortion followed by folding of the wall and/or rupture along one or more lines of weakness. The result will of course be influenced, in each case, by wall thickness and plasticity, and the intensity of compression.

The majority of acritarch assemblages examined in this study show evidence of damage due to the growth of pyrite crystals. This phenomenon has been described in detail by Neves and Sullivan (1964). Most of their discussion relates to the modification of fossil spore exines although they do refer to the occurrence of simple polygonal cavities in the acritarch genus Veryhachium (op. cit. p. 445). Cavities of this type, with well defined margins, were observed in most of the acritarch species encountered in this study. Cavity occurrence was apparently random, and not governed by ornament or other structural details. When closely spaced a reticulate effect was produced similar to that described by Neves and Sullivan (1964).

Corrosion (oxidation and biodegradation)

Although the wall of a microfossil may be thinned by mechanical abrasion, chemical attack is generally a much more important 'thinning' process. The corrosion may be caused by natural oxidation or by the secretions of saprophytic bacteria and fungi which digest the wall substance. In advanced cases the wall may become severely pitted or perforate.

No detailed studies of wall corrosion in acritarchs have ever been undertaken but it is useful to note the results of investigations into the decay of pollen and spore exines. Havinga (1964, 1967 and 1971) showed that the processes of oxidation and biodegradation were closely linked. He demonstrated that if pollen were first oxidised, resistance to subsequent

microbial attack was drastically reduced. He also showed that species differed considerably in corrosion susceptibility and concluded that susceptible species might therefore be absent from assemblages subjected to oxidation and microbial attack.

In a study of degredation phenomena in pollen and spores caused by saprophytic fungi, Goldstein (1960) commented that the phycomycetes 'were prominent among those organisms responsible for weakening spore walls'. He suggested that the rhizoids digest their way through, leaving a smooth edged perforation. He further remarked that such penetrations paved the way for the decomposition of grains by other biological agencies and physical factors.

With reference to miospores, Elsik (1966 and 1971) distinguished several types of scar of microbial origin. These included small circular perforations less than 1μ in diameter, attributed to bacteria; circular perforations up to approximately 2.5μ in diameter attributed to the rhizoids and exit tubes of Phycomycetes, and various rosette-like scars, sometimes branching, not necessarily penetrating the wall, produced by individual or colonies of bacteria and fungi.

The work of Havinga, Goldstein and Elsik, on the degredation of pollen and spore exines, can only be considered relevant to the present study if it is accepted that the walls of sporomorphs and those of acritarchs are chemically similar. Fortunately there is an increasing amount of evidence to support this view. Brooks (1971), for example, records the presence of substances, chemically similar to those forming the walls of pollen and spores (sporopollenin), in sedimentary rocks of Pre-Cambrian age.

Part C of Table 14 is an attempt to quantify the degree of corrosion undergone by acritarchs. Because the majority of specimens

examined were opaque, surface corrosion was often difficult to assess. It is apparent however, that the assemblages from Priestweston and Lyde in the Shropshire area are the most severely affected. Most specimens from these assemblages are reduced to perforate subspherical bodies, devoid of processes, often with unevenly thinned walls. Rectangular perforations are clearly due to the growth of pyrite, but numerous small subcircular perforations may be due to mycorrhizal penetrations.

Assemblages from Lake District samples were in general, rather less corroded than those from most other localities, and the low recovery of acritarchs from the samples west of Bassenthwaite is probably due to carbonisation and fragmentation rather than corrosion. In contrast, corrosion does appear to have been an additional factor influencing acritarch recovery in the Arenig area, for the fragments which have survived are frequently much corroded.

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ADDENDUM

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MAPS

Ordnance Survey maps consulted during the course of fieldwork included the following:

1:63360	Sheet No.	82, 83, 84, 88, 114.
1:25000	Sheet No.	NY 12, 13, 22, 23, 32, 33.
		SJ 20, 30.
		SO 29, 39.
1:10560	Sheet No.	SH 46 SE.
		SH 57 SW, and SE.
		SH 67 SW.
		SH 83 NW.

PLATES

PLATES 1, 2, 3

Microfloral assemblage from the Afon Saint, Caernarvon, (Lower Arenig)

PLATES 4, 5, 6

Microfloral assemblage from the Afon Saint, Caernarvon, (Upper Arenig)

PLATES 7, 8

Microfloral assemblage from the Afon Saint, Caernarvon (Lower Llanvirn)

PLATES 9, 10, 11, 12

Microfloral assemblages from Garth Point, Bangor, (Lower Arenig)

PLATES 9, 10, 11, 12

Microfloral assemblages from Garth Point, Bangor, (Lower Arenig)

PLATES 13, 14, 15, 16

Microfloral assemblage from Hope, Shropshire, (Lower Llanvirn)

PLATES 17, 18, 19

Microfloral assemblage from Hope, Shropshire, (Lower Arenig)

PLATES 20, 21, 22, 23, 24, 25, 26, 27

Microfloral assemblages from Whitsburn, Shropshire, (Lower Llanvirn)

PLATE 28

Microfloral assemblage from Rorrington, Shropshire, (Upper Llanvirn)

PLATES 29, 30

Microfloral assemblage from the Tailbert-Llanshaw tunnel, Lake District, (Lower Llanvirn)

PLATES 31, 32, 33, 34, 35

Microfloral assemblage from the Tarn Moor tunnel, Lake District, (Upper Llanvirn)

Note: The full reference to each specimen includes a slide code, which is best explained by reference to an example.

C6 20 2 6 1017 383 L38/2

C6 - Sample number (see Chapter 1.2 for sample numbers and location of samples)

20 - Size fraction in μ (in this case, that between 20μ and 53μ)

2 - Slide number

6 - Oxidation time in hours

The specimen coordinates (1017 383) are from Leitz Orthoplan microscope No. 746714. L38/2 is an 'England Finder' reference.

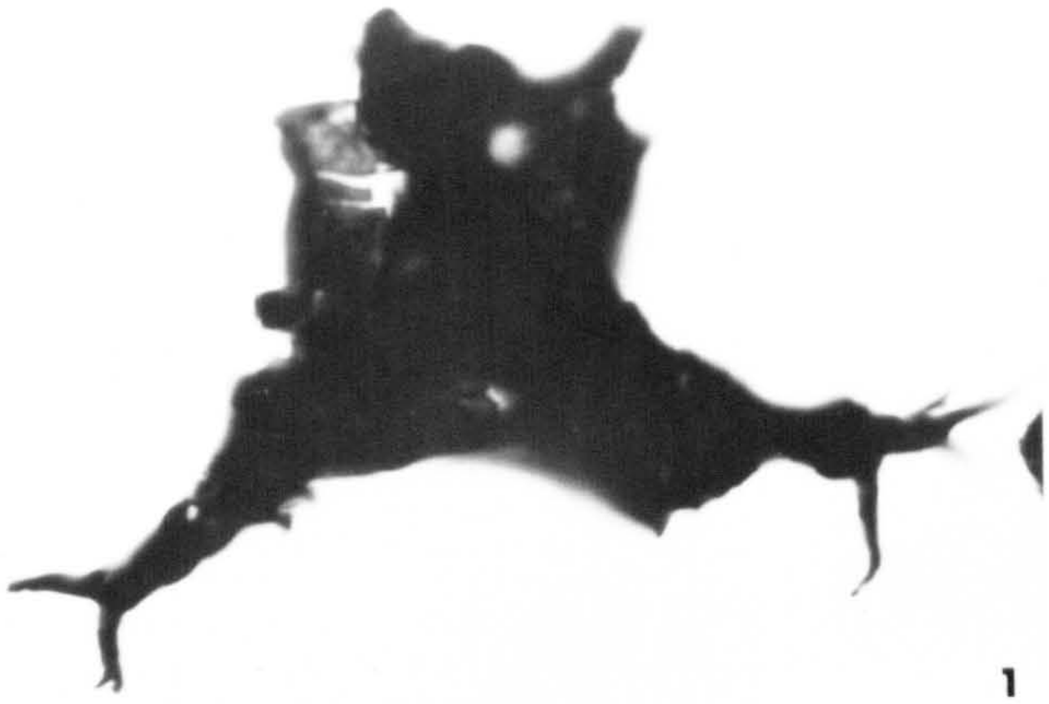
Magnification is x 1000 unless otherwise stated.

PLATE 1

Microfloral assemblage from the Afon Saint, Caernarvon, (Lower Arenig)

1.	Schizodiacrodium sp. B	C6	20	2	6	1017	383	L38/2
2.	Schizodiacrodium sp. B	C6	20	2	6	972	494	F27/3
3.	Peteinosphaeridium sp. A	C6	20	2	6	1076	488	R27/4
4.	Peteinosphaeridium sp. C	C6	20	2	6	1049	505	029/3
5.	Peteinosphaeridium trifurcatum (Eisenack, 1938) (al breviradiata, Eisenack, 1959)	C6	20	2	6	1068	303	Q46/4
6.	Peteinosphaeridium trifurcatum (Eisenack, 1938) (al breviradiata, Eisenack, 1959)	C6	20	2	6.	980	495	G27/3
7.	Peteinosphaeridium sp. B	C6	20	3	6	1016	450	L31/2
8.	Peteinosphaeridium sp. B	C6	20	2	6	1036	359	N41/1
9.	Multiplicisphaeridium? sp. C	C6	20	2	6	975	326	G44/2
10, 11.	Peteinosphaeridium cf. paucifurcatum (Eisenack, 1959) Eisenack et al., 1973	C6	<20	4	6	1109	307	U46/4

PLATE 1



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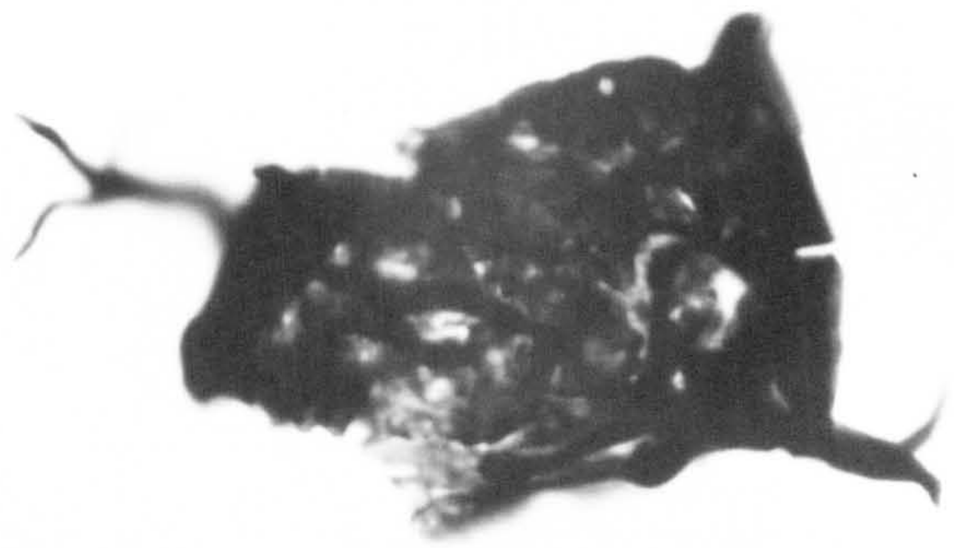

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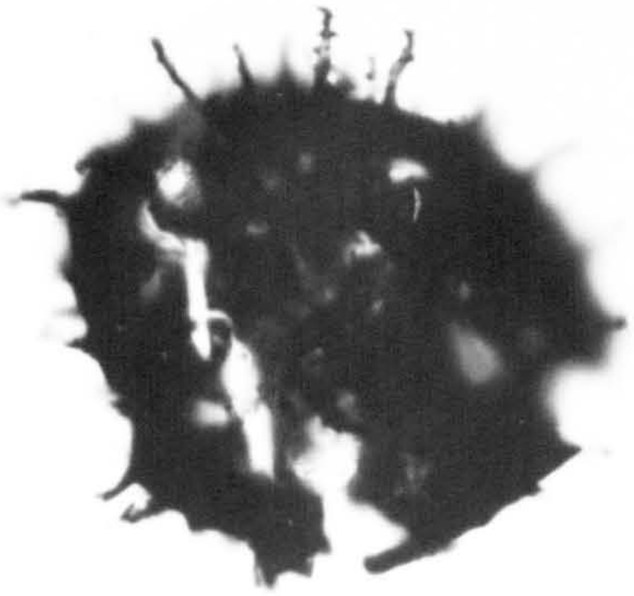

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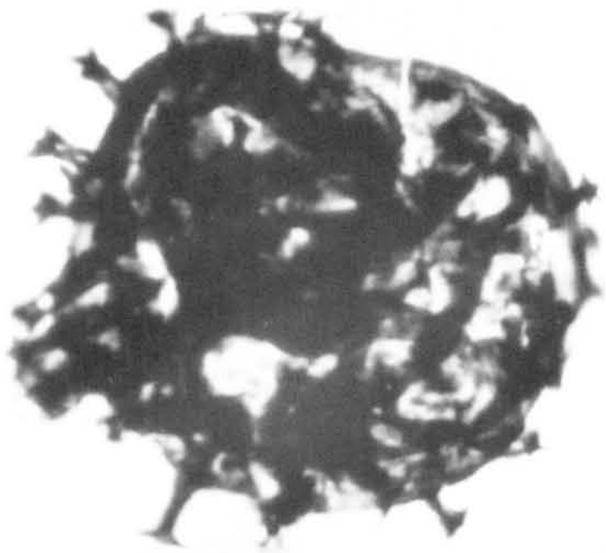

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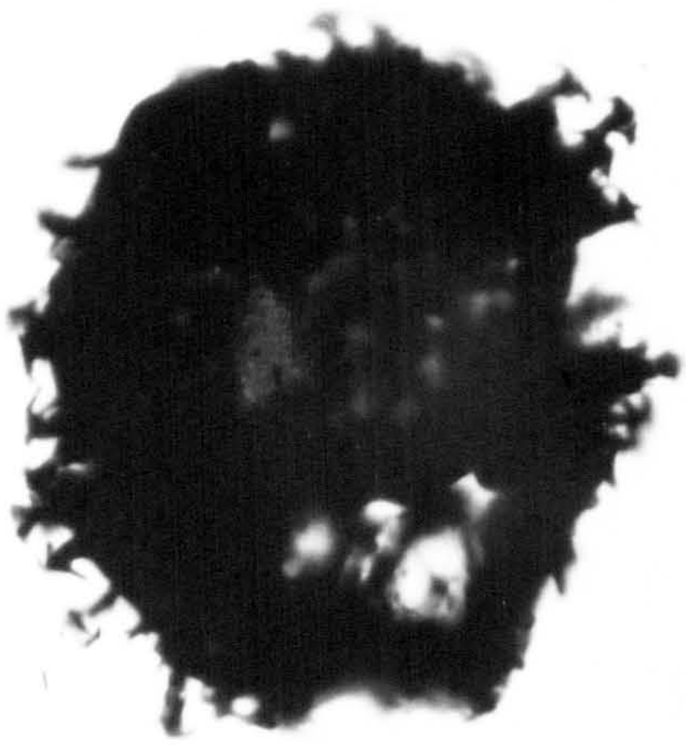

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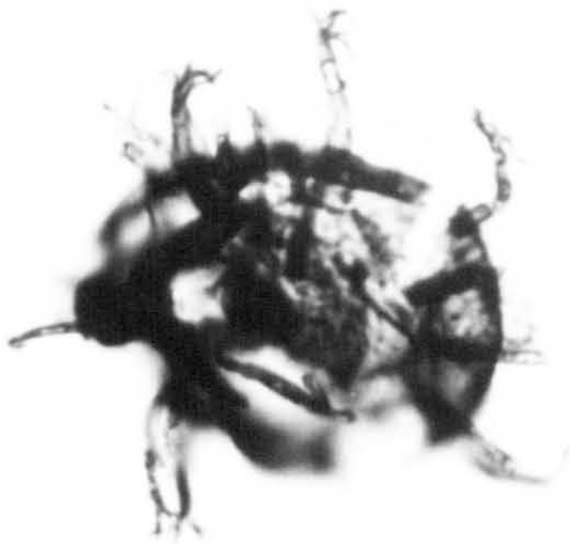
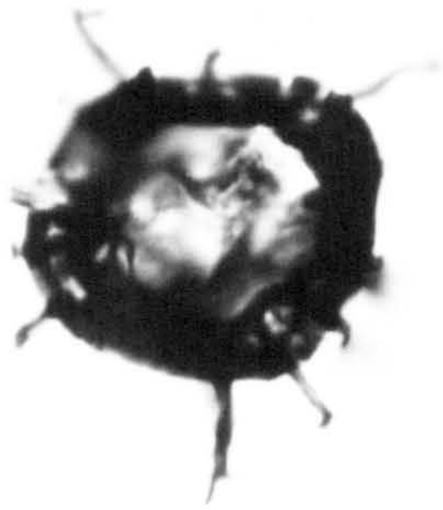
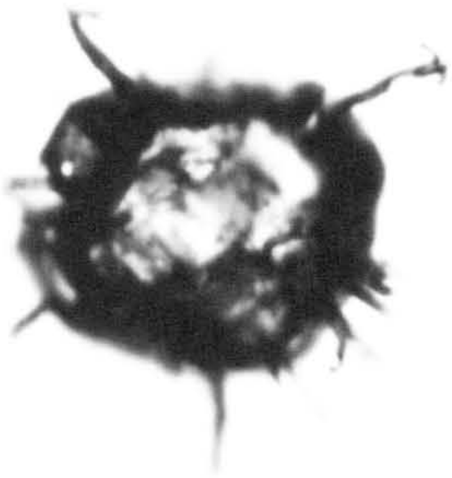


9



10



11

PLATE 2

Microfloral assemblage from the Afon Saint, Caernarvon,(Lower Arenig)

1.	Arbusculidium cf. bicuspidatum Burmann, 1968 comb. nov.	C6	20	6	8	978	361	G40/2
2.	Polygonium gracile Vavrdova, 1966 emend.	C6	20	2	6	1063	532	Q23/1
3.	Polygonium gracile Vavrdova, 1966 emend.	C6	20	2	6	1062	502	Q26/1
4.	Baltisphaeridium? sp. C	C6	20	2	6	1067	343	Q42/2
5.	?Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959	C6	20	2	6	1109	264	U50/4
6.	Baltisphaera sp.	C6	20	2	6	1063	460	Q30/2
7.	Multiplicisphaeridium sp.	C6	20	2	6	1025	459	M30/2
8.	Leiofusa sp.	C6	<20	4	6	1114	343	V42/2
9.	Leiofusa sp.	C6	<20	4	6	1139	500	X26/4
10.	Leiofusa sp.	C6	<20	3	4	1143	308	Y46/3
11.	Elektoriskos? sp. A	C6	<20	4	6	1135	467	X29/4
12.	?Micrhystridium cf. cleae Martin, 1972	C6	<20	4	2	1051	250	P52/1
13.	Micrhystridium subtile sp. nov.	C6	<20	3	4	1128	400	W36/4
14.	Micrhystridium subtile sp. nov.	C6	<20	3	4	1128	463	W30/3
15.	Multiplicisphaeridium sp.	C6	<20	4	6	1126	255	W51/4

PLATE 2

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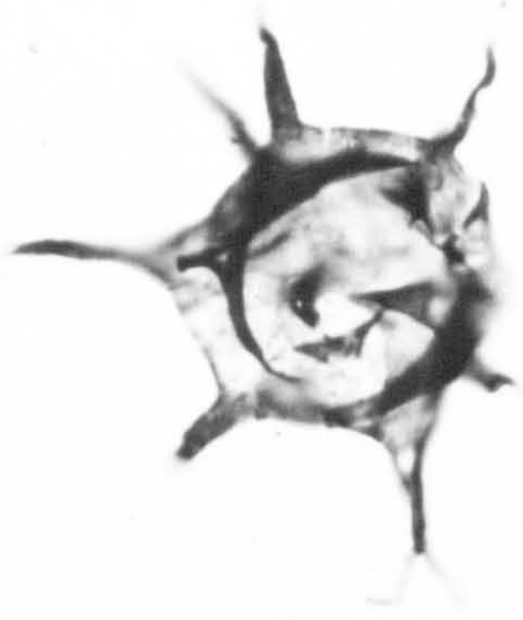

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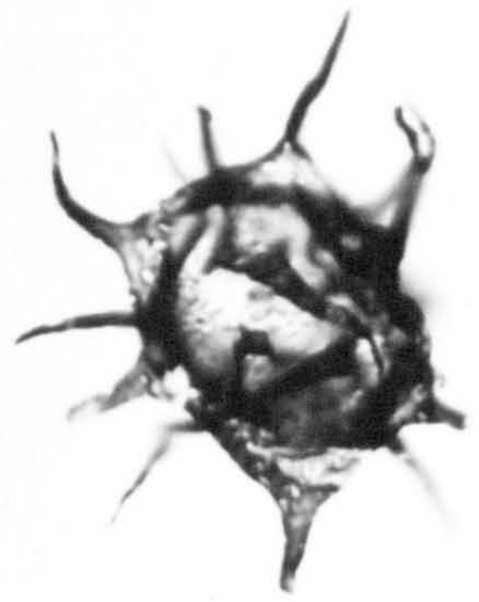

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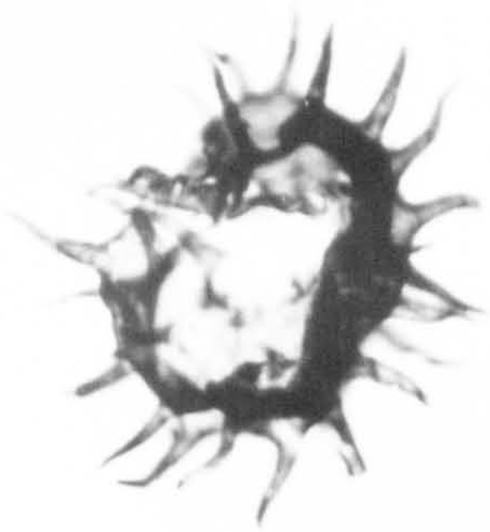

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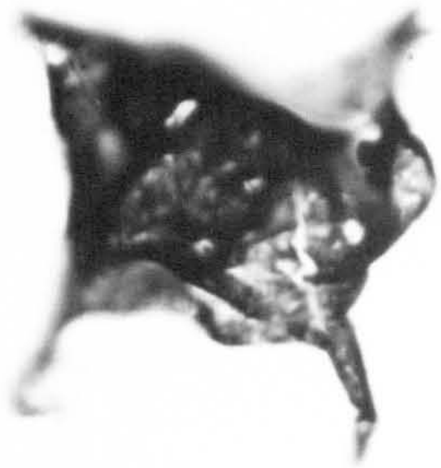

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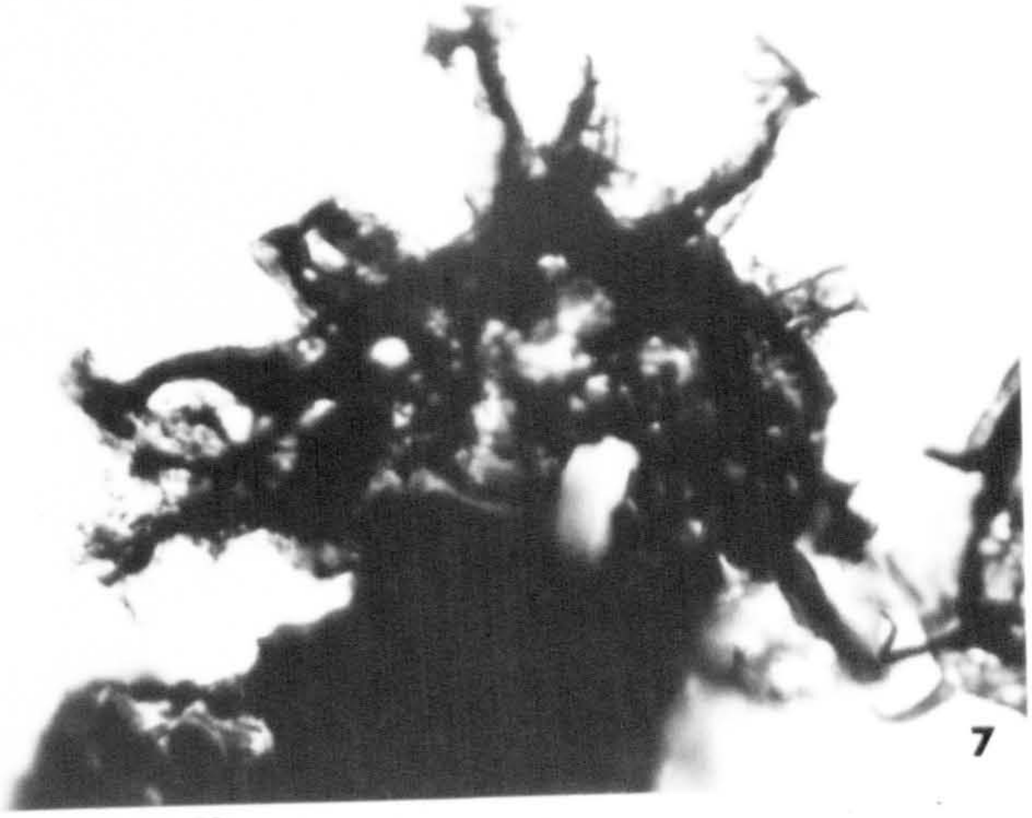

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PLATE 3

Microfloral assemblage from the Afon Saint, Caernarvon, (Lower Arenig)

1. Acanthodiacrodium tasselii Martin, 1969
C6 <20 4 6 1092 311 T46/1

2. Acanthodiacrodium sp. B C6 20 2 6 1114 237 V53/4

3. Acanthodiacrodium sp. C6 <20 4 6 1099 332 T43/4

4. Multiplicisphaeridium sp. C6 20 2 6 1017 519 L24/2

5. Polygonium cf. pungens Timofeev, 1959 comb. nov.
C6 20 2 6 1122 396 W37/1

6. Schizodiacrodium sp. A C6 <20 4 6 1123 340 W44/1

7. Striatotheca rarirrugulatum (Cramer et al., 1974b) Eisenack et al., 1976
C6 <20 4 6 1131 301 X47/1

8. S. rarirrugulatum (Cramer et al., 1974b) Eisenack et al., 1976
C6 <20 4 6 1113 288 V48/1

9. Frankea sartbernardense (Martin, 1966) Burmann, 1970
C6 <20 3 4 1132 249 X52/1

10. Micrhystridium aremoricanum Paris & Deunff, 1970, comb. nov.
C6 <20 3 4 1134 434 X33/1

11. M. aremoricanum Paris & Deunff, 1970, comb. nov.
C6 <20 3 4 1126 520 W24/3

12. M. aremoricanum Paris & Deunff, 1970, comb. nov.
C6 <20 4 6 1090 377 S39/3

13. Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b
C6 <20 4 6 1132 376 X39/1

14. Coryphidium bohemicum Vavrdova, 1972
C6 <20 3 4 1136 515 X52/1

15. Veryhachium trispinosum Formgroup, Cramer, 1964b
C6 <20 4 6 1116 548 V21/2

PLATE 3

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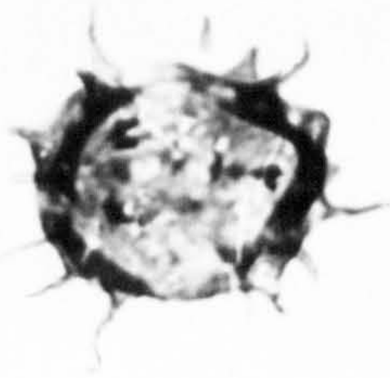

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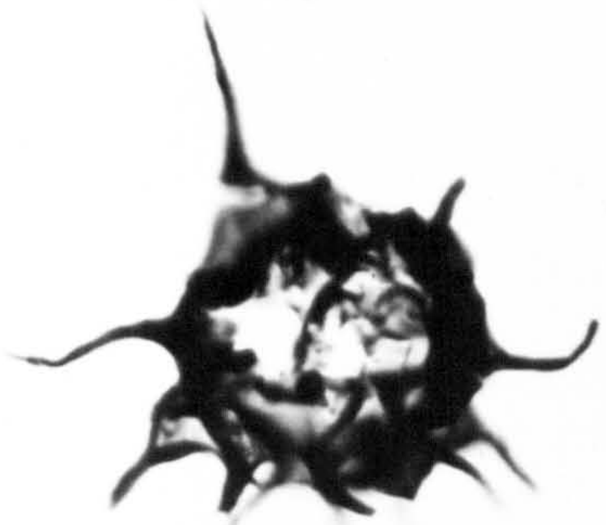

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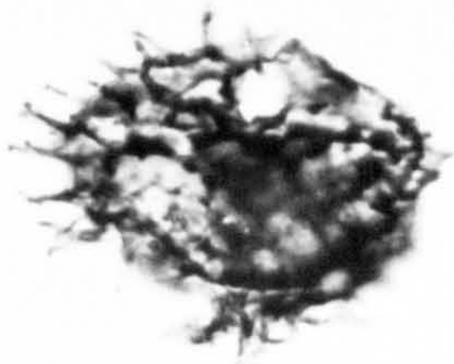

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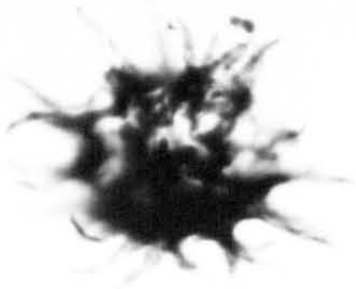

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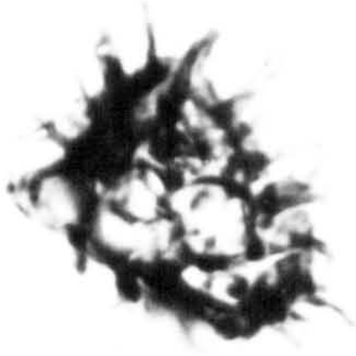

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PLATE 4

Microfloral assemblage from the Afon Saint, Caernarvon,(Upper Arenig)

1. Vulcanisphaera cirrita Rasul, 1976 C5 20 1 0 967 484 F28/1

2. ?Baltisphaeridium hirsutoides (Eisenack, 1951) Eisenack, 1958 a
C5 20 1 0 1047 364 040/4

3. Peteinosphaeridium lepton sp. nov. C5 20 1 0 1026 255 M51/2

4. Baltisphaeridium? sp. D C5 20 1 0 1047 235 053/4

5. Multiplicisphaeridium maroquense Cramer et al., 1974a
C5 20 1 0 1026 308 M46/2

6. Multiplicisphaeridium sp. C5 20 1 0 978 329 G44/3

7. Peteinosphaeridium trifurcatum (Eisenack,1938)(al.breviradiata Eisenack, 1959)
C5 20 1 0 1043 333 043/2

8. Peteinosphaeridium sp. C C5 20 1 0 950 242 D53/3

9. Recavisentis uncinatus Downie, 1958 comb. nov.
C5 20 1 0 1013 256 L51/2

10. Peteinosphaeridium cf. paucifurcatum (Eisenack et al., 1973)
C5 20 1 0 1043 501 026/1

11. Polygonium cf. tener Timofeev, 1959 comb. nov. (x 500)
C5 20 1 0 1050 465 030/3

12. Frankea sartbernardense (Martin, 1966) Burmann, 1970
C5 <20 1 2 1048 305 046/4

13. Striatotheca rarirrugulatum (Cramer et al., 1974b) Eisenack et al., 1976
C5 20 1 2 1050 399 037/3

14. Coryphidium bohemicum Vavrdova, 1972
C5 20 1 2 1045 469 029/2

15.	Veryhachium minutum Downie, 1958	C5	<20	1	2	1002 399	J37/3
16.	Micrhystridium subtile sp. nov.	C5	<20	1	2	1049 418	034/4
17.	M. crispum sp. nov.	C5	<20	1	2	1043 376	039/1
18.	Micrhystridium sp.A	C5	<20	1	2	1052 271	P50/1
19.	M. robustum Downie, 1958	C5	<20	1	2	1043 406	036/1
20.	?M. nannacanthum Deflandre, 1942 ex Deflandre, 1945	C5	<20	1	2	1048 388	038/3

PLATE 4

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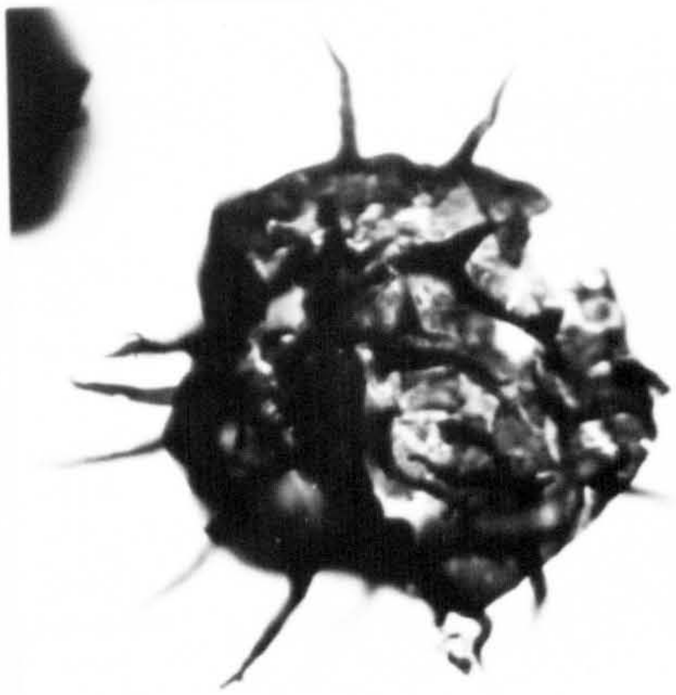

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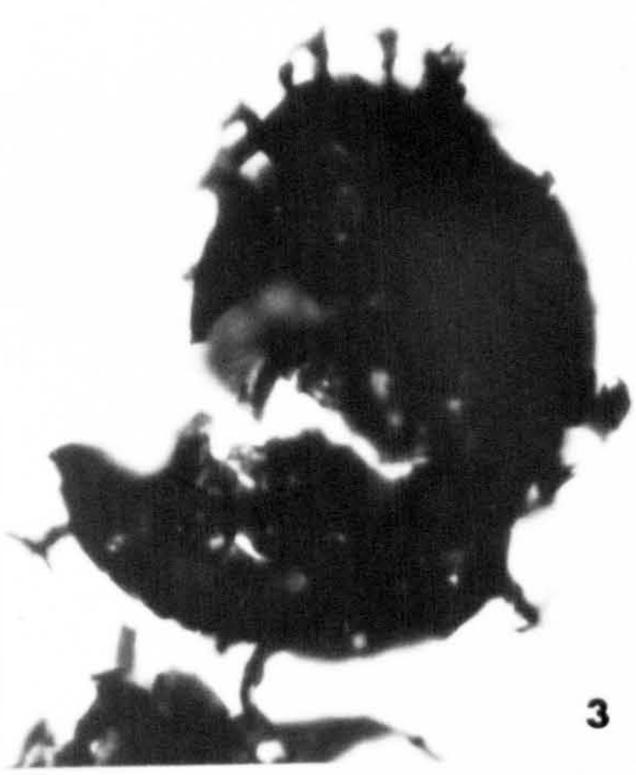

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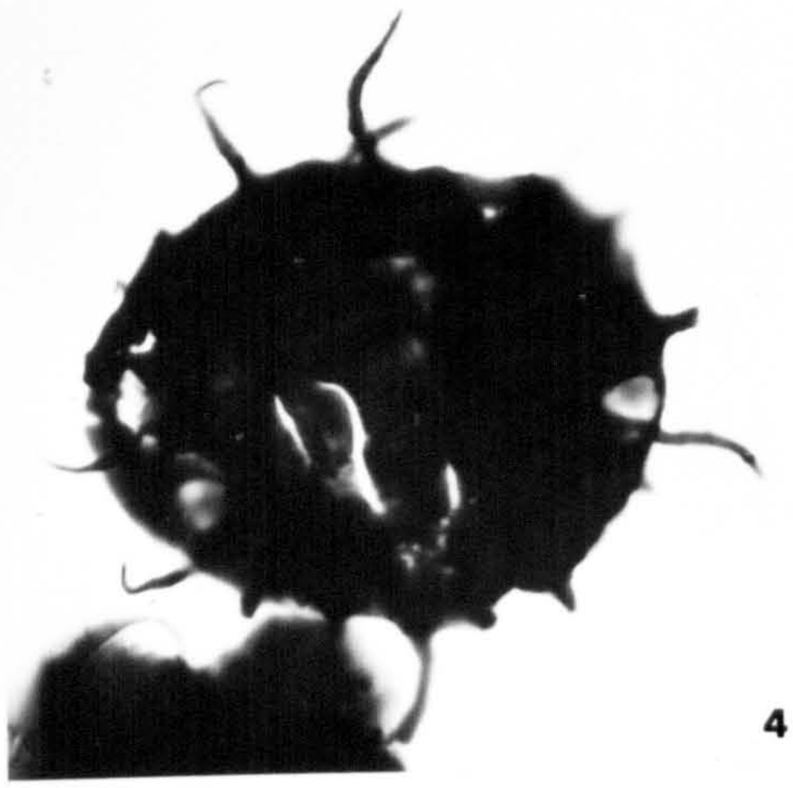

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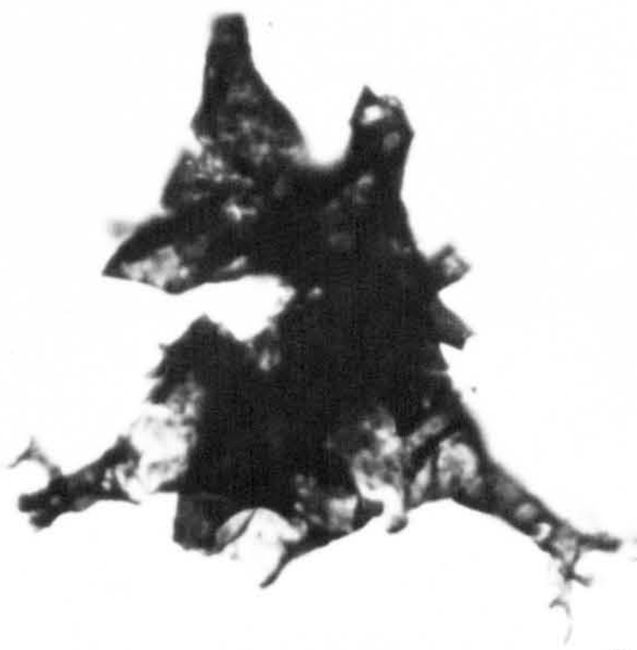

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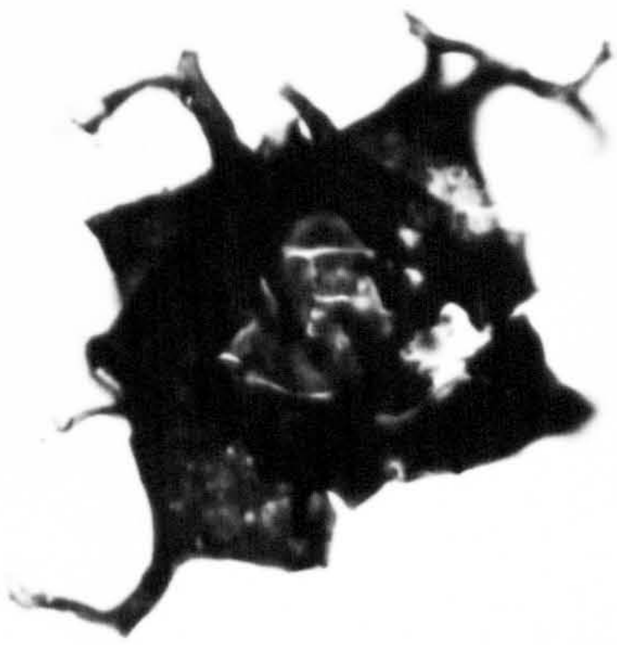

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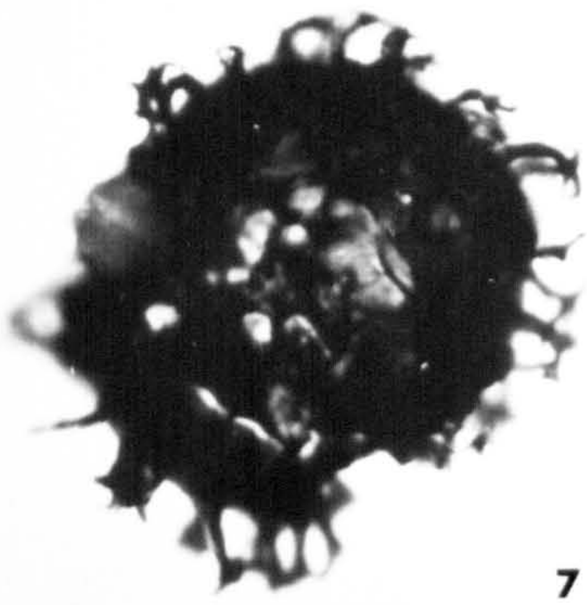

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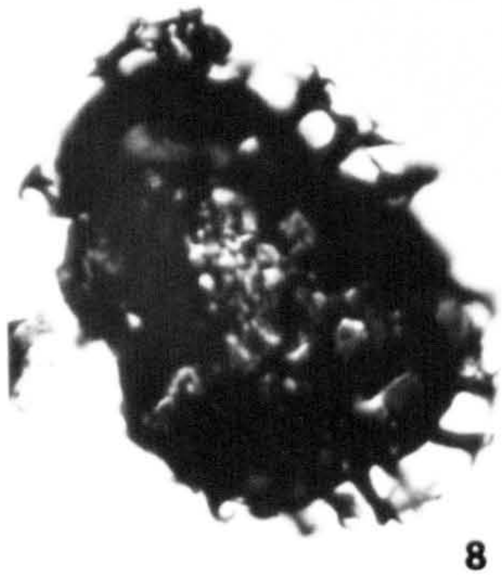

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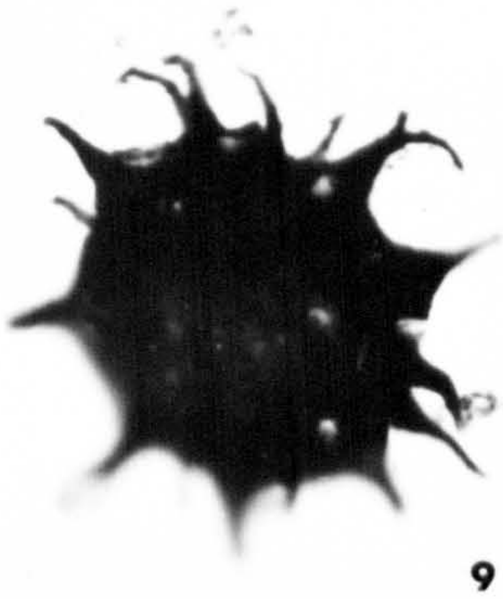

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PLATE 5

Microfloral assemblage from the Afon Saint, Caernarvon,(Upper Arenig)

1. Baltisphaeridium? sp. A — C4 20 1 0 — 1078 378 — R39/3

2. Peteinosphaeridium lepton sp. nov. — C4 20 1 0 — 1018 367 — L40/1

3. Multiplicisphaeridium sp. A — C4 20 1 0 — 1037 493 — N27/1

4. Peteinosphaeridium sp. C — C4 20 1 0 — 1009 236 — K53/4

5. Baltisphaeridium hirsutoides (Eisenack, 1951) Eisenack, 1958 a
C4 20 1 0 — 980 282 — G49/3

6. ?Recavisentis uncinatus Downie, 1958 comb. nov.
C4 20 1 0 — 956 433 — E33/2

7. Baltisphaeridium? sp. C — C4 20 1 0 — 987 259 — H51/2

8. Recavisentis uncinatus Downie, 1958 comb. nov. (x 500)
C4 20 1 0 — 948 264 — D51/1

9. Uncinisphaera? sp. A (x 500) — C4 20 1 0 — 1000 364 — J40/4

10. Polygonium cf. tener Timofeev, 1959 comb. nov. (x 500)
C4 20 1 0 — 1005 468 — K29/2

11. Schizodiacrodium sp. B (x 500) — C4 20 1 0 — 977 277 — G49/2

12. ?Multiplicisphaeridium maroquense Cramer et al., 1974a (x 500)
C4 20 1 0 — 991 344 — H42/4

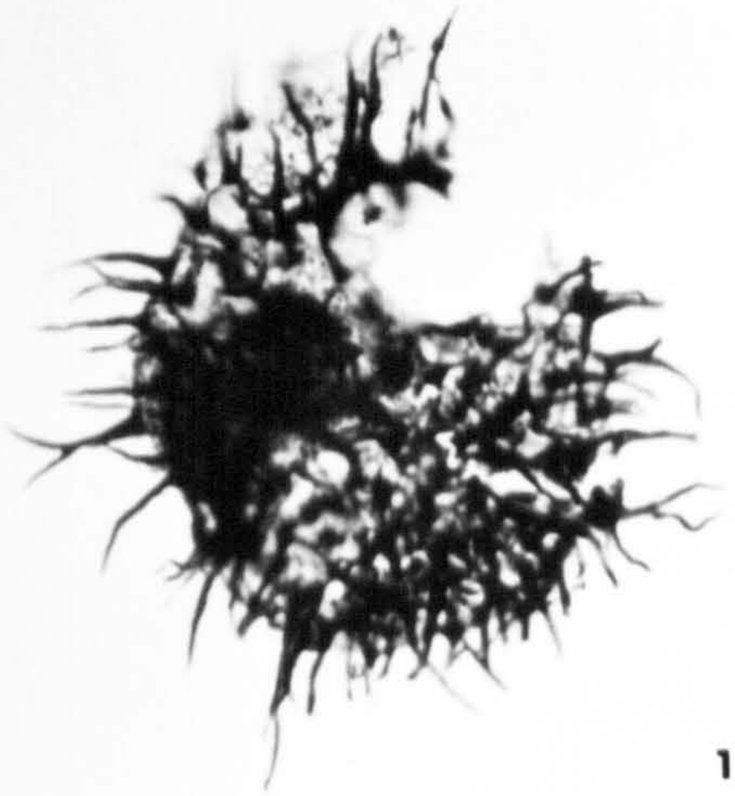
13. Peteinosphaeridium cf. paucifurcatum (Eisenack, 1959) Eisenack et al., 1973.
C4 <20 1 0 — 1075 384 — R38/2

14. P. cf. paucifurcatum (Eisenack, 1959) Eisenack et al., 1973
C4 <20 1 0 — 1017 257 — L51/4

15. Coryphidium bohemicum Vavrdova, 1972
C4 <20 1 0 — 1055 423 — P34/1

16.	C. bohemicum Vavrdova, 1972	C4	<20	1	0	1089	474	S29/3
17.	C. bohemicum Vavrdova, 1972	C4	<20	1	0	1097	514	T25/3
18.	Acanthodiacrodium sp. E	C4	<20	1	0	1098	355	T41/4

PLATE 5



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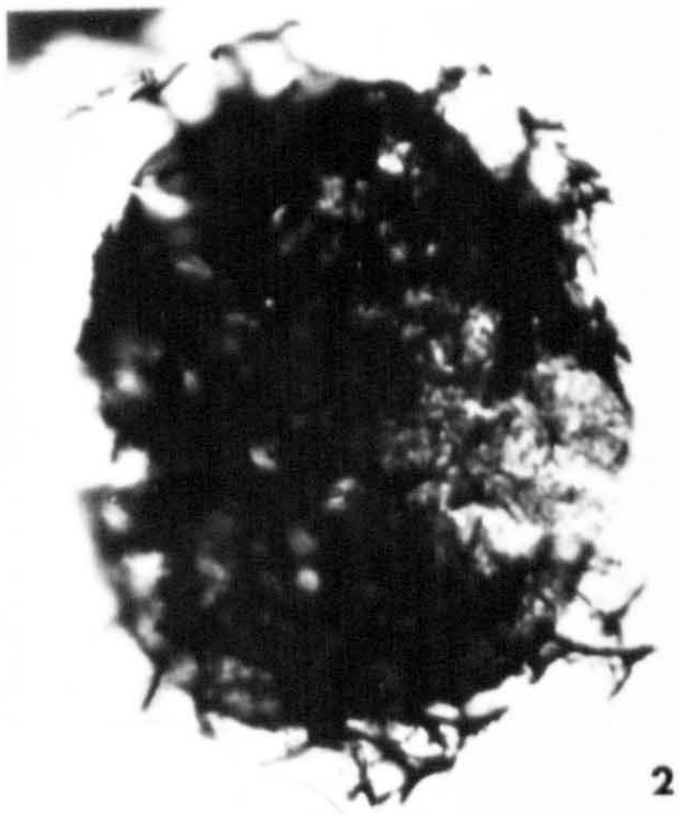

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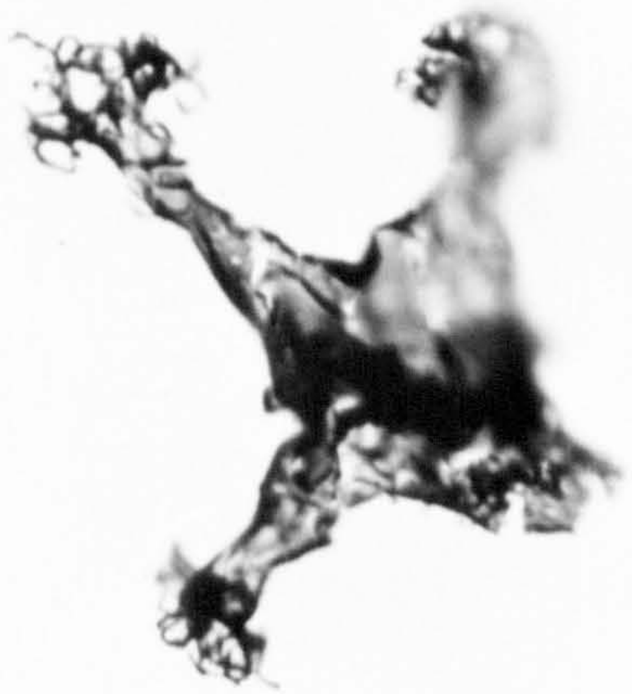

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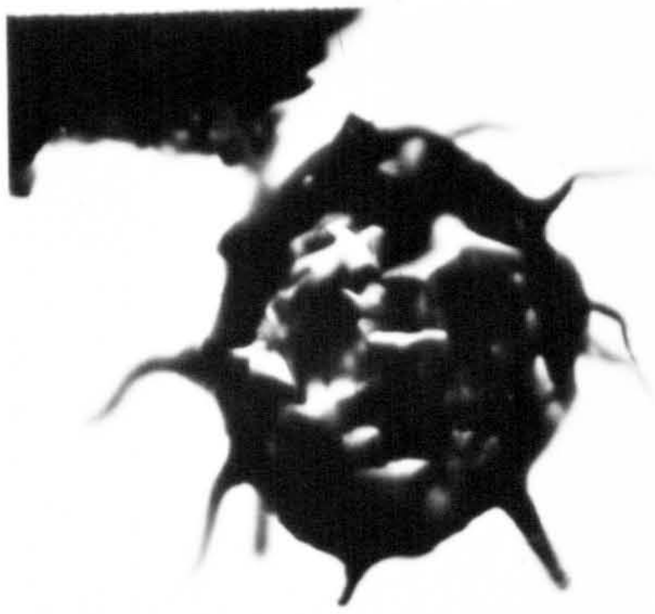

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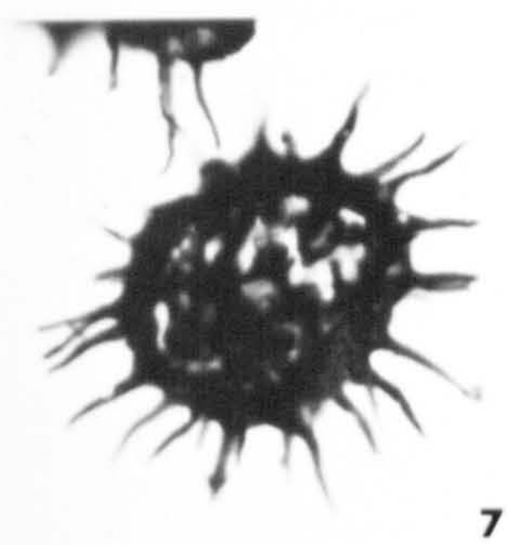

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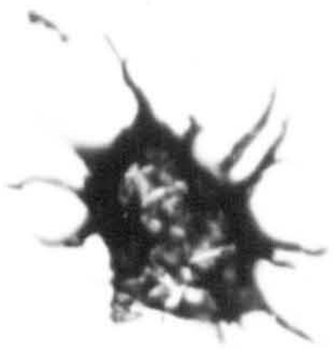

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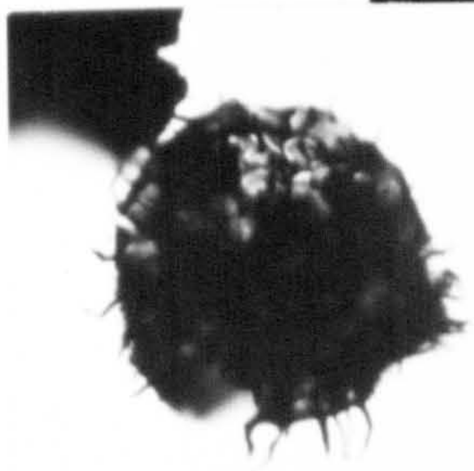

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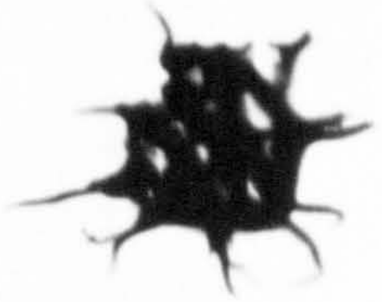

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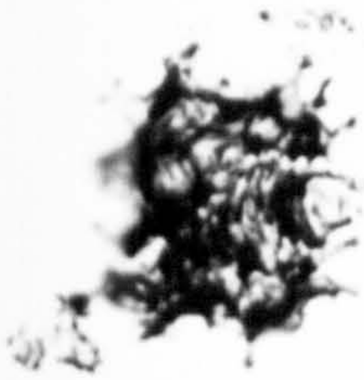

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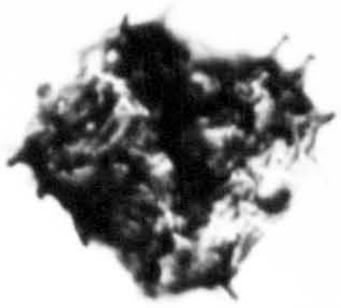

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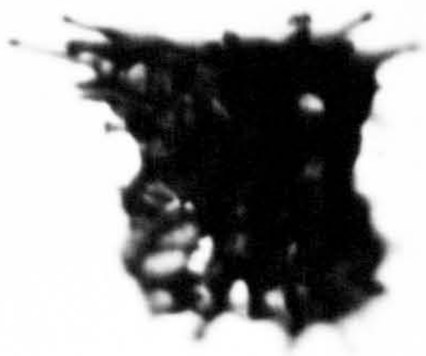

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Microfloral assemblage from the Afon Saint, Caernarvon,(Upper Arenig)

1. Cymatiogalea cf. granulata Vavrdova, 1966
C4 <20 1 0 1083 486 T31/3

2. Stelliferidium sp. C4 <20 1 0 1045 323 044/2

3. Electoriskos? sp. A C4 <20 1 0 1110 279 V49/1

4. Electoriskos? sp. A C4 <20 1 0 1106 427 U34/1

5. Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b
C4 <20 1 0 1094 492 T27/1

6. M. raspum (Cramer, 1964b) Lister, 1970b
C4 <20 1 0 1033 491 M27/4

7. Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.
C4 <20 1 0 1044 357 041/1

8. Micrhystridium sp. B C4 <20 1 0 1051 326 044/3

9. Micrhystridium crispum sp. nov. (Holotype)
C4 <20 1 0 1014 461 L30/2

10. M. crispum sp. nov. C4 <20 1 0 1125 288 W48/1

11. Micrhystridium sp. A C4 <20 1 0 1023 373 M39/2

12. ?Micrhystridium nannacanthum Deflandre, 1942 ex Deflandre, 1945
C4 <20 1 0 1095 491 T31/2

13. Frankea sartbernardense (Martin, 1966) Burmann, 1976
C4 <20 1 0 1077 398 R37/3

14. Cymatiogalea cf. ancora Paris & Deunff, 1970
C4 <20 1 0 1078 296 R47/4

15. Coryphidium elegans Cramer et al., 1974a
C4 <20 1 0 1022 284 L48/4

16. Micrhystridium subtile sp. nov. C4 <20 1 0 1036 312 N46/1

17. Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959
C4 <20 1 0 1110 358 U41/3

18. Striatotheca rarirrugulatum (Cramer et al., 1974b) Eisenack et al., 1976
C4 <20 1 0 1101 260 U51/1

19. Veryhachium minutum Downie, 1958
C4 <20 1 0 1044 446 032/1

20. ?Vulcanisphaera cirrita Rasul, 1976
C4 <20 1 0 1112 392 V37/2

PLATE 6

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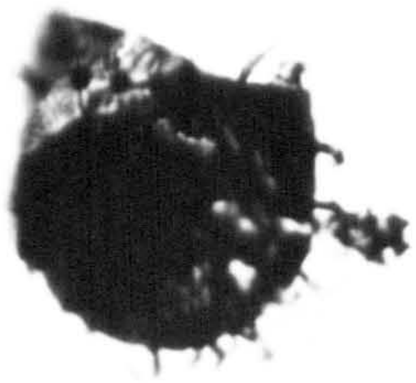

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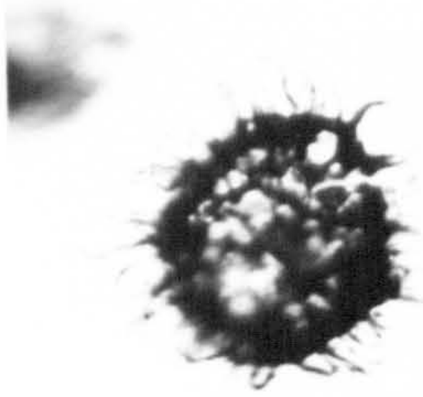

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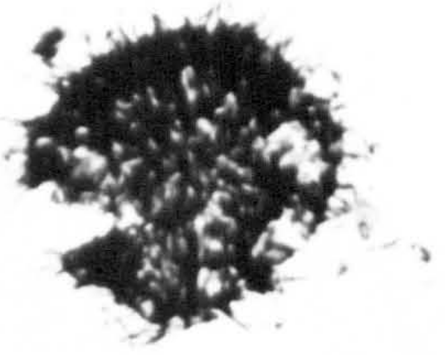

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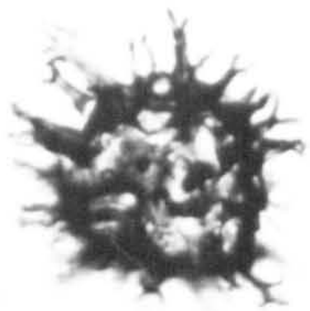

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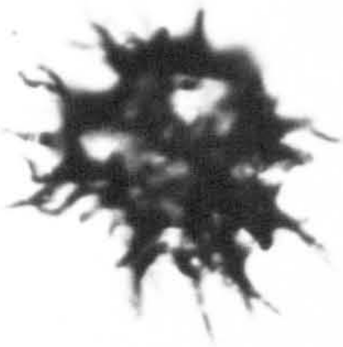

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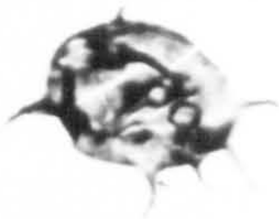

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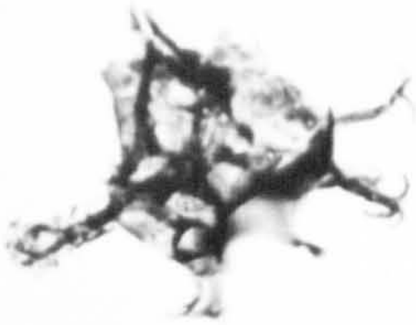

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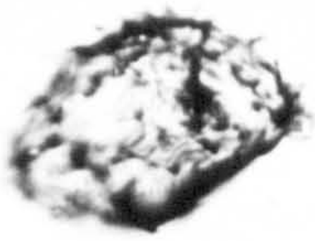

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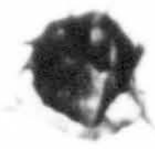

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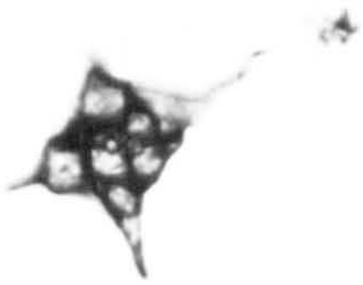

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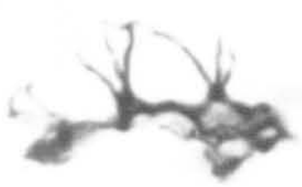

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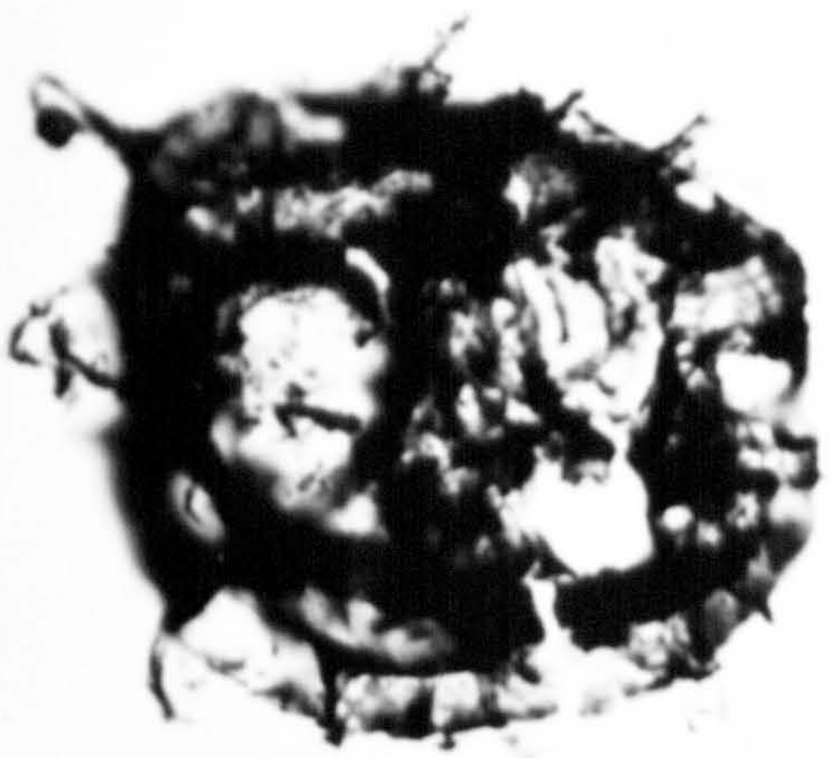
PLATE 7

Microfloral assemblage from the Afon Saint, Caernarvon,(Lower Llanvirn)

1.	Uncinisphaera? sp. A.	C1	20	1	0	1082	258	R51/3
2.	Vulcanisphaera cirrita Rasul, 1976	C1	20	1	2	982	315	G45/4
3.	Astropheos celestum Martin, 1969 comb. nov.	C1	20	1	2	1040	409	W35/4
4.	A. celestum Martin, 1969 comb. nov.	C1	20	1	2	1122	389	W38/1
5.	Stelliferidium striatulum (Vavrdova, 1966) Deunff, Gorka & Rauscher, 1974	C1	20	1	2	1036	318	N45/3
6.	?Uncinisphaera? exilis sp. nov.	C1	20	1	2	970	437	F33/3
7.	Striatotheca quieta (Martin, 1969) Rauscher, 1974	C1	<20	1	1	1098	311	T46/3
8.	?Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959	C1	<20	1	1	1084	453	
9.	Elektoriskos? sp. A	C1	<20	1	1	984	376	F39/2
10.	Multiplicisphaeridium sp.	C1	<20	1	1	998	484	J28/1

PLATE 7



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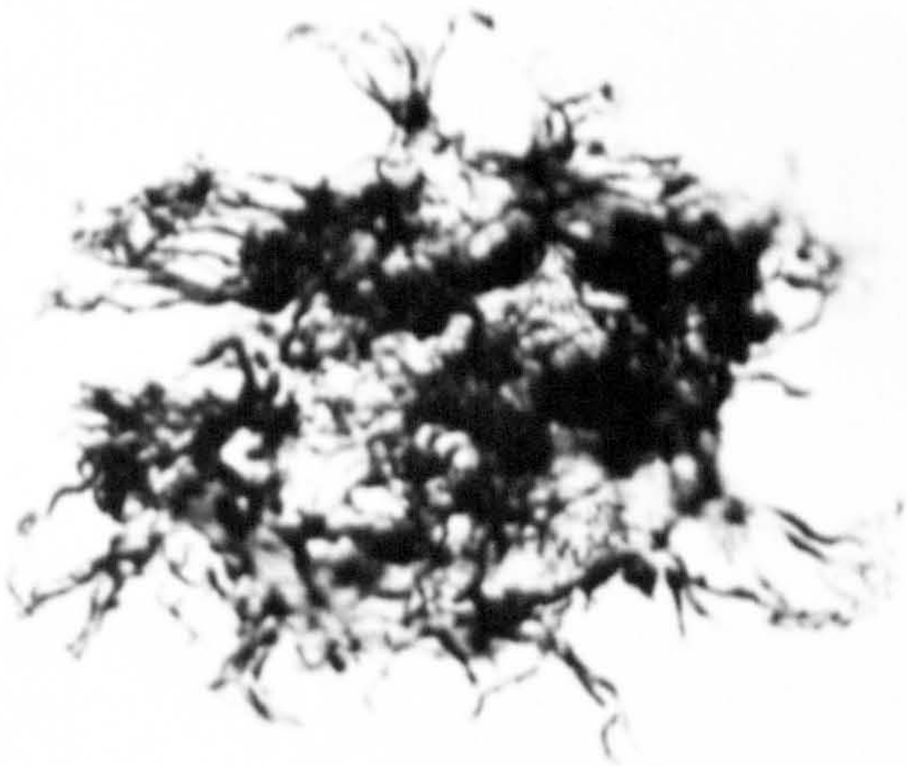

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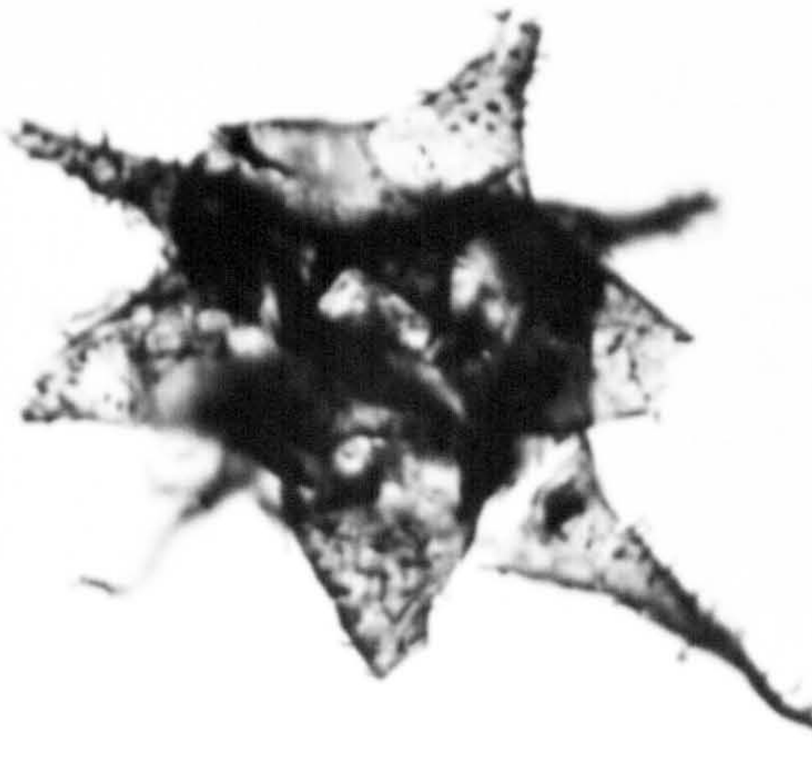

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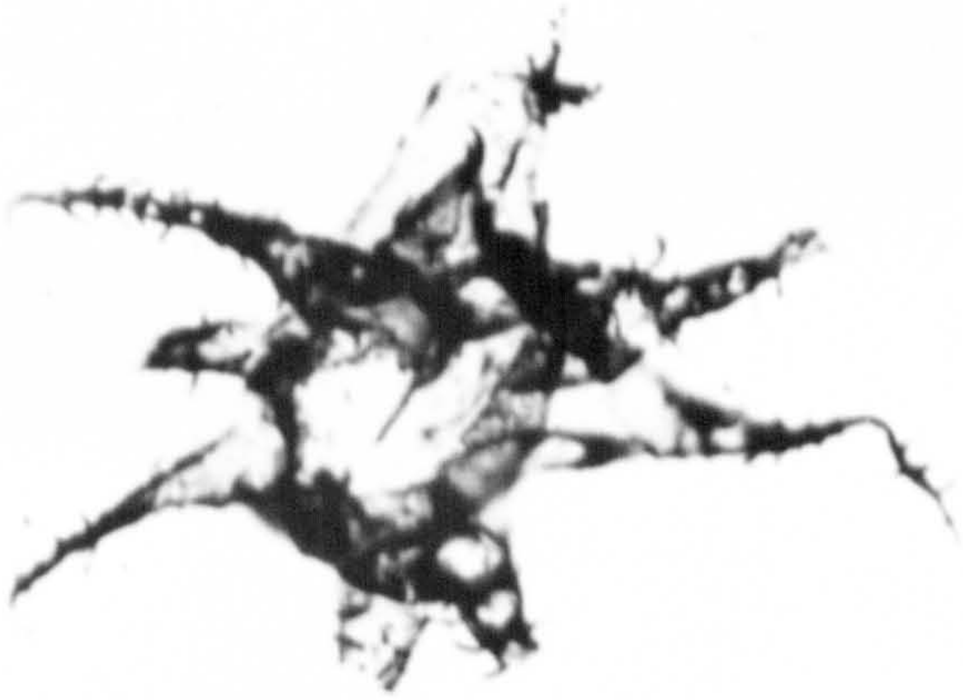

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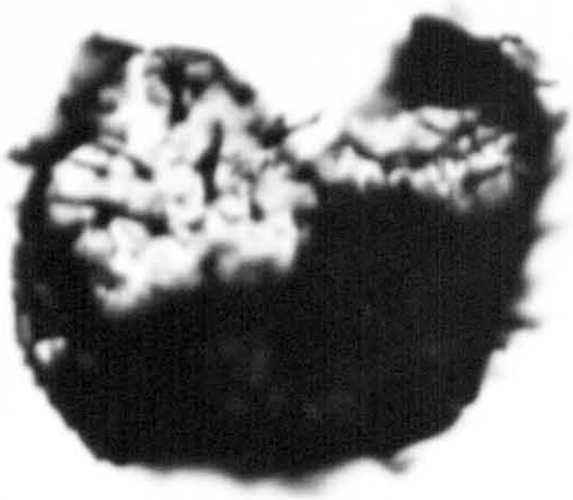

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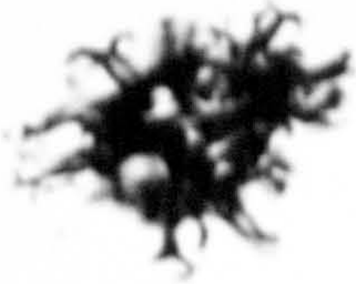

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PLATE 8

Microfloral assemblage from the Afon Saint, Caernarvon, (Lower Llanvirn)

1.	Tectitheca sp. A	C1	<20	1	1	1033 293	N47/2
2.	Acanthodiacrodium sp. D	C1	<20	1	1	1104 443	U32/2
3.	Acanthodiacrodium rectinerve Burmann, 1968	C1	<20	1	1	1073 476	R29/1
4.	Tectitheca? sp. B	C1	<20	1	1	944 488	C27/4
5.	Acanthodiacrodium sp.	C1	<20	1	1	1004 257	K51/2
6.	Veryhachium trispinosum Formgroup, Cramer, 1964b	C1	<20	1	1	1132 336	X43/2
7.	Micrhystridium sp.	C1	<20	1	1	960 323	E44/3
8.	Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.	C1	<20	1	1	1048 493	027/1
9.	Multiplicisphaeridium? sp. E	C1	<20	1	1	923 334	A43/4
10.	Frankea hamata Burmann, 1970	C1	<20	1	1	1131 443	X32/2
11.	Micrhystridium robustum Downie, 1958	C1	<20	1	1	939 326	C44/4
12.	M. subtile sp. nov.	C1	<20	1	1	943 385	C38/4

PLATE 8

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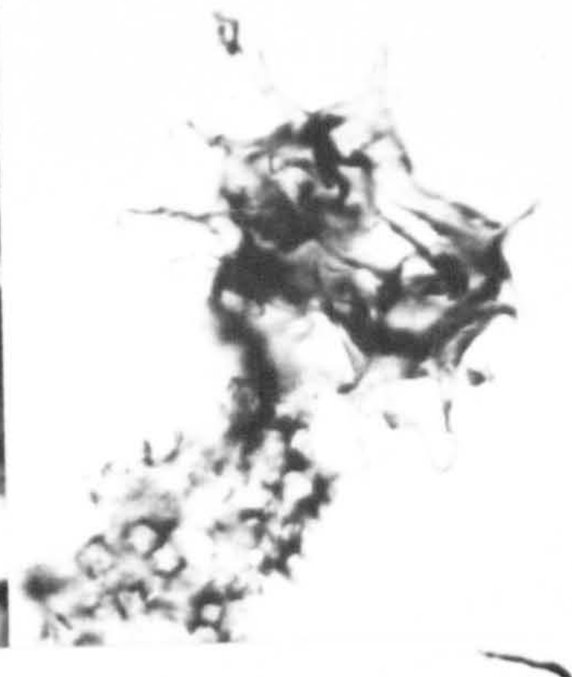

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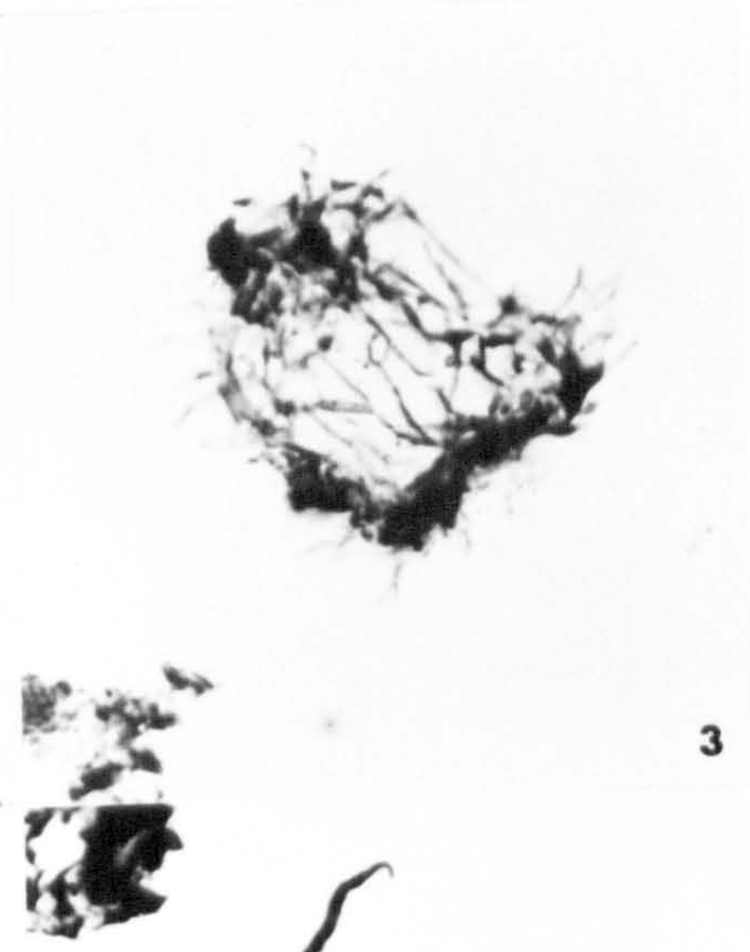

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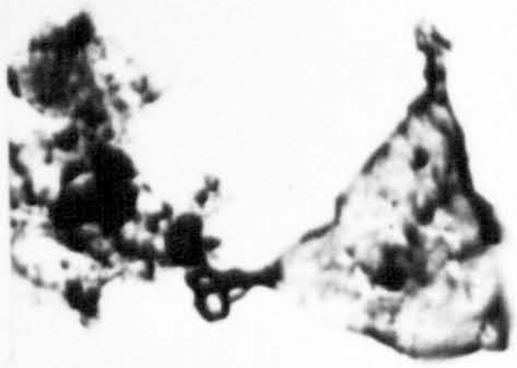

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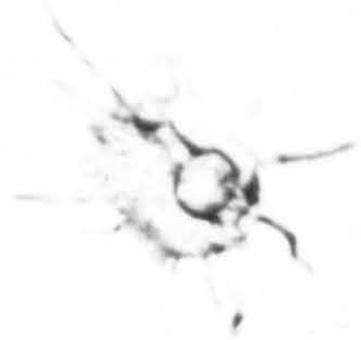

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PLATE 9

Microfloral assemblage from Garth Point, Bangor,(Lower Arenig)

1. Stelliferidium striatulum (Vavrdova, 1966) Deunff, Gorka & Rauscher, 1974

B1 20 1 2 962 237 F54/1

2. S. striatulum (Vavrdova, 1966) Deunff, Gorka & Rauscher, 1974

B1 20 1 2 1003 414 K35/2

3. S. striatulum (Vavrdova, 1966) Deunff, Gorka & Rauscher, 1974

B1 20 1 2 1045 239 053/2

4. S. striatulum (Vavrdova, 1966) Deunff, Gorka & Rauscher, 1974

B1 20 2 2 1034 528 N23/2

5. Veryhachium trispinosum Formgroup, Cramer, 1964b

B1 <20 8 0.5 1062 274 Q49/2

6. Stelliferidium fimbrium Rasul, 1974, comb. nov.

B1 20 1 2 1110 448 V32/1

7. Peteinosphaeridium lepton sp. nov.

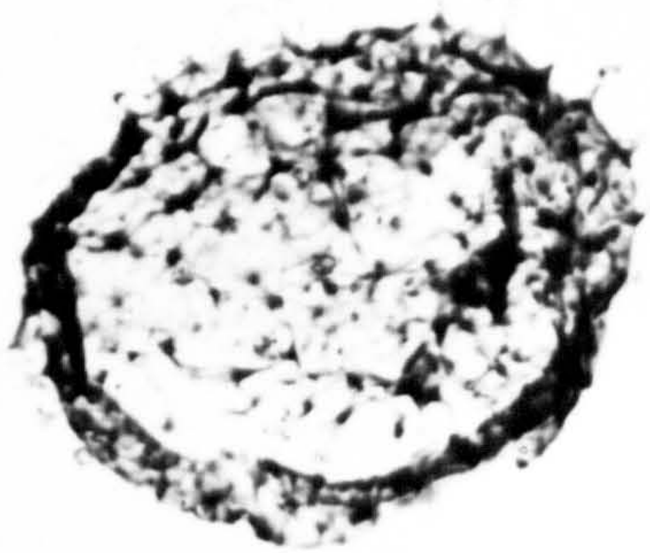
B1 20 1 2 967 408 F36/1

8. P. lepton sp. nov. B1 20 1 2 989 437 H33/3

9. Multiplicisphaeridium sp. D B1 20 1 2 1062 419 Q35/1

10. Multiplicisphaeridium sp. D B1 20 1 2 1040 438 N33/3

PLATE 9



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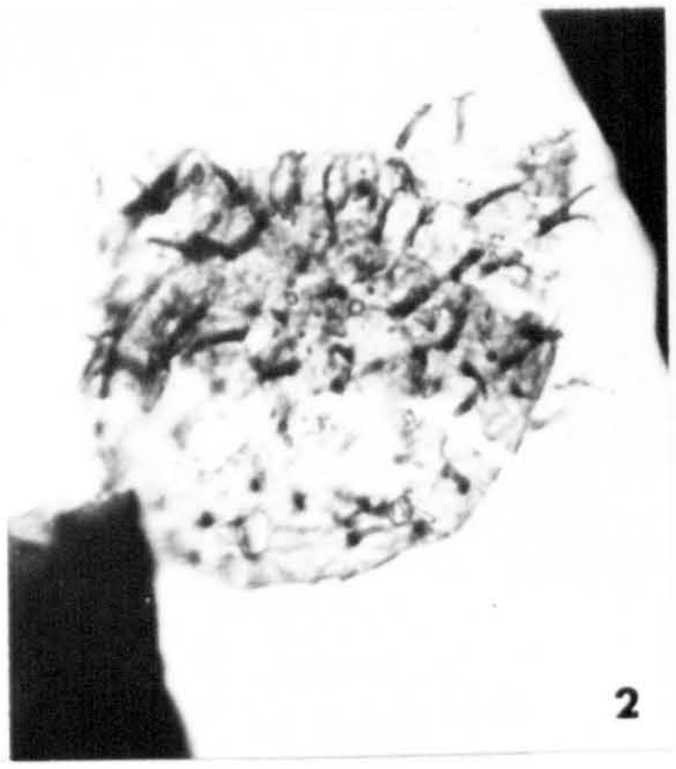

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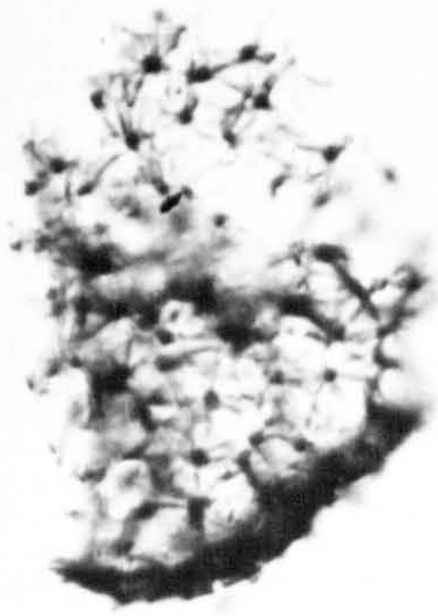

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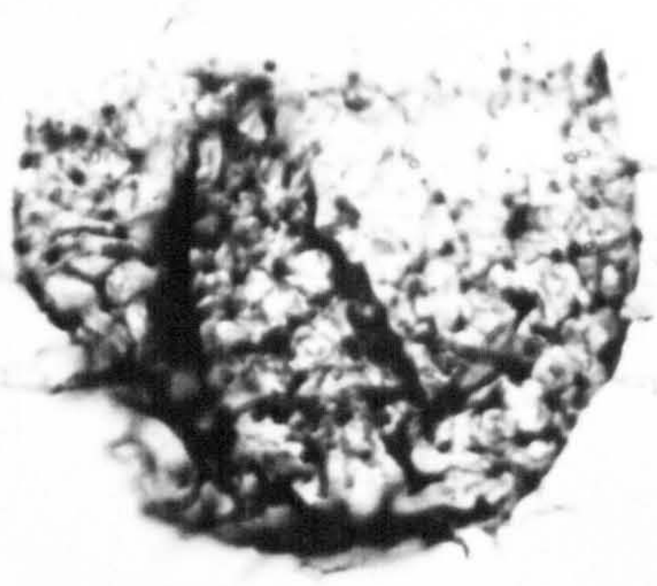

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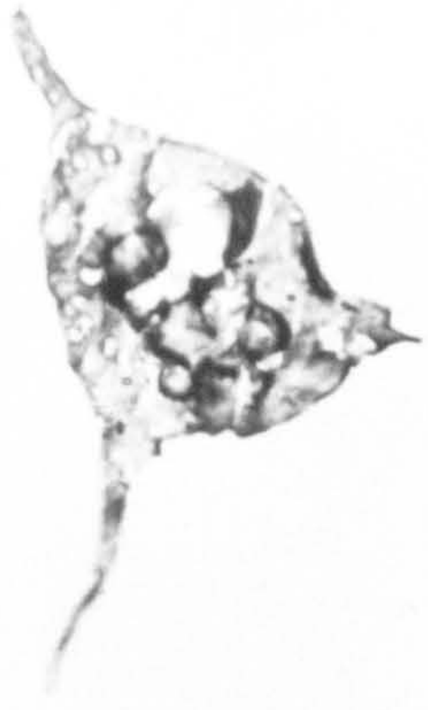

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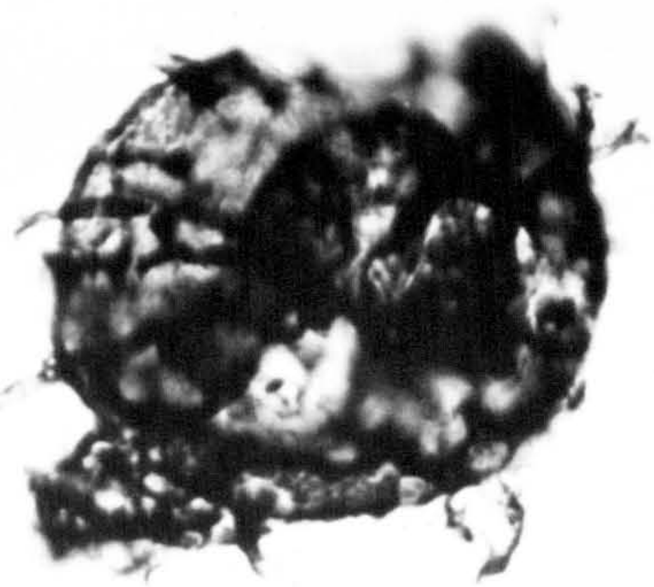

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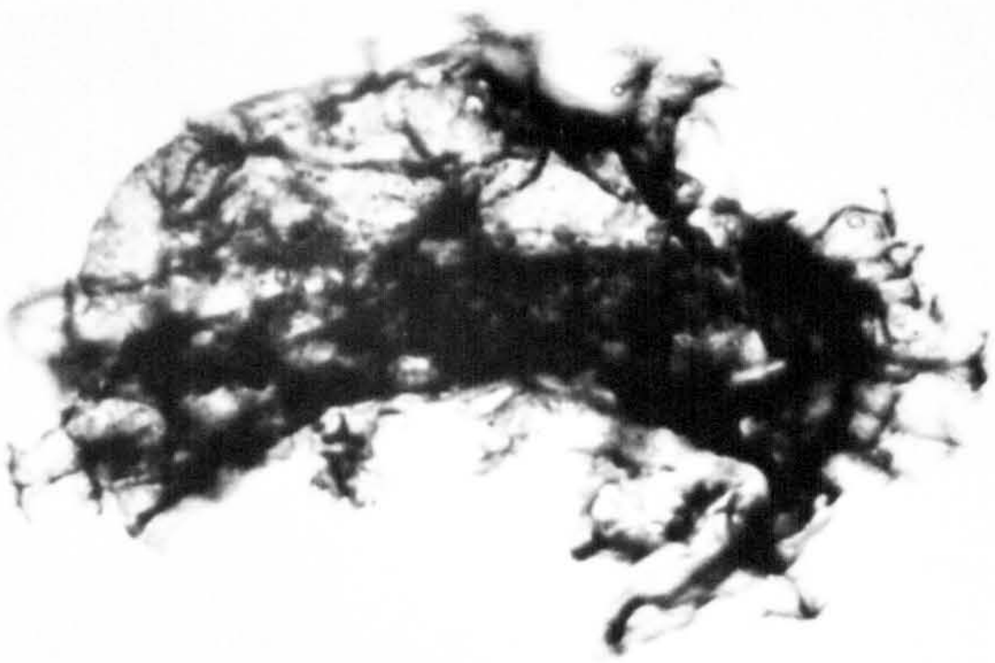

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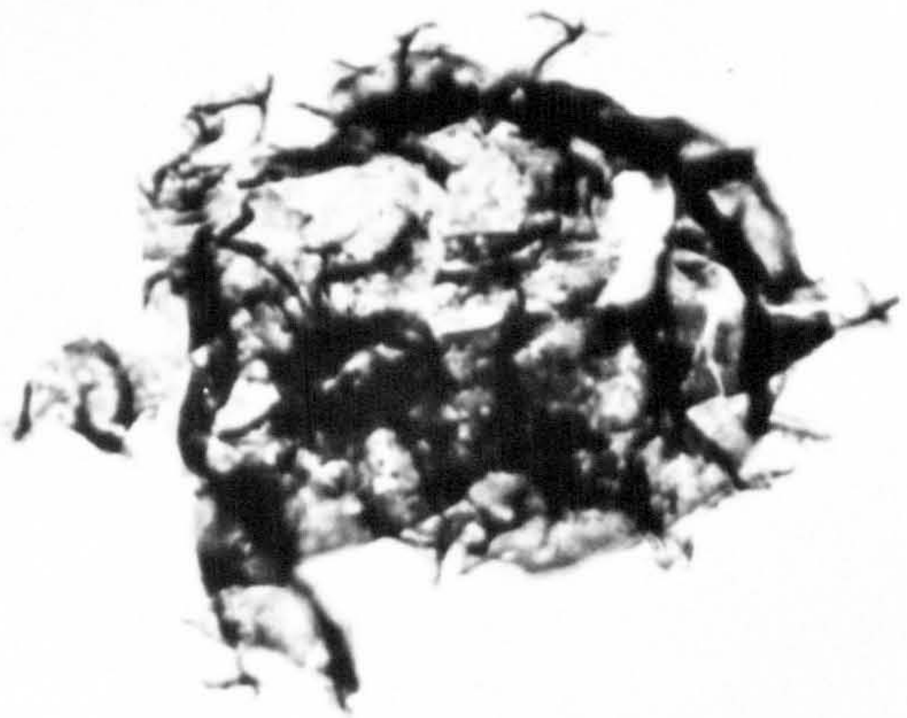

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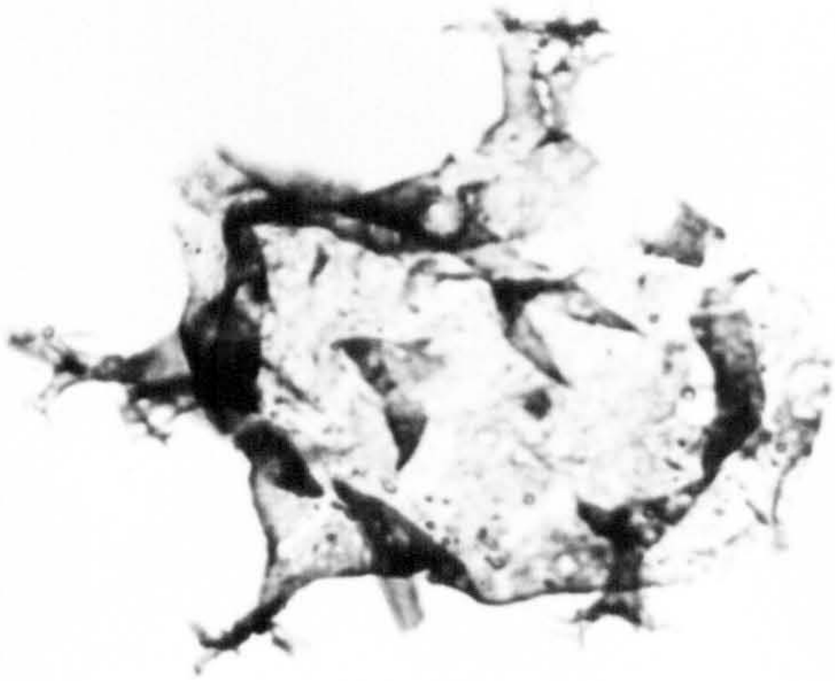

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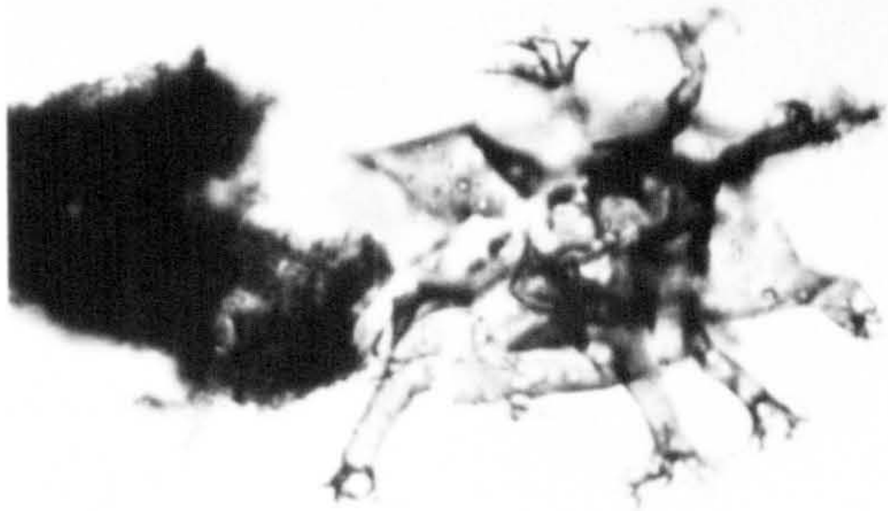

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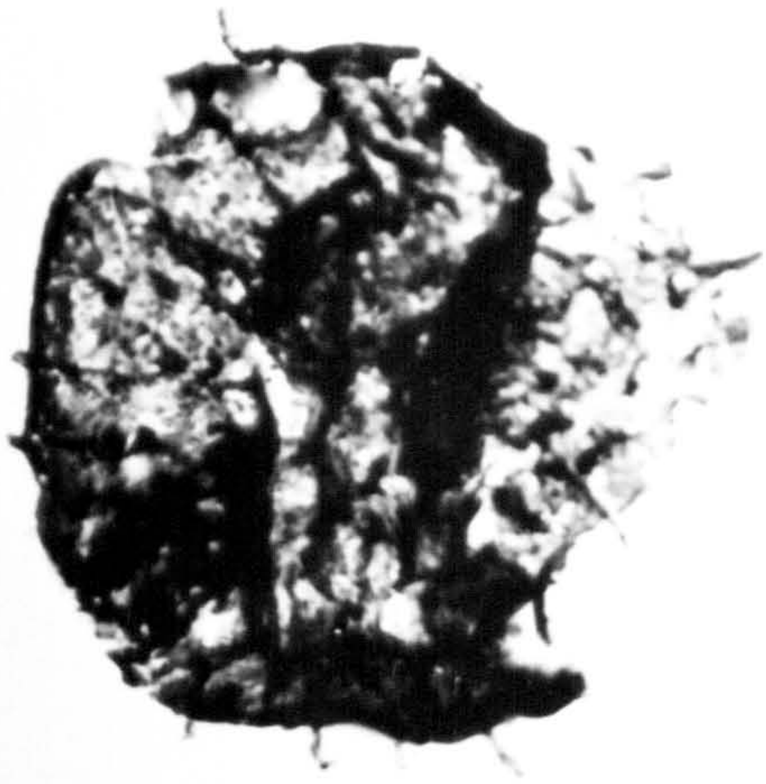
PLATE 10

Microfloral assemblage from Garth Point, Bangor, (Lower Arenig)

1.	Uncinisphaera? sp. A	B1	20	1	2	1070	260	R51/1
2.	Poikilofusa sp. A	B1	<20	12	0.8	1023	490	L27/4
3.	Coryphidium bohemicum Vavrdova, 1972	B1	<20	12	0.8	999	255	J51/4
4.	C. bohemicum Vavrdova, 1972	B1	<20	8	0.5	1075	514	R25/1
5.	Striatotheca rarirrugulatum (Cramer et al., 1974b) Eisenack et al., 1976	B1	<20	5	0.3	996	298	J47/2
6.	Cymatiogalea cf. ancora Paris & Deunff, 1970	B1	<20	4	0.3	1126	475	W29/3
7.	Striatotheca principalis parva Burmann, 1970	B1	<20	5	0.3	967	458	F30/2
8.	Polygonium cf. pungens Timofeev, 1959 comb. nov.	B1	20	1	2	1039	464	N30/3
9.	?Stelliferidium sp.	B1	20	1	2	1045	287	048/2
10.	Polygonium cf. pungens Timofeev, 1959 comb. nov.	B1	<20	4	0.3	1125	234	W53/4
11.	Cymatiogalea cuvillieri (Deunff, 1961) Deunff, 1964	B1	<20	8	0.5	1014	441	L32/2
12.	Cymatiogalea cf. ancora Paris & Deunff, 1970	B1	<20	12	0.8	991	519	H24/4
13.	?Stelliferidium sp.	B1	<20	8	0.5	1031	491	L27/3

PLATE 10



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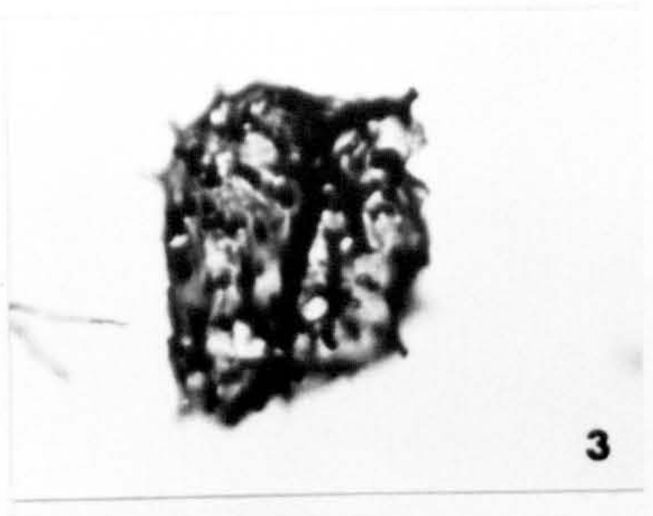

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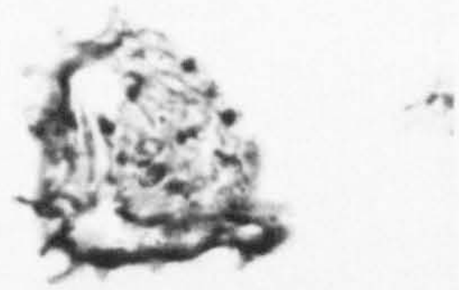

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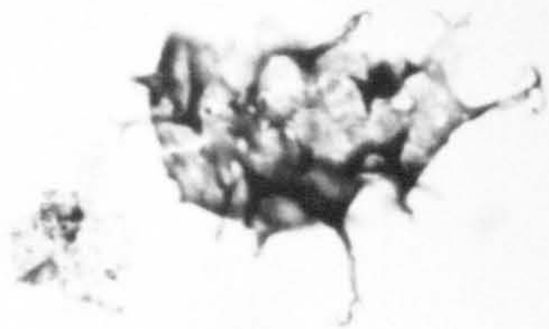

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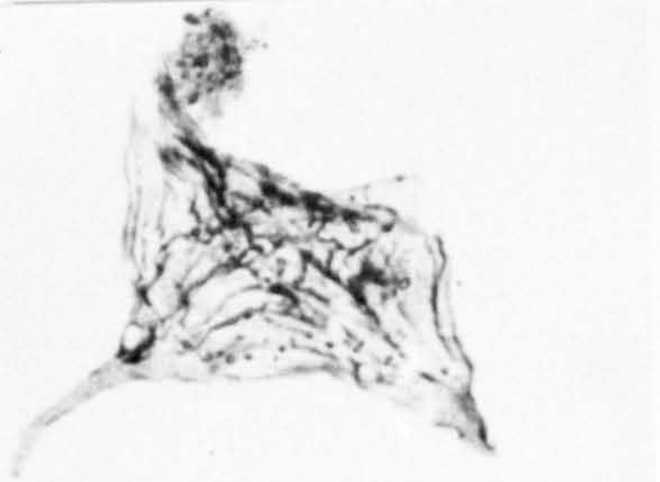

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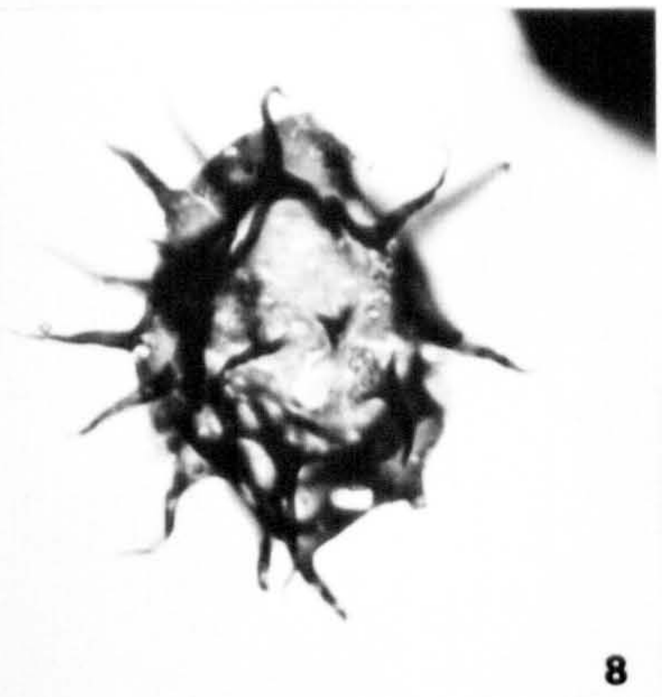

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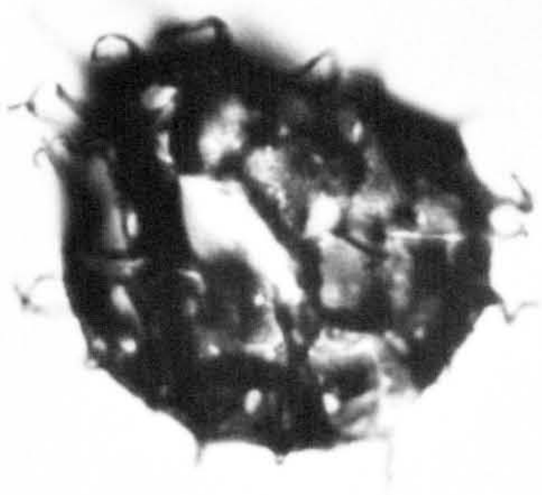

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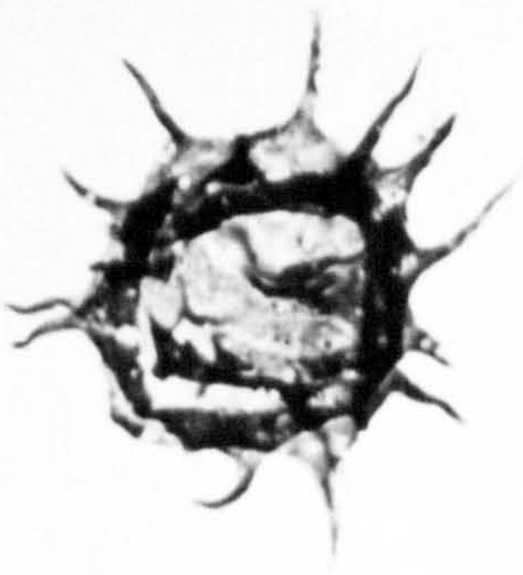

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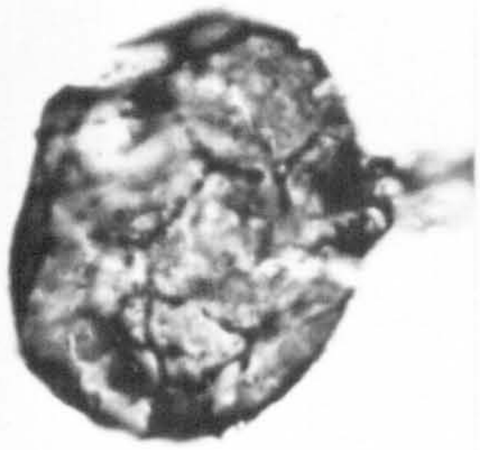

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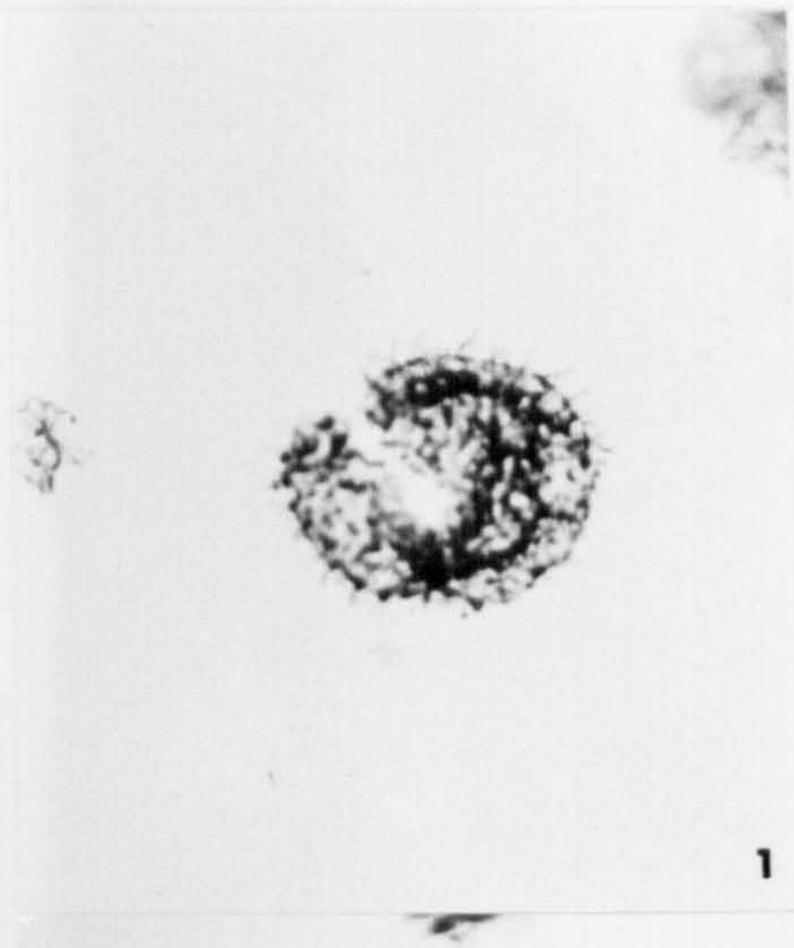
PLATE 11

Microfloral assemblage from Garth Point, Bangor, (Lower Arenig)

1.	Elektoriskos? sp. A	B1	<20	12	0.8	1021 303	L46/4
2.	?Corphidium bohemicum Vavrdova, 1972	B1	<20	8	0.5	1064 395	Q37/1
3.	Polygonium gracile Vavrdova, 1966 emend.	B1	<20	4	0.3	1123 447	W32/1
4.	Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.	B1	<20	4	0.3	1131 266	X50/2
5.	?M. nannacanthum Deflandre, 1942 ex Deflandre, 1945	B1	<20	12	0.8	1041 354	N14/4
6.	Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970	B1	<20	8	0.5	1034 491	N27/2
7.	Elektoriskos? sp. A	B1	<20	8	0.5	1047 406	036/1
8.	Acanthodiacrodium cf. simplex Combaz, 1967	B1	<20	8	0.5	1031 491	M27/4
9.	A. cf. simplex Combaz, 1967	B1					
10.	A. cf. simplex Combaz, 1967	B1	<20	12	0.8	1026 396	M37/1
11.	Multiplicisphaeridium? sp. E	B1	<20	12	0.8	1018 528	L23/4
12.	Acanthodiacrodium sp.	B1	<20	5	0.3	992 465	H30/3
13.	Acanthodiacrodium sp. A	B1	<20	4	0.3	1126 310	W46/3
14.	Multiplicisphaeridium sp.	B1	<20	12	0.8	1036 320	N45/3

PLATE 11



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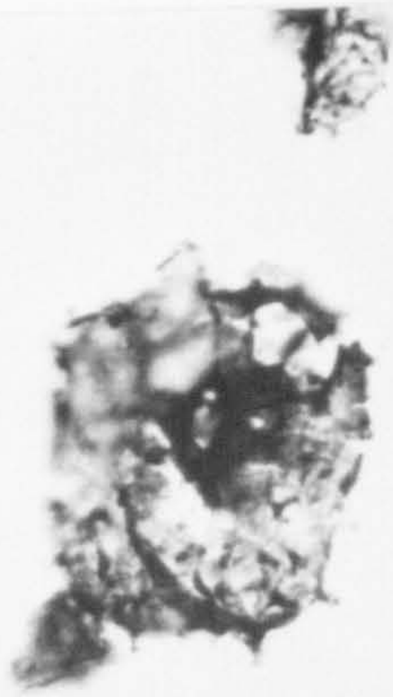

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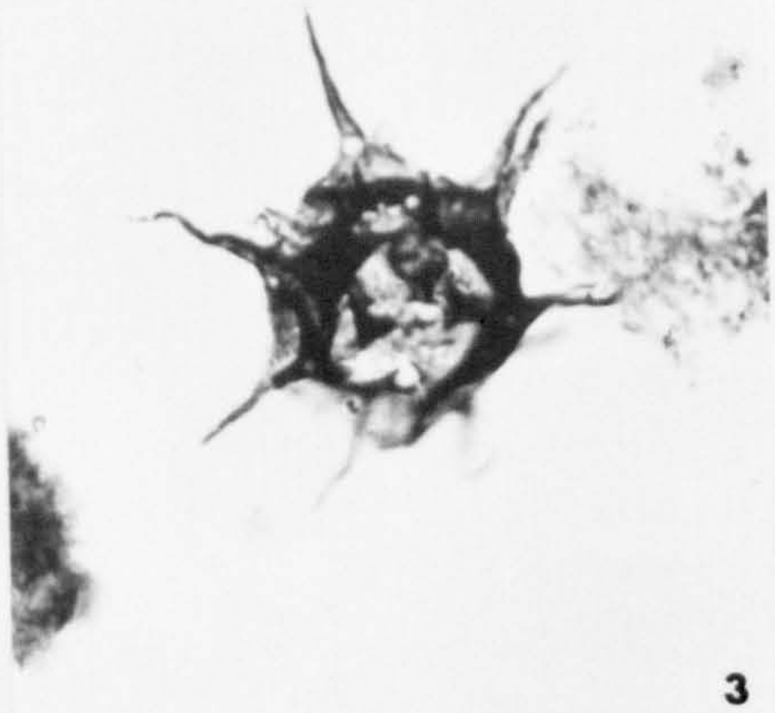

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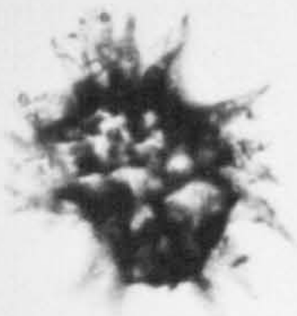

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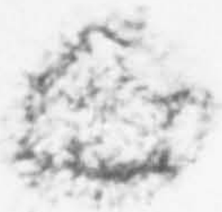

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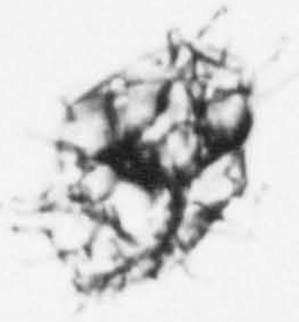

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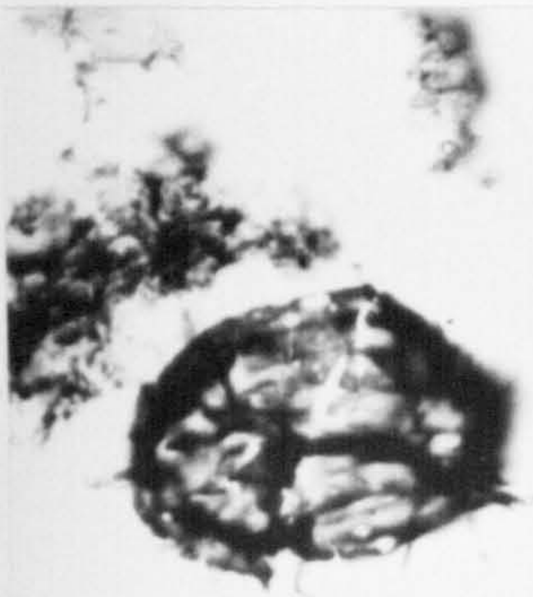

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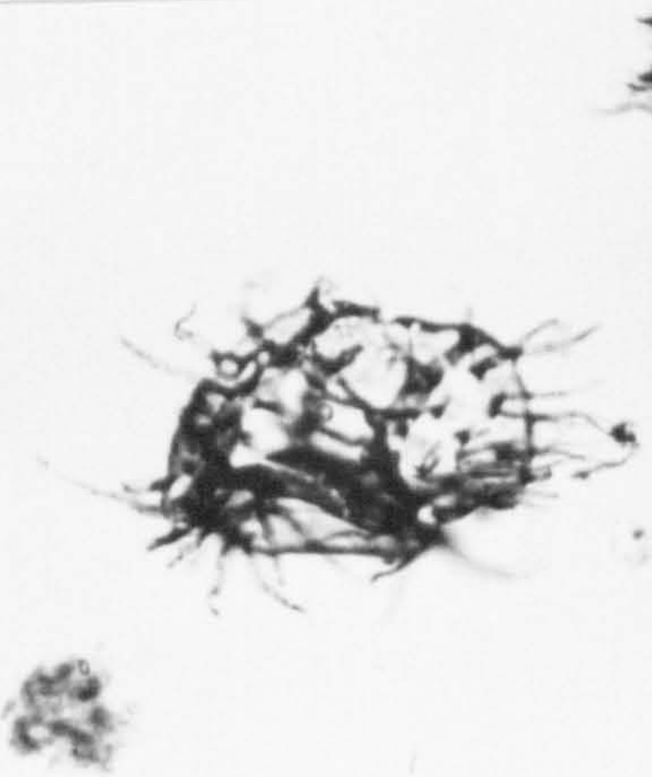

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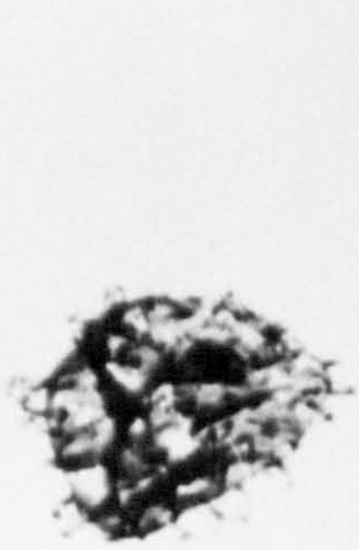

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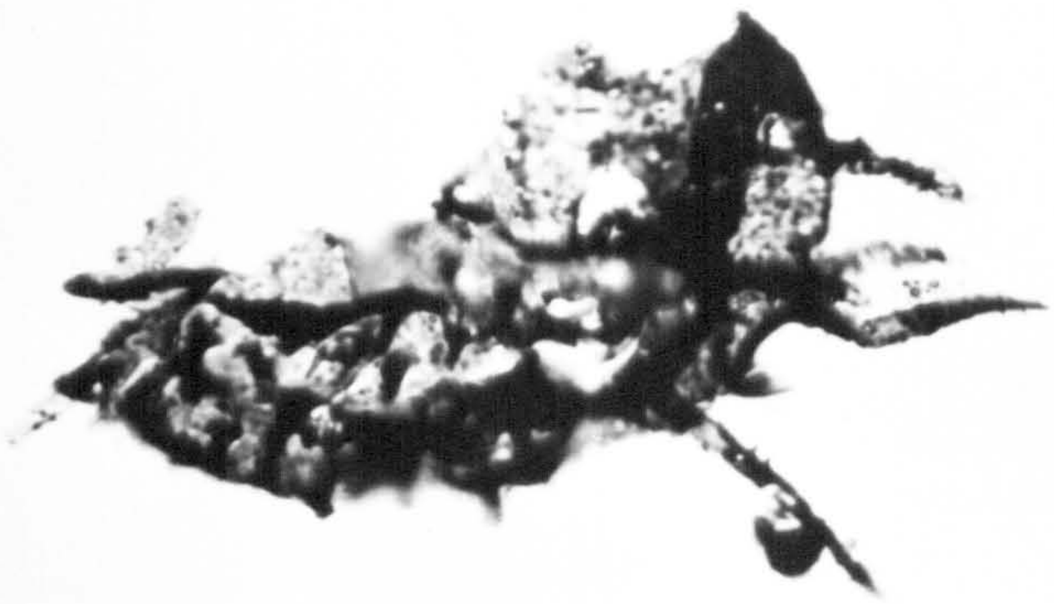
PLATE 12

Microfloral assemblage from Garth Point, Bangor, (Lower Arenig)

1.	Baltisphaeridium sp.	B2	20	1	0	944 497	C26/4
2.	?Multiplicisphaeridium sp. D	B2	<20	1	0	1004 406	
3.	Micrhystridium henryi Paris & Deunff, 1970	B2	<20	1	0	1051 514	025/3
4.	M. henryi Paris & Deunff, 1970	B2	<20	1	0	1038 365	
5.	M. aremoricanum Paris & Deunff, 1970 comb. nov.	B2	<20	1	0	1005 396	
6.	M. aremoricanum Paris & Deunff, 1970 comb. nov.	B2	<20	1	0	1046 511	025/1
7.	M. aremoricanum Paris & Deunff, 1970 comb. nov.	B2	<20	1	0	1011 284	J48/4
8.	M. henryi Paris & Deunff, 1970	B2	<20	1	0	1031 496	
9.	?Coryphidium bohemicum Vavrdova, 1972	B2	<20	1	0	1020 454	
10.	?Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.	B2	<20	1	0	1012 312	
11.	Acanthodiacrodium sp.	B2	<20	1	0	1011 332	

PLATE 12



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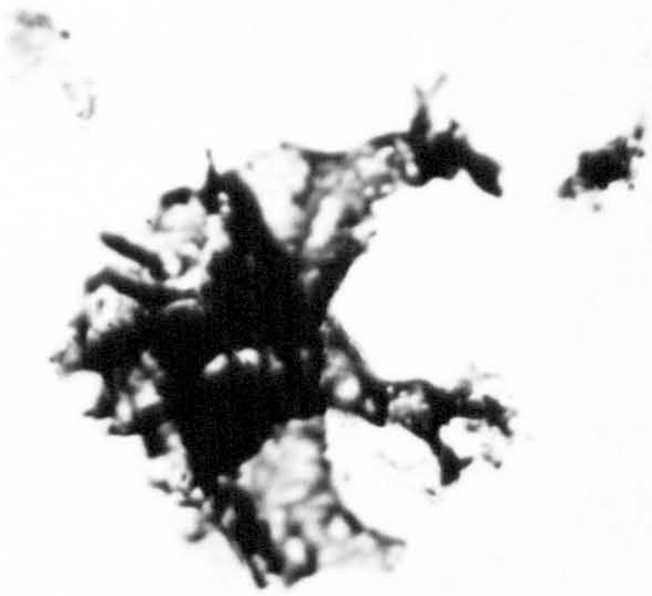

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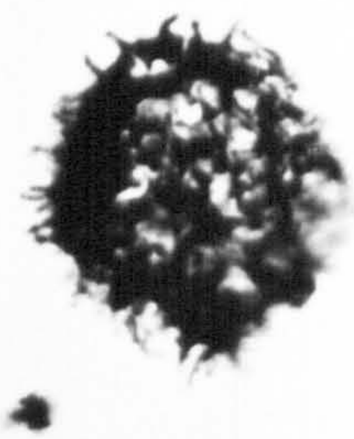

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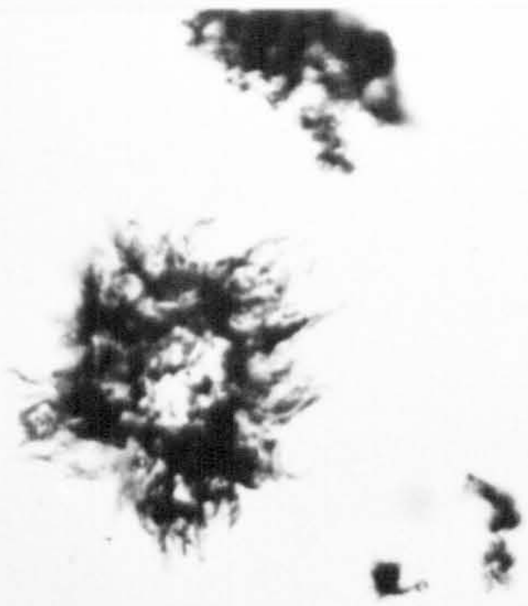

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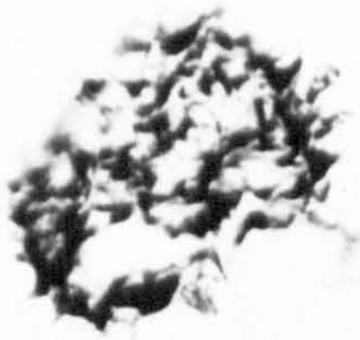

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PLATE 13

Microfloral assemblage from Menai, Bangor, (Lower Arenig)

1. Baltisphaeridium? sp. E
M2 20 1 0 952 347 D42/3

2. ?Stelliferidium distinctum Rasul, 1974 comb. nov.
M2 20 1 0 1046 342 042/2

3. ?S. distinctum Rasul, 1974 comb. nov.
M2 20 1 0 993 503 H26/3

4. Polygonium gracile Vavrdova, 1966 emend.
M2 20 1 0 973 262 F51/3

5. Peteinosphaeridium trifurcatum (Eisenack, 1938)(al breviradiata, Eisenack, 1959)
M2 20 1 0 1021 354 L41/4

6. Baltisphaeridium? sp. C
M2 20 1 0 1038 403 N36/4

7. Peteinosphaeridium lepton sp. nov.
M2 20 1 0 1100 308 045/1

8. Striatotheca principalis parva Burmann, 1970
M2 <20 1 0.9 1029 265 M50/4

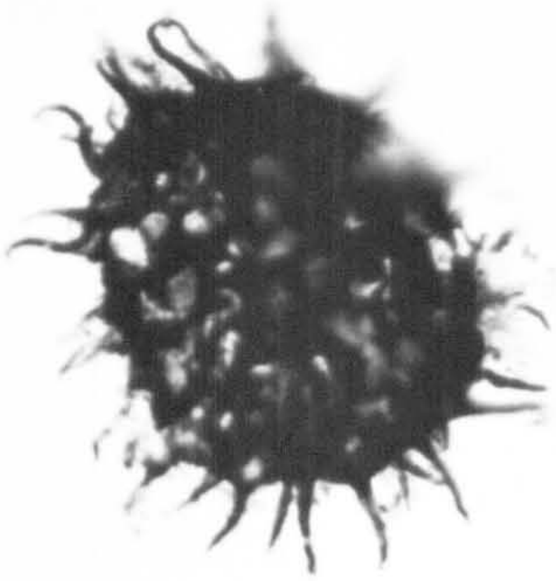
9. Veryhachium trispinosum Formgroup, Cramer, 1964 b
M2 <20 1 0.9 1039 323 M44/4

10. Elektoriskos? sp. A
M2 <20 1 0.9 1028 362 M40/4

11. Micrhystridium henryi Paris & Deunff, 1970
M2 <20 1 0.9 1058 298 P47/3

12. Frankea sartbernardense (Martin, 1966) Burmann, 1970
M2 <20 1 0.9 1047 275 049/4

PLATE 13



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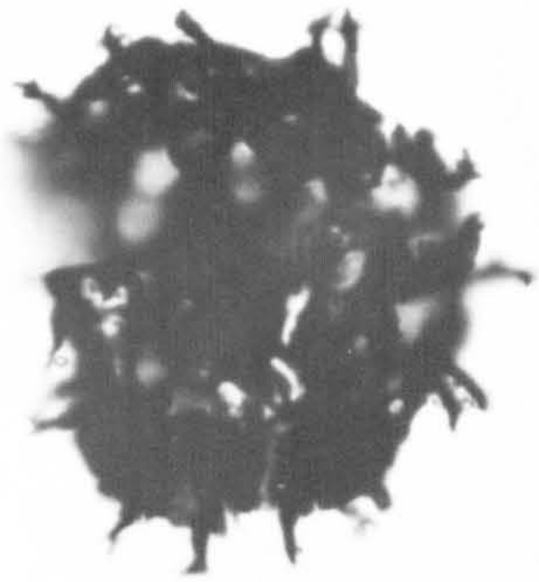

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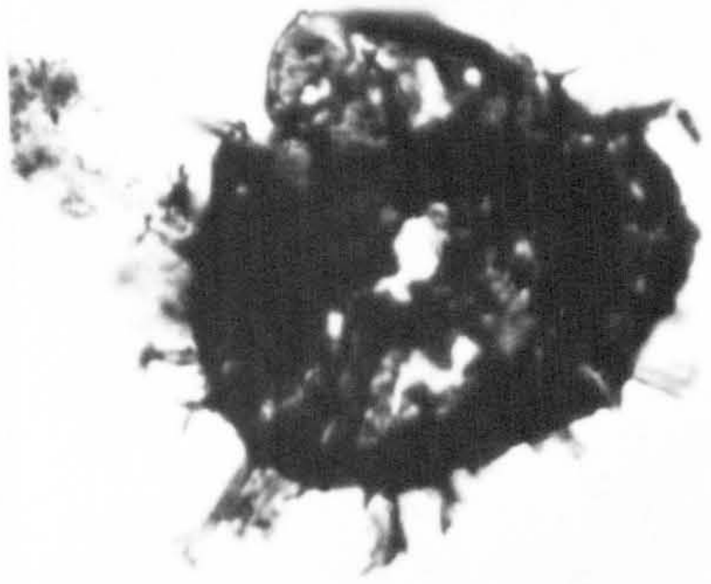

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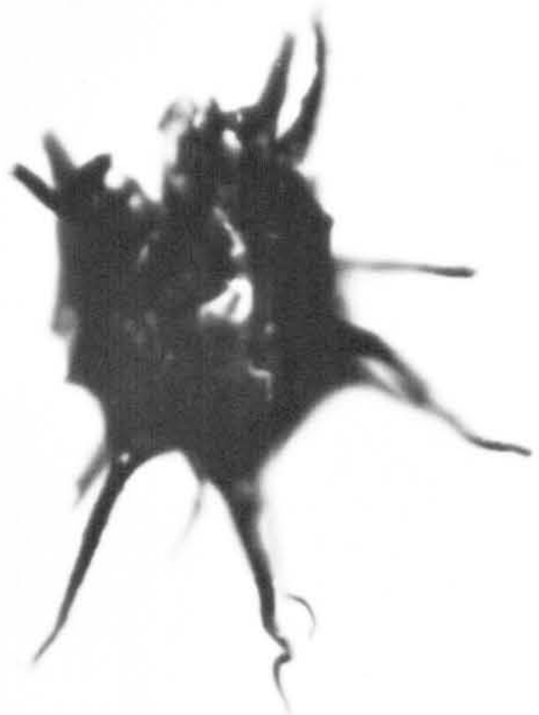

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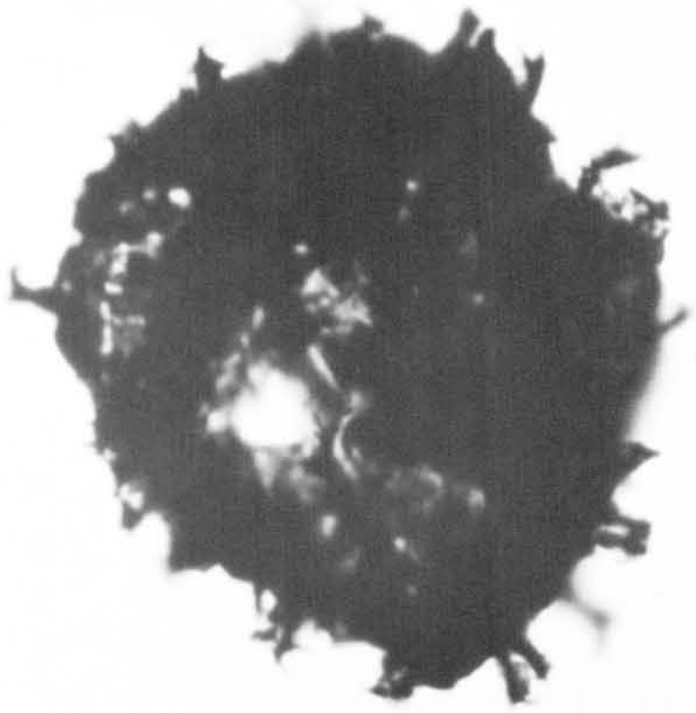

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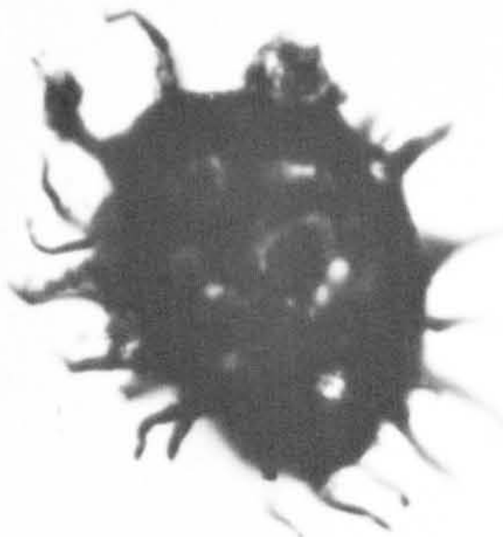

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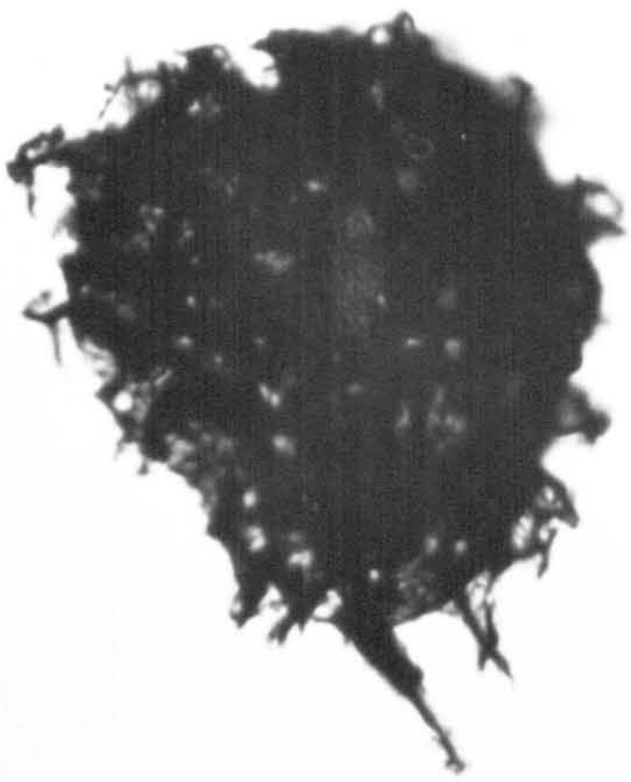

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Microfloral assemblage from Menai, Bangor, (Lower Arenig)

1. Coryphidium bohemicum Vavrdova, 1972
M2 <20 1 0.9 1031 492 M27/3

2. C. bohemicum Vavrdova, 1972 M2 <20 1 0.9 1026 394 M37/2

3. C. bohemicum Vavrdova, 1972 M2 <20 1 0.9 1023 356 L41/3

4. C. elegans Cramer et al., 1974a M2 <20 1 0.9 1021 345 L42/4

5. Striatotheca rarirrugulata (Cramer et al., 1974b) Eisenack et al., 1976
M2 <20 1 0.9 1041 329 N44/3

6. S. rarirrugulata (Cramer et al., 1974b) Eisenack et al., 1976
M2 <20 1 0.9 1032 415 M35/3

7. S. rarirrugulata (Cramer et al., 1974b) Eisenack et al., 1976
M2 <20 1 0.9 1136 400 X38/4

8. ?Micrhystridium nannacanthum Deflandre, 1942 ex Deflandre, 1945
M2 <20 1 0.9 1031 301 M47/3

9. M. aremoricanum Paris & Deunff, 1970 comb. nov.
M2 <20 1 0.9 1032 520 M24/3

10. Micrhystridium sp. C M2 <20 1 0.9 1079 528 R23/4

11. Micrhystridium sp. B M2 <20 1 0.9 1095 297 T47/4

12. Micrhystridium subtile sp. nov. (Holotype)
M2 <20 1 0.9 1046 343 042/2

13. M. subtile sp. nov. M2 <20 1 0.9 1022 402 L36/4

14. M. cf. cleae Martin, 1972 M2 <20 1 0.9 1091 374 T39/2

15. M. cf. cleae Martin, 1972 M2 <20 1 0.9 1080 534 R23/3

16. M. cf. cleae Martin, 1972 M2 <20 1 0.9 1097 396 T37/3

PLATE 14

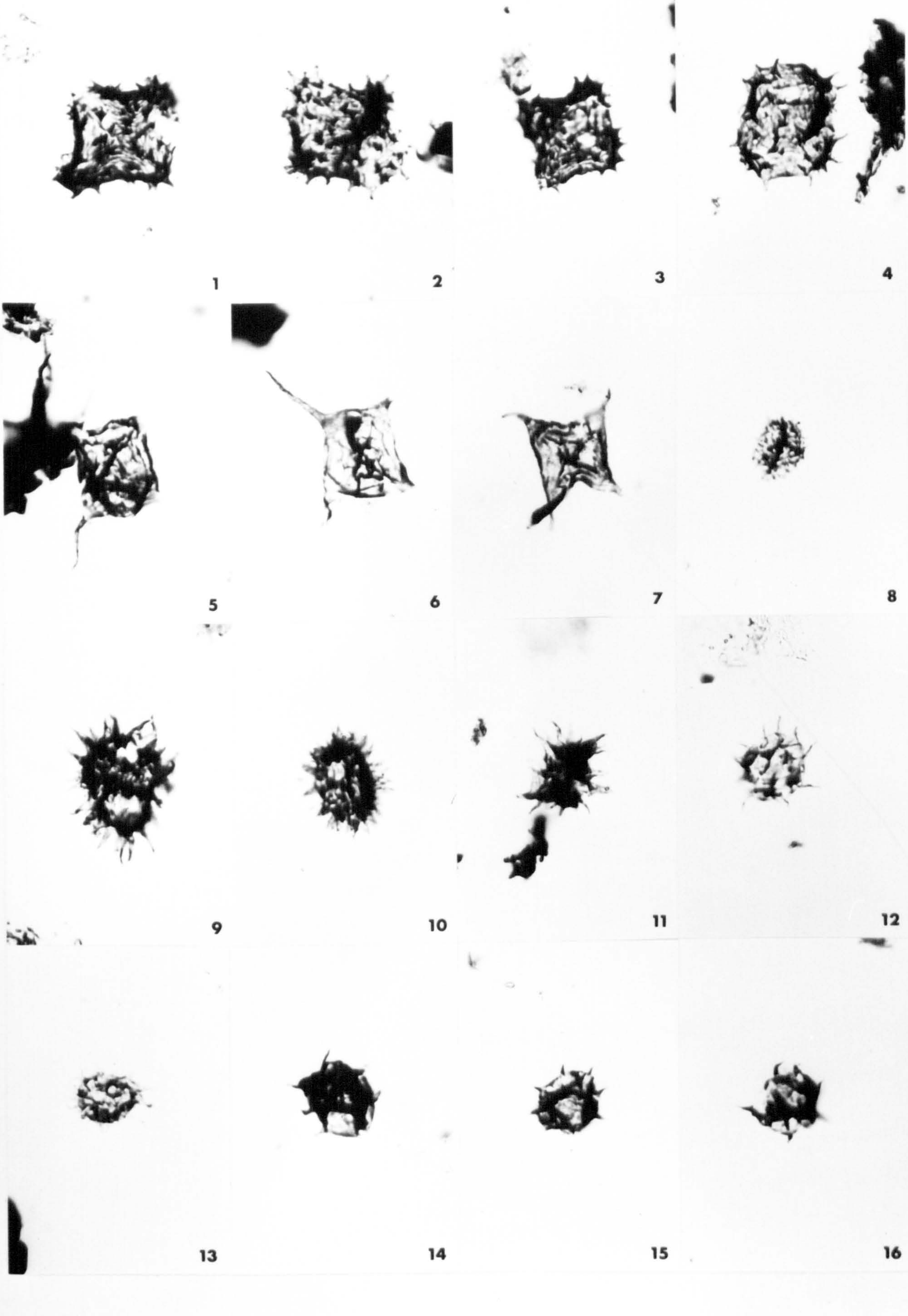

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PLATE 15

Microfloral assemblage from Menai, Bangor, (Lower Arenig)

1.	Uncinisphaera? sp. A	M3	20	1	0	1003	444	J32/3
2.	Baltisphaeridium sp.	M3	20	1	3.0	1006	320	K45/1
3.	Multiplicisphaeridium sp.	M3	20	1	0	1051	315	045/4
4.	Baltisphaeridium sp.	M3	20	1	3.0	1006	320	K45/1
5.	Schizodiacrodium sp. B	M3	20	1	3.0	1010	431	K33/4
6.	Peteinosphaeridium sp. C	M3	20	1	3.0	1000	353	J41/4
7.	Peteinosphaeridium lepton sp. nov. (Holotype)	M3	20	1	3.0	1054	395	P37/1
8.	Peteinosphaeridium hymenoferum (Eisenack, 1938) Eisenack, 1969	M3	20	1	0	1016	302	L47/1
9.	?Multiplicisphaeridium maroquense Cramer et al., 1974a	M3	20	1	3.0	985	419	H34/2
10.	Polygonium gracile Vavrdova, 1966 emend.	M3	20	1	3.0	1015	467	L30/1
11.	Baltisphaeridium? sp. E	M3	20	1	3.0	1008	500	K26/2
12.	Baltisphaeridium? sp. C	M3	20	1	3.0	1018	353	L41/4

PLATE 15

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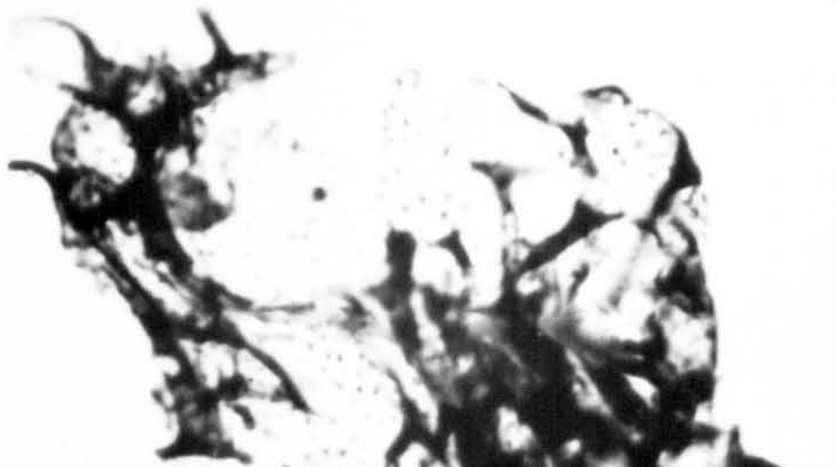

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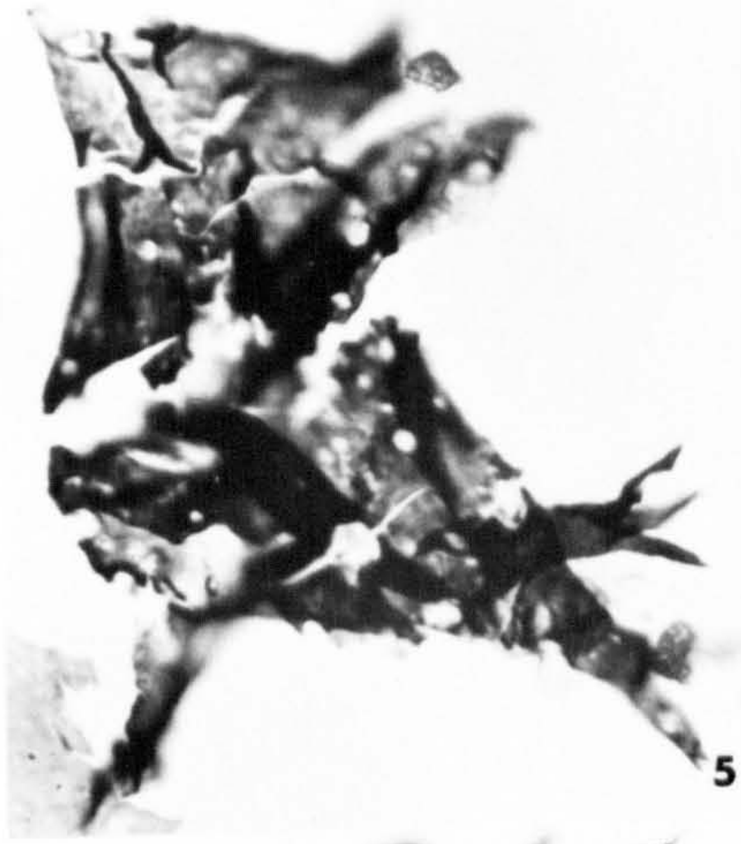

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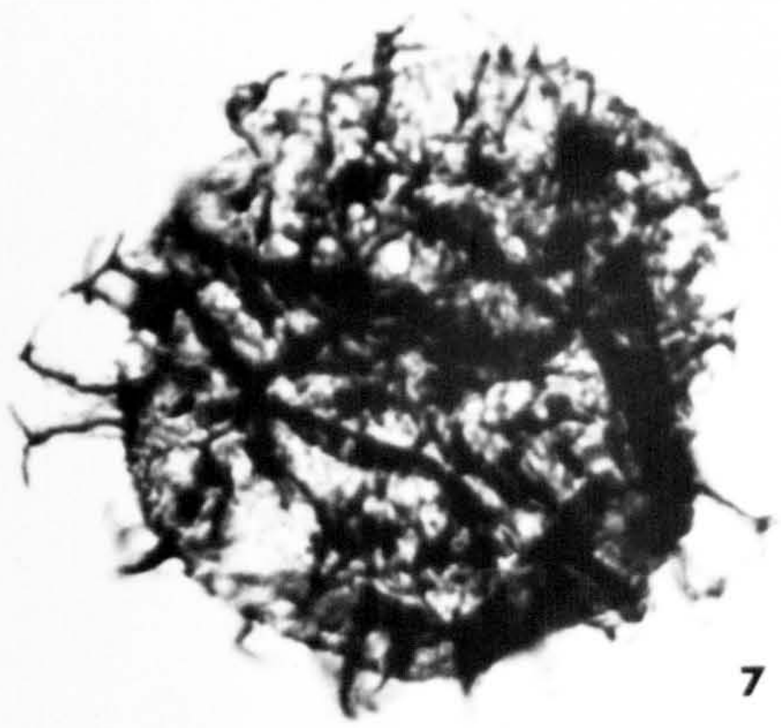

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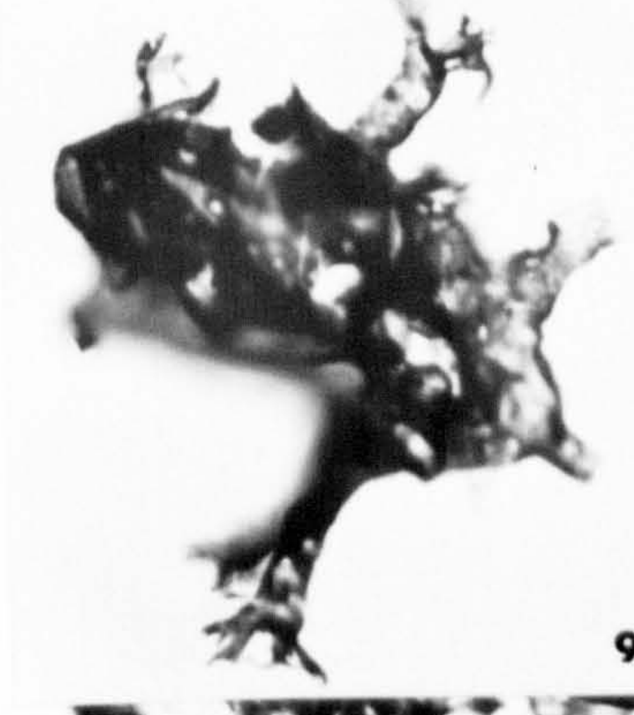

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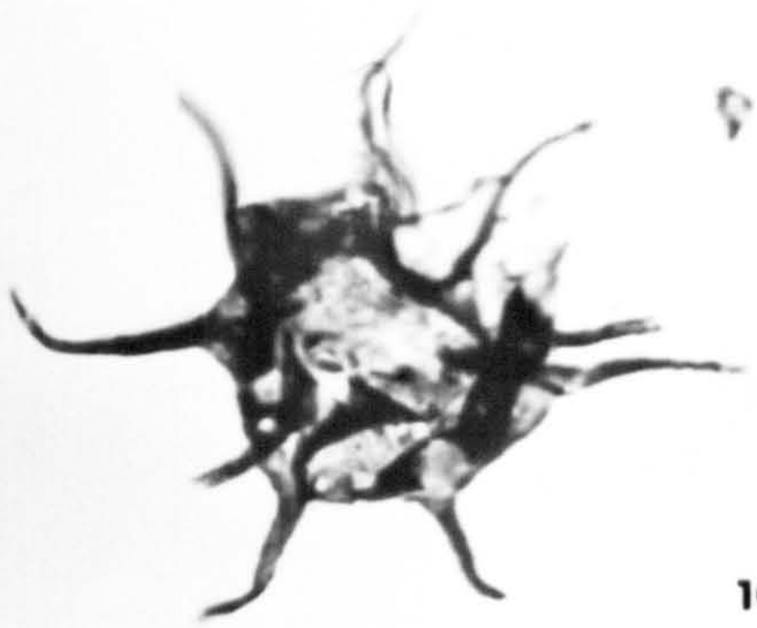

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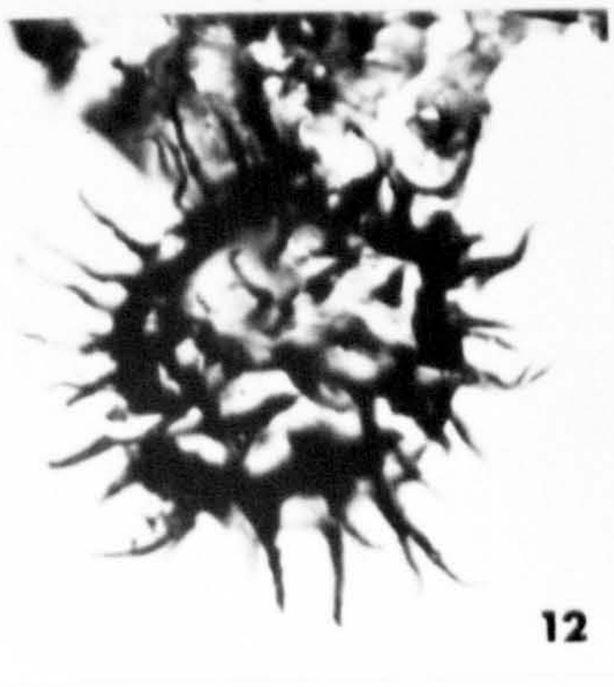

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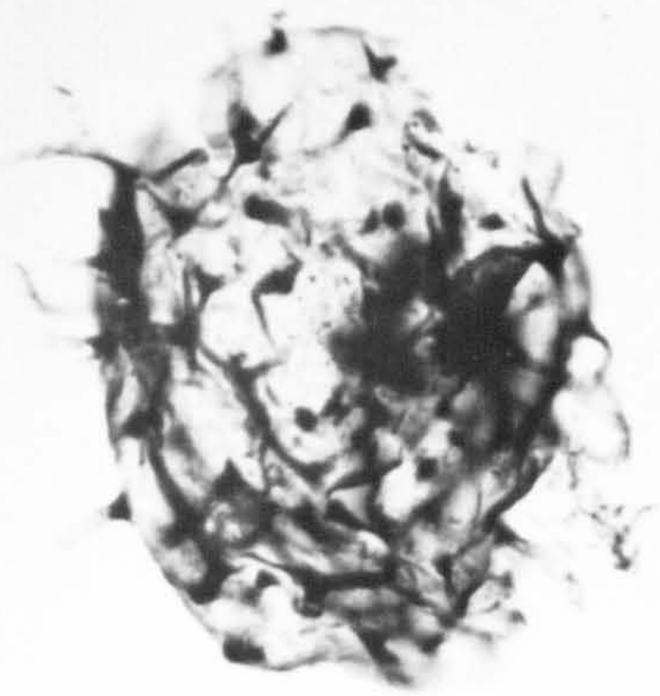
PLATE 16

Microfloral assemblage from Menai, Bangor, (Lower Arenig)

1.	Baltisphaeridium sp.	M3	20	1	3.0	944 436	C33/3
2.	Baltisphaera sp.	M3	20	1	3.0	1072 350	R42/1
3.	Micrhystridium subtile sp. nov.	M3	<20	1	0.75	1068 424	Q34/3
4.	Micrhystridium sp. C	M3	<20	1	0.75	1026 448	M31/2
5.	?Veryhachium minutum Downie, 1958	M3	<20	1	0.75	1047 398	037/3
6.	Striatotheca rarirrugulatum (Cramer et al., 1974b) Eisenack et al., 1976	M3	<20	1	0.75	973 367	F40/3
7.	S. rarirrugulatum (Cramer et al., 1974b) Eisenack et al., 1976	M3	<20	1	0.75	1103 350	U41/2
8.	Coryphidium bohemicum Vavrdova, 1972	M3	<20	1	0.75	1060 297	P47/4
9.	Elektoriskos? sp. A	M3	<20	1	0.75	1020 471	L29/4
10.	Micrhystridium cleae Martin, 1972	M3	<20	1	0.75	1028 511	P25/3
11.	M. cf. cleae Martin, 1972	M3	<20	1	0.75	1068 428	Q34/3
12.	M. cf. cleae Martin, 1972	M3	<20	1	0.75	1069 428	Q33/4
13.	Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b	M3	<20	1	0.75	1037 223	N55/3
14.	Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.	M3	<20	1	0.75	1014 506	L26/1
15.	Micrhystridium sp. B	M3	<20	1	0.75	1026 448	M31/2
16.	?Frankea hamata Burmann, 1970	M3	<20	1	0.75	1036 268	N50/4

PLATE 16



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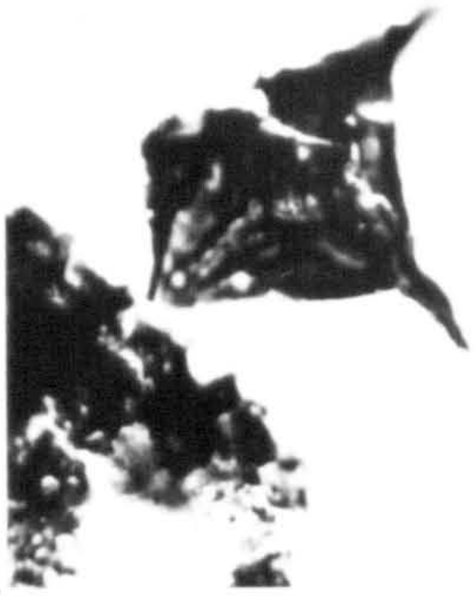

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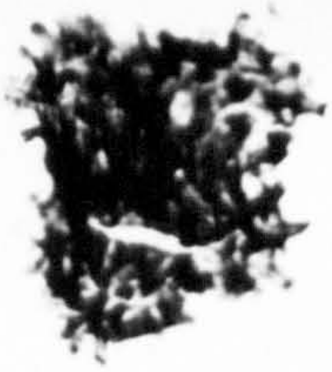

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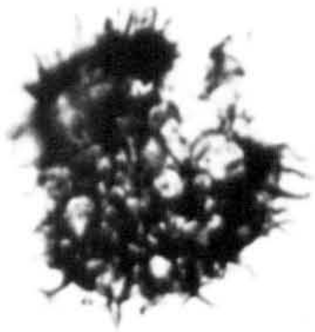

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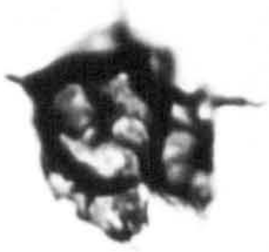

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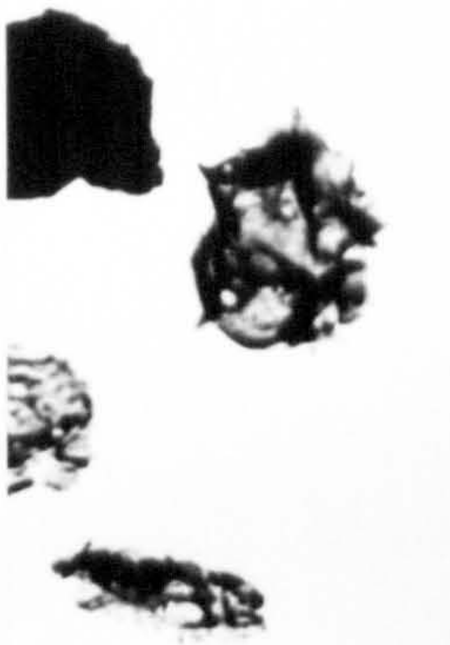

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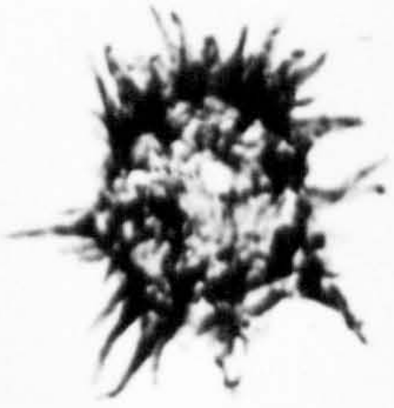

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PLATE 17

Microfloral assemblage from Hope, Shropshire, (Lower Llanvirn)

1. Astropheos celestum Martin, 1969, comb. nov.
H5 20 1 0.5 1032 306 N46/2

2. Uncinisphaera? exilis sp. nov. H5 20 1 0.5 995 390 J38/1

3. Striatotheca frequens Burmann, 1970
H5 20 1 0 1009 272 K50/3

4. Arkonia virgata Burmann, 1970 H5 20 1 0 1048 295 047/4

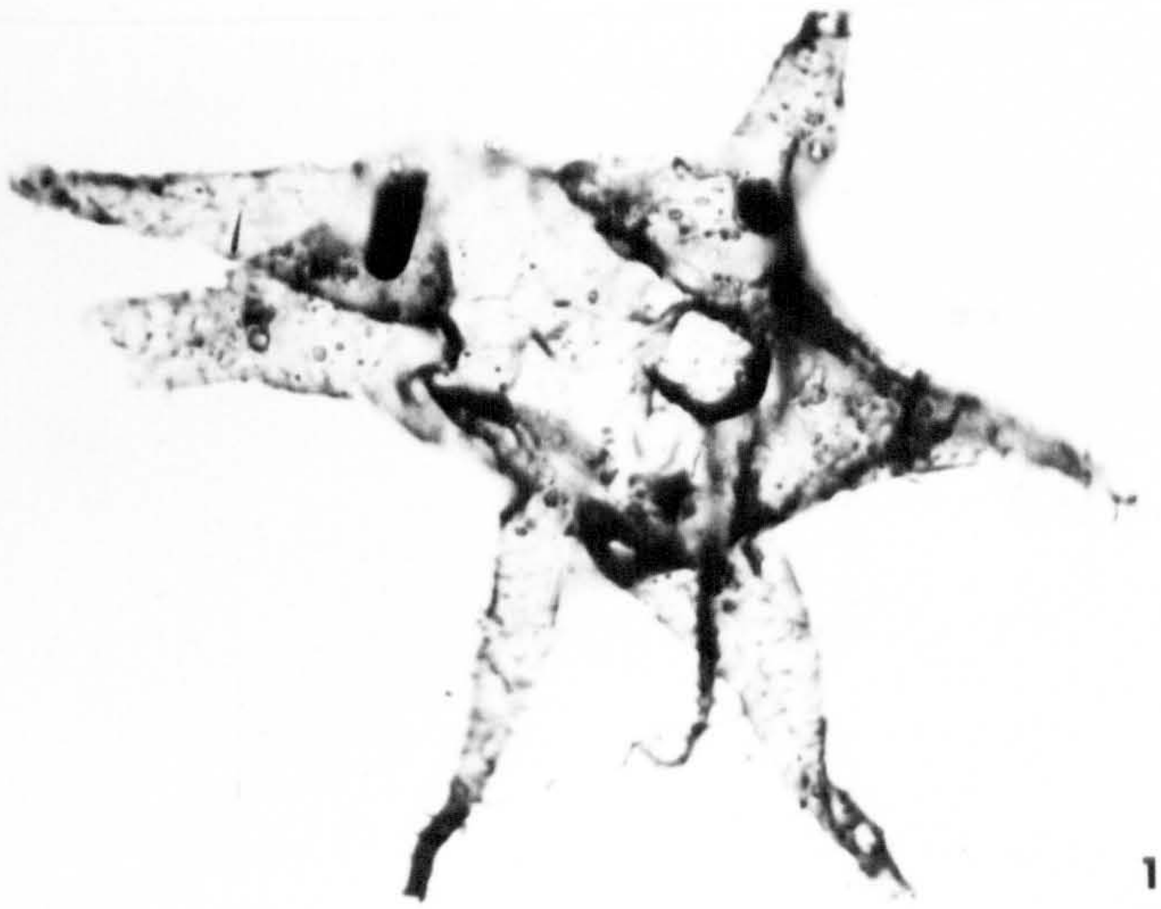
5. Veryhachium trispinosum Formgroup, Cramer, 1964b
H5 20 1 0.5 994 389 J38/1

6. V. trispinosum Formgroup, Cramer, 1964
H5 20 1 0 1022 399 M37/1

7. Tectitheca contracta Burmann, 1968
H5 20 1 0 1103 415 U35/1

8. Striatotheca quieta (Martin, 1969) Rauscher, 1974
H5 20 1 0.5 1021 482 L28/3

PLATE 17



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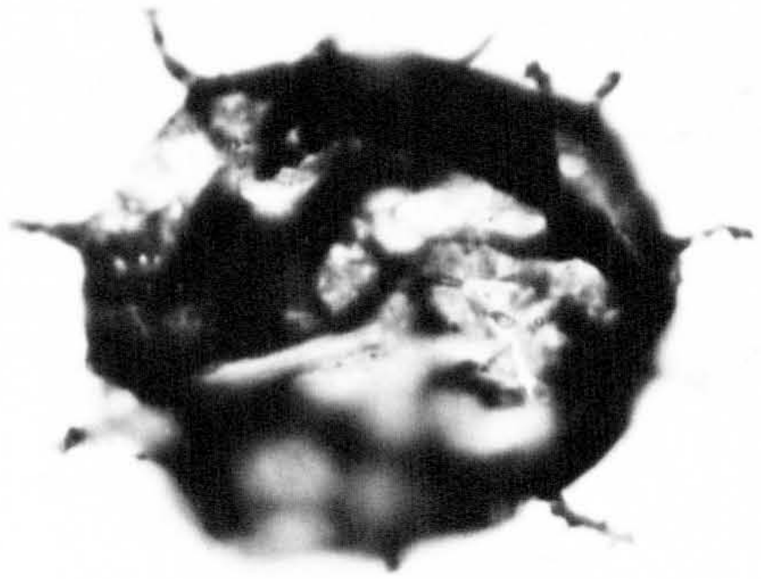

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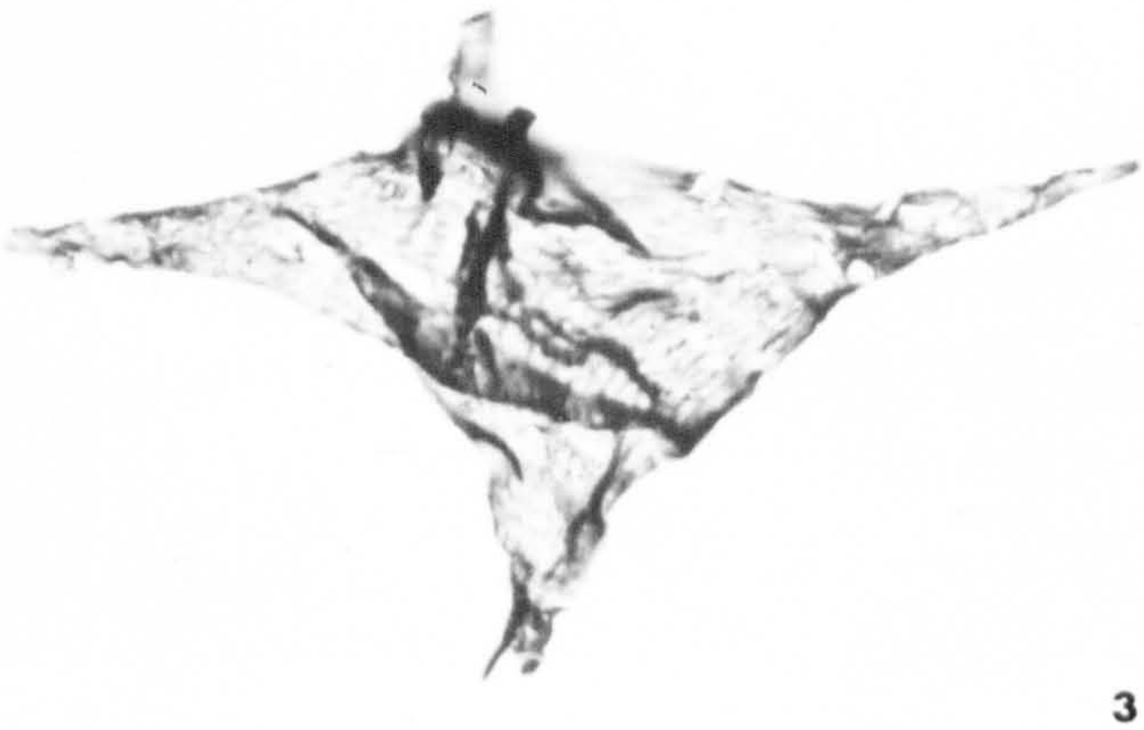

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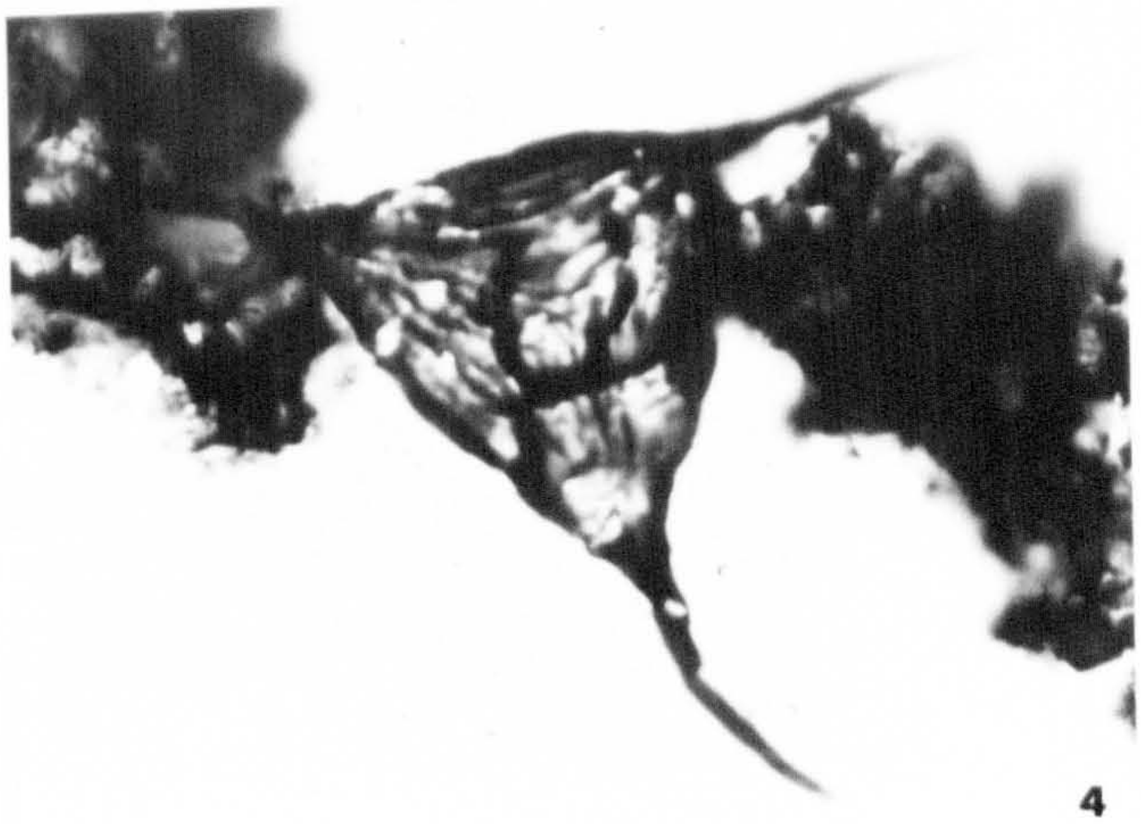

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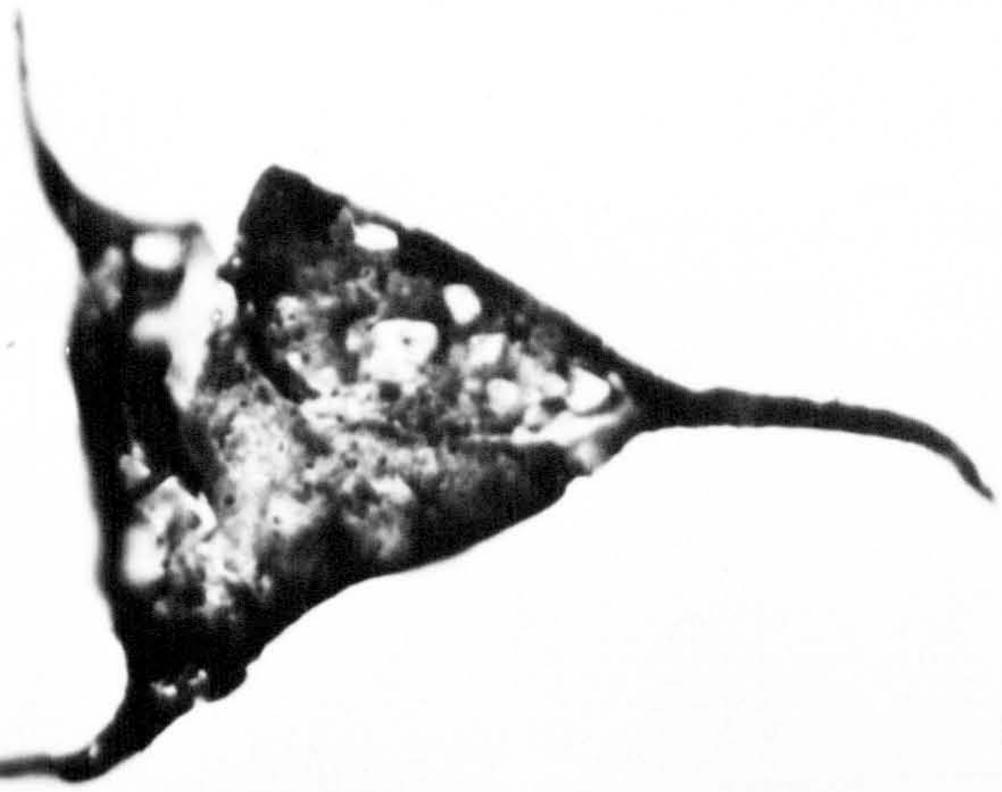

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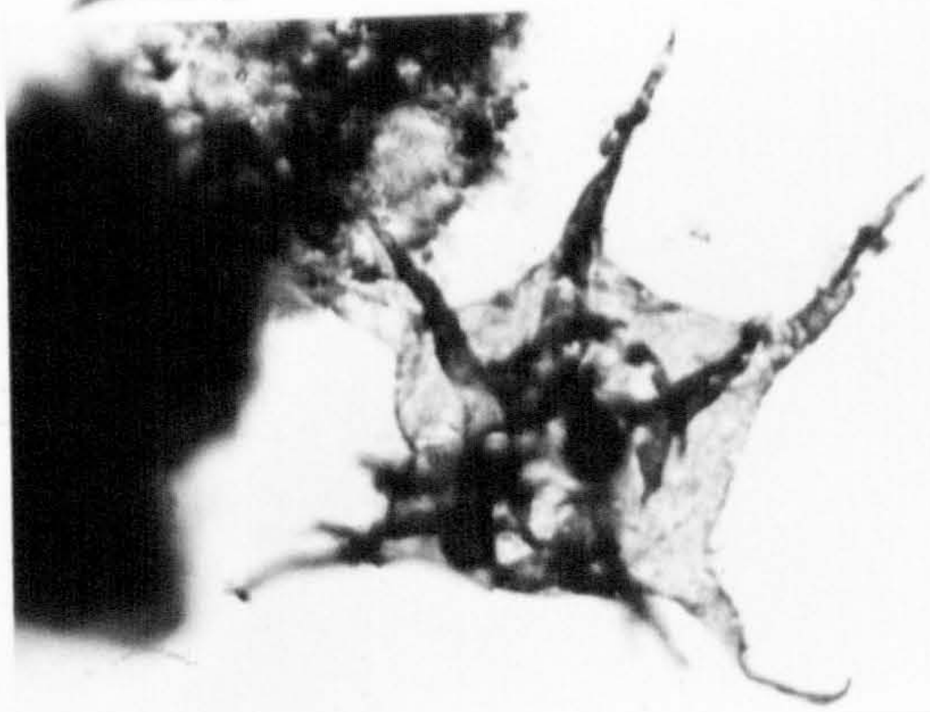

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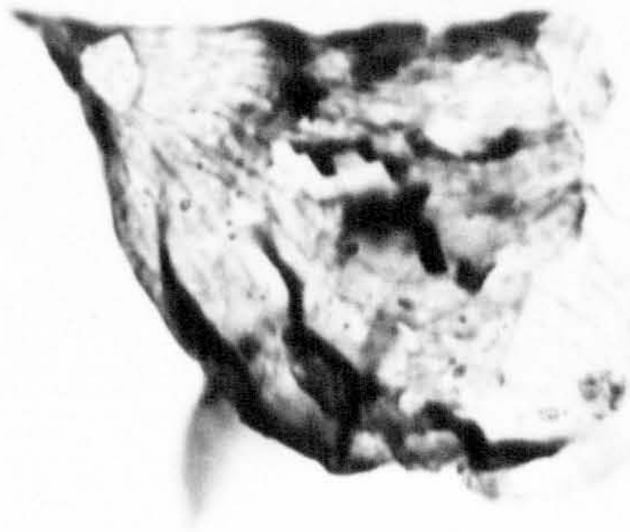

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Microfloral assemblage from Hope, Shropshire, (Lower Llanvirn)

1. Multiplicisphaeridium sp. H5 20 1 0.5 997 383 J38/2

2. Multiplicisphaeridium sp. H5 <20 3 0 1038 506 N25/4

3. Culcitispina brevis gen. & sp. nov.
H5 20 1 0 1018 303 L46/4

4. Baltisphaeridium longispinosum (Eisenack, 1931) Eisenack, 1959 forma longispinosum
H5 20 1 0 1025 366 M40/1

5. Baltisphaera sp. (see also Pl. 19, fig. 8)
H5 20 1 0.5 987 282 H49/3

6. Baltisphaeridium sp. H5 20 1 0.5 1017 233 L54/3

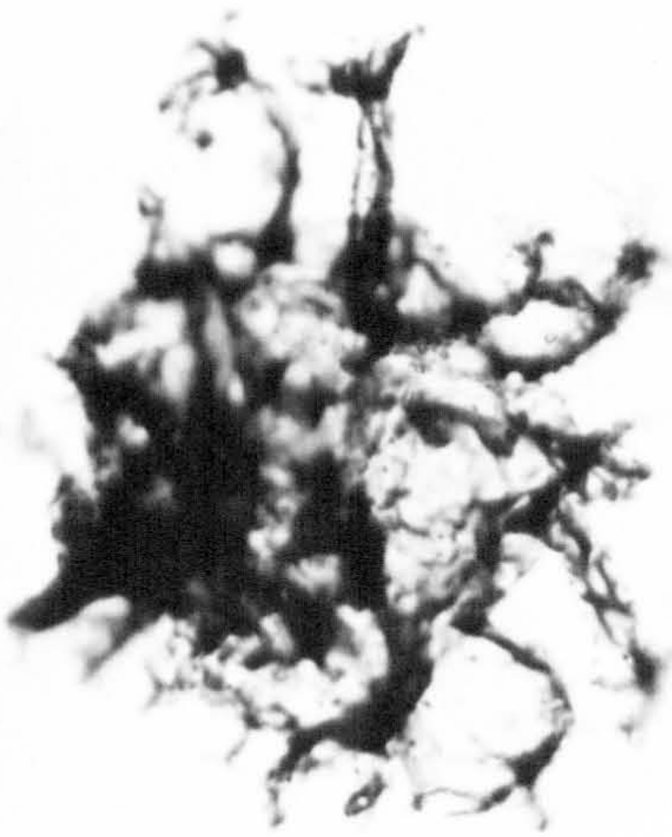
7. ?Baltisphaeridium filosum Kjellström, 1971a
H5 20 1 0.5 1028 331 M44/3

8. Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b
H5 <20 3 0 1028 496 M27/1

9. ?Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.
H5 <20 3 0 1054 414 P35/1

10. Acanthodiacrodium sp. F H5 <20 3 0 1005 475 K29/1

PLATE 18



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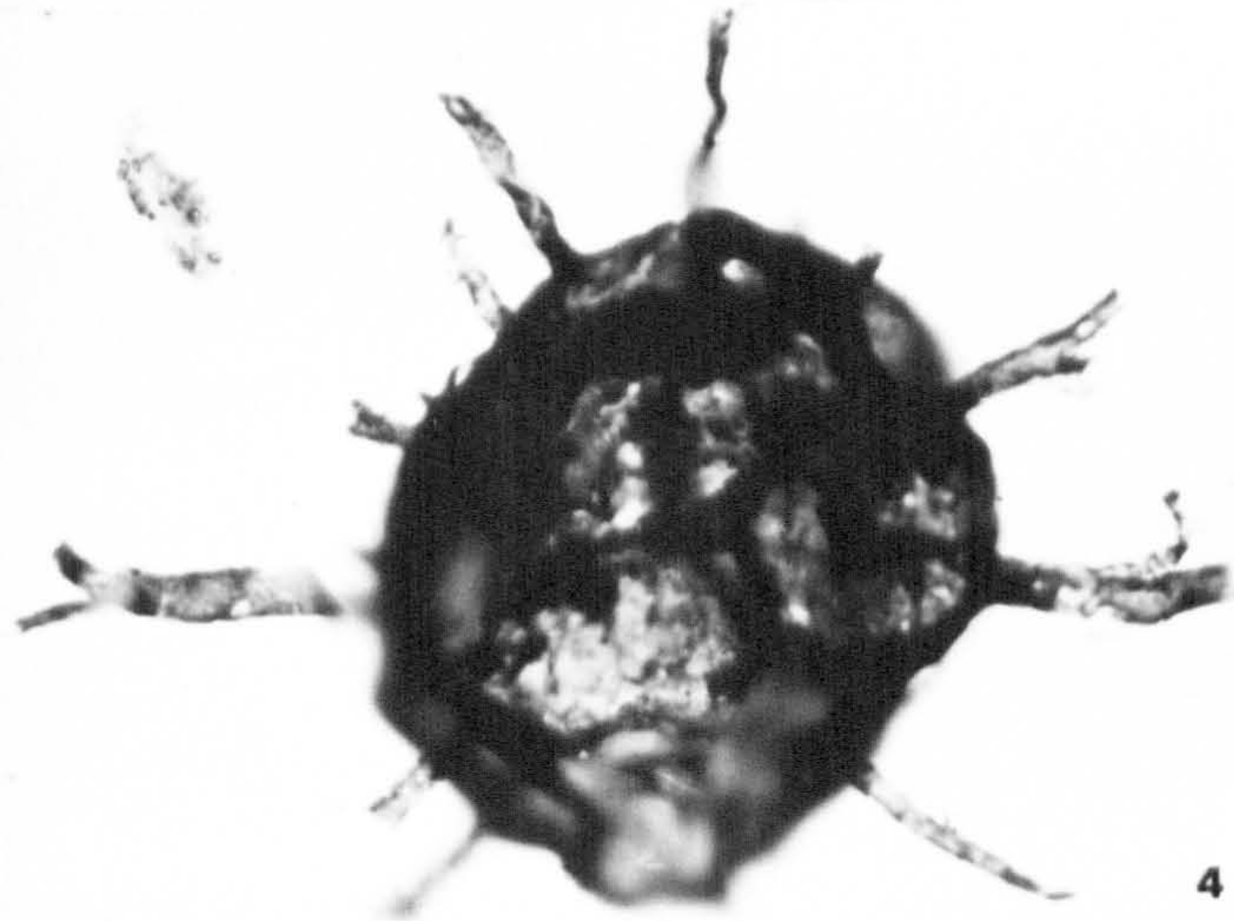

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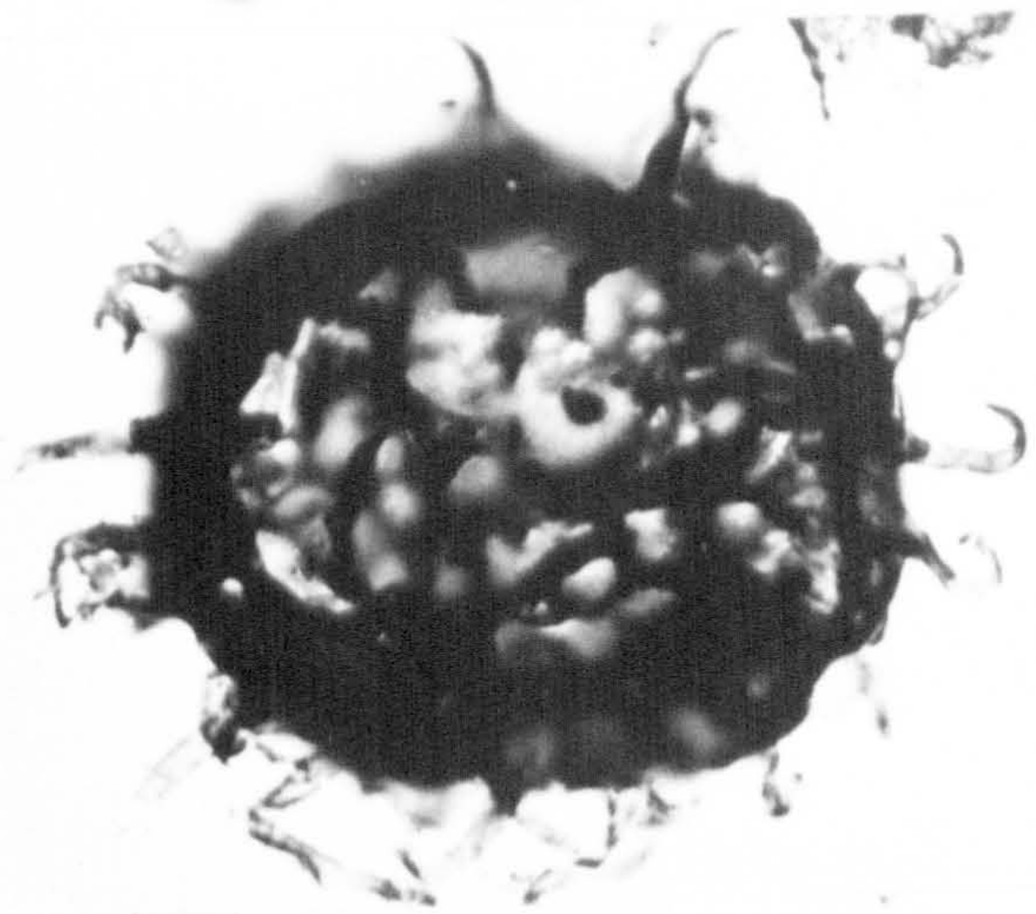

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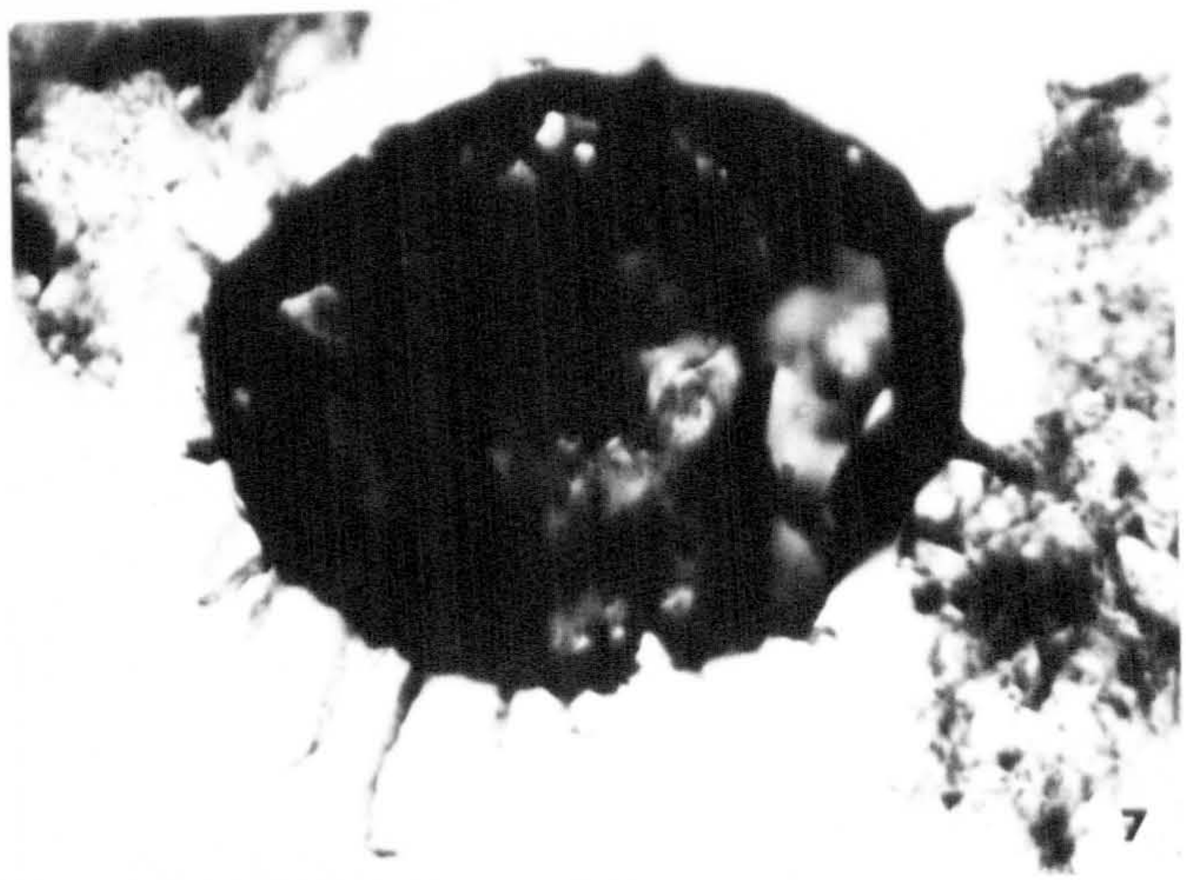

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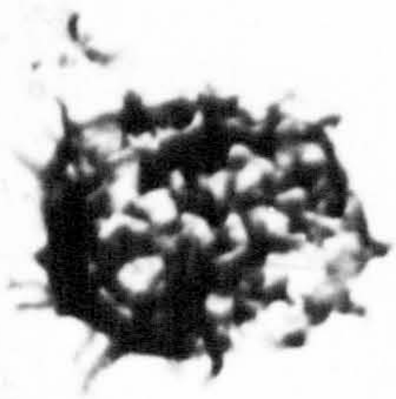

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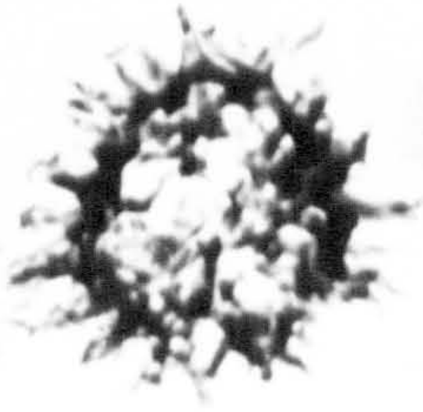

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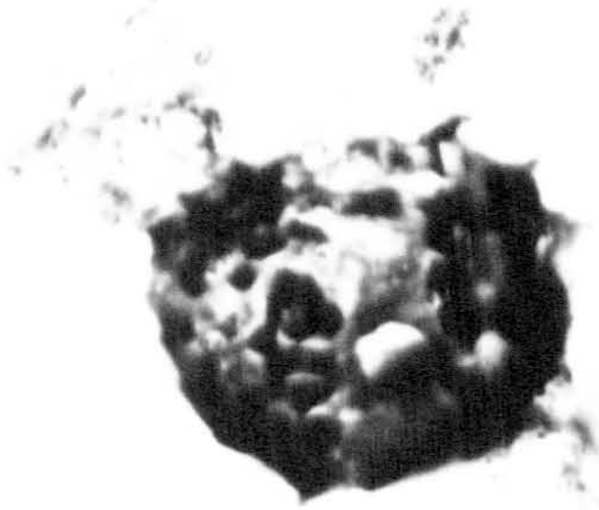

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PLATE 19

Microfloral assemblage from Hope, Shropshire, (Lower Llanvirn)

1. Baltisphaeridium cf. constrictum Kjellström, 1971a
H5 20 1 0.5 1047 321 045/3

2. Multiplicisphaeridium sp. H5 20 1 0 980 449 G31/4

3. Baltisphaeridium diversum sp. nov.
H5 20 1 0.5 995 505 J26/1

4. Elektoriskos? sp. A H5 <20 3 0 1026 518 M24/2

5. Arkonia tenuata Burmann, 1970 H5 <20 3 0 1060 372 P39/4

6. A. tenuata Burmann, 1970 H5 <20 3 0 1064 342 Q42/2

7. Astropheos celestum Martin, 1969 comb. nov. (x 500 See also Pl. 17, fig. 1)
H5 20 1 0.5 1032 306 N46/2

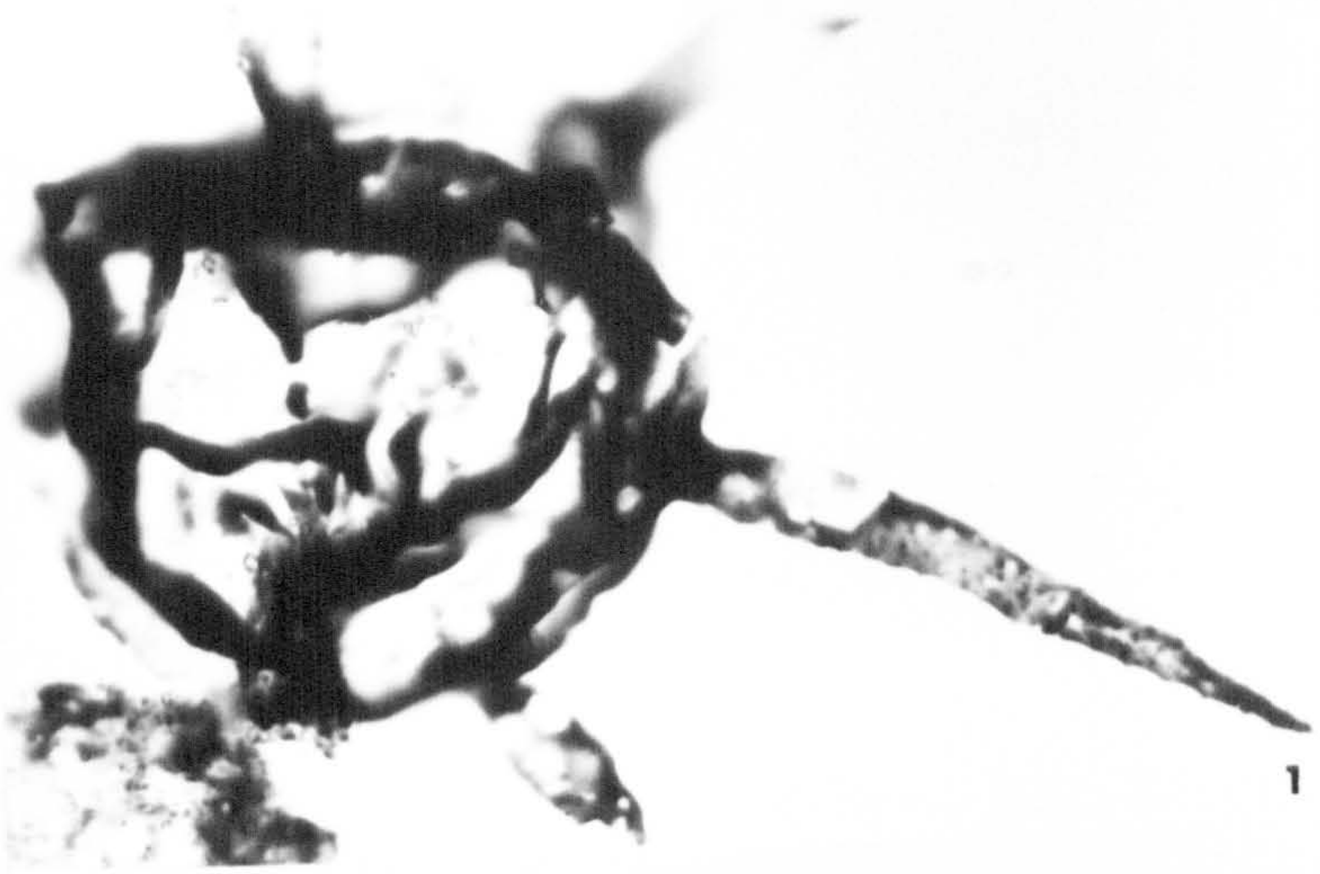
8. Baltisphaera sp. (x 500 See also Pl. 18, fig. 5)
H5 20 1 0.5 987 282 H49/3

9. B. ternata Burmann, 1970 (x 500) H5 20 1 0 952 413 D35/4

10. Baltisphaeridium sp. (x 500) H5 20 1 0.5 983 355 G41/4

11. Uncinisphaera? sp. A (x 500) H5 20 1 0.5 1005 428 K34/1

PLATE 19



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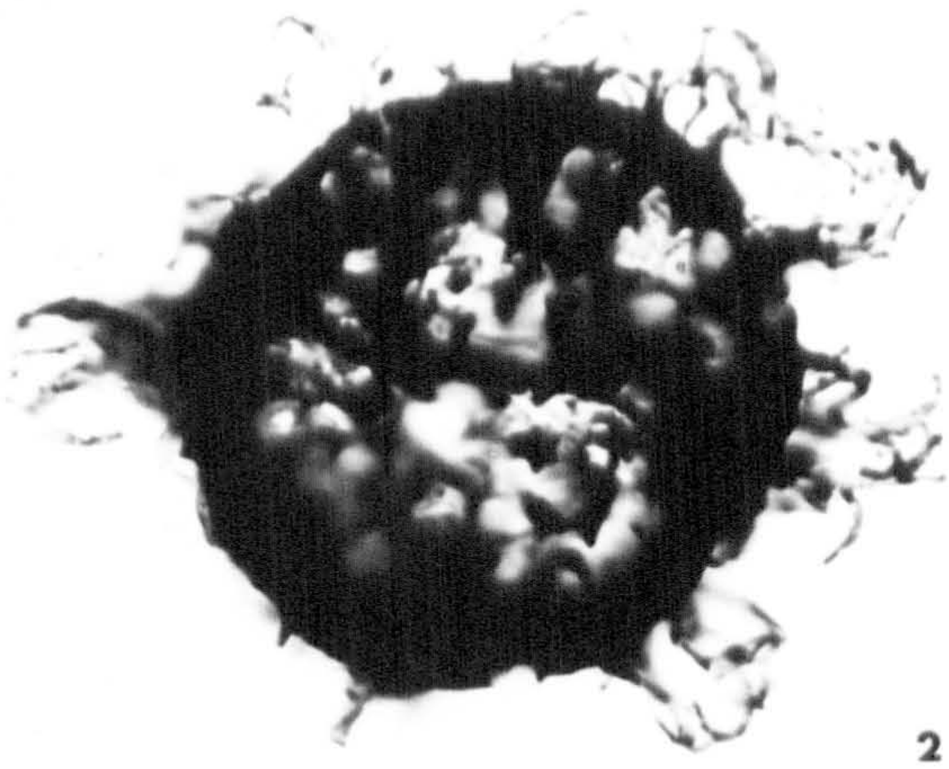

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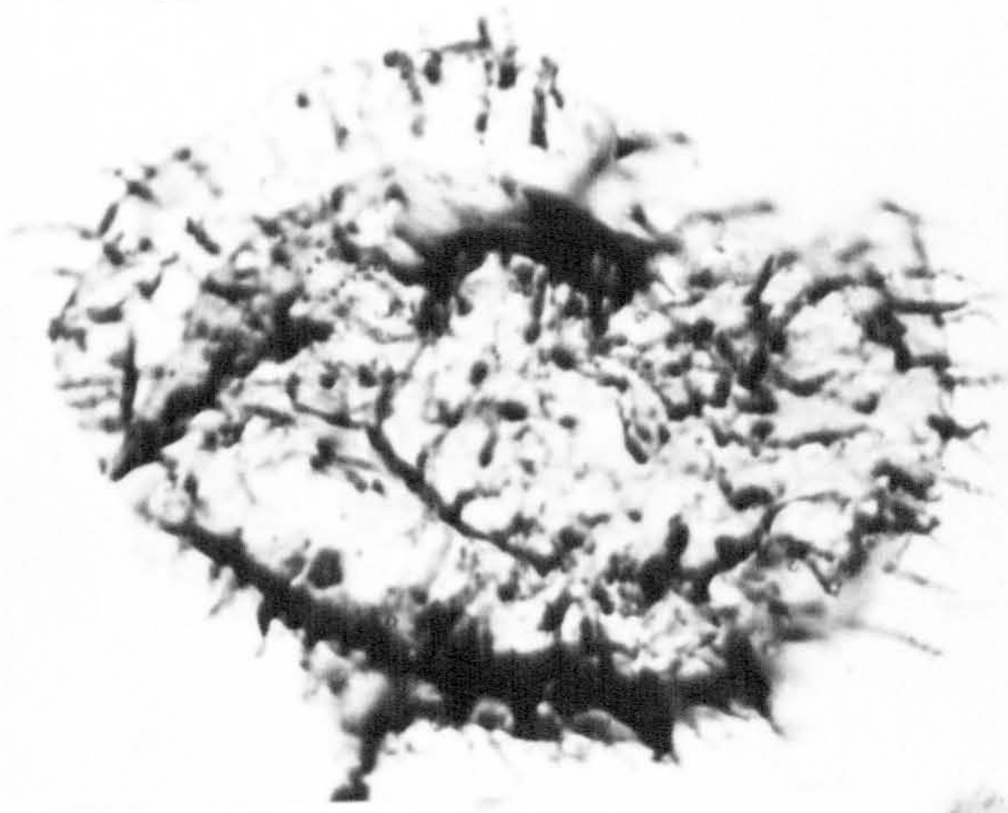

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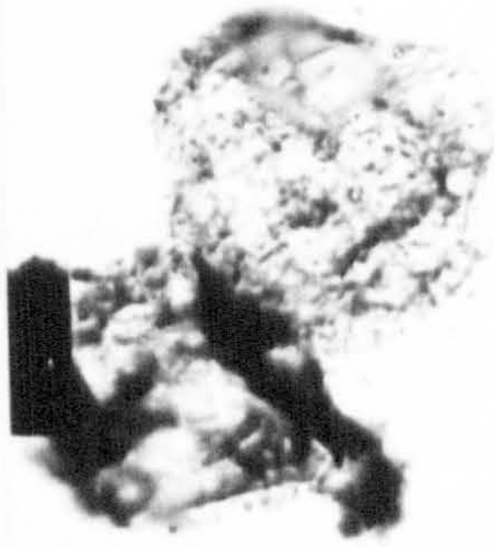

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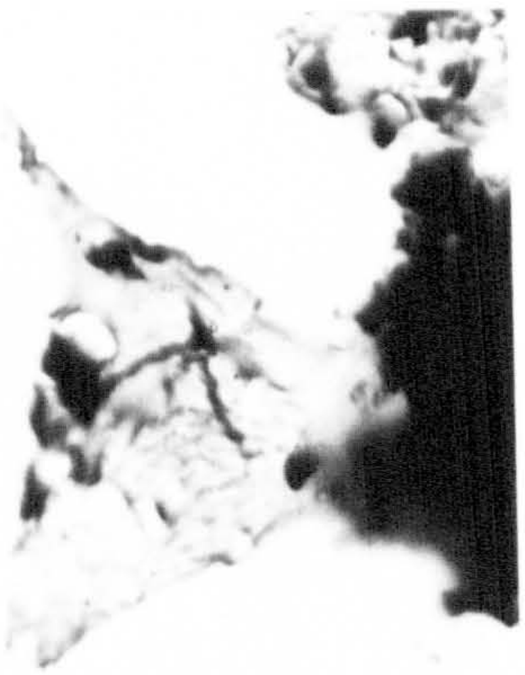

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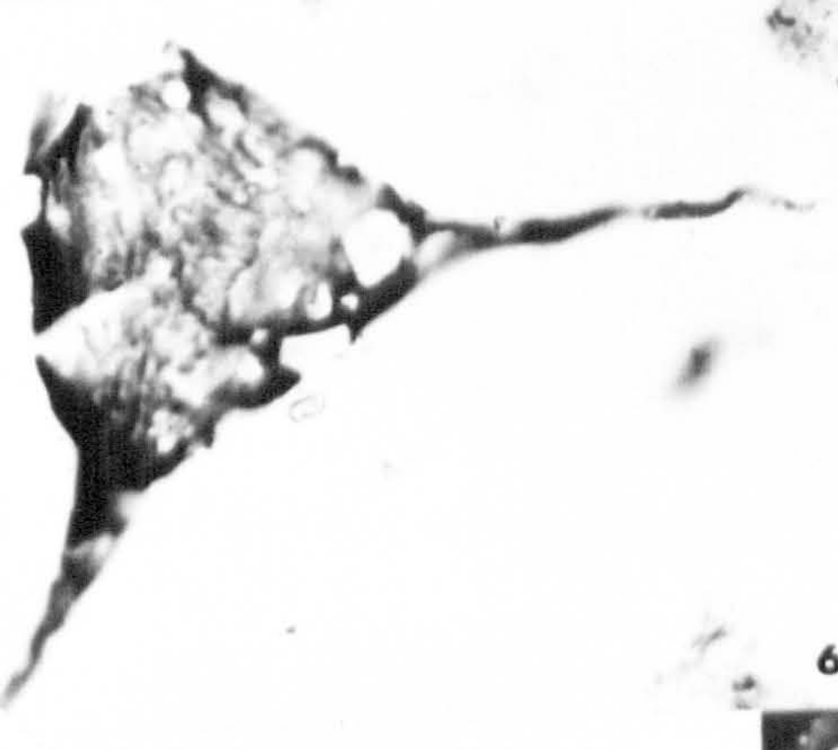

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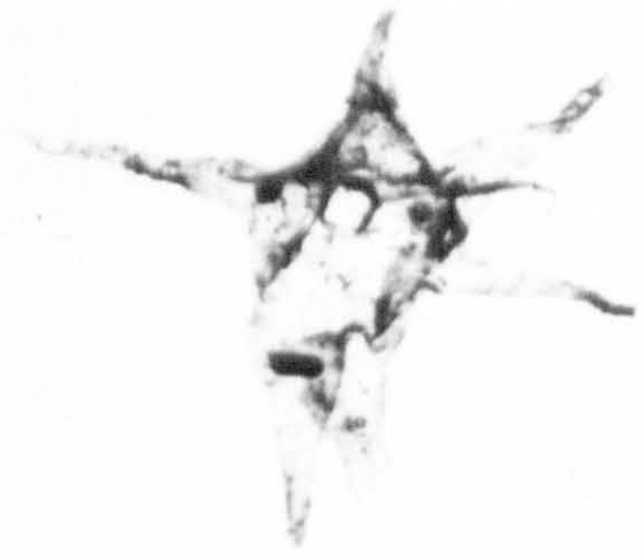

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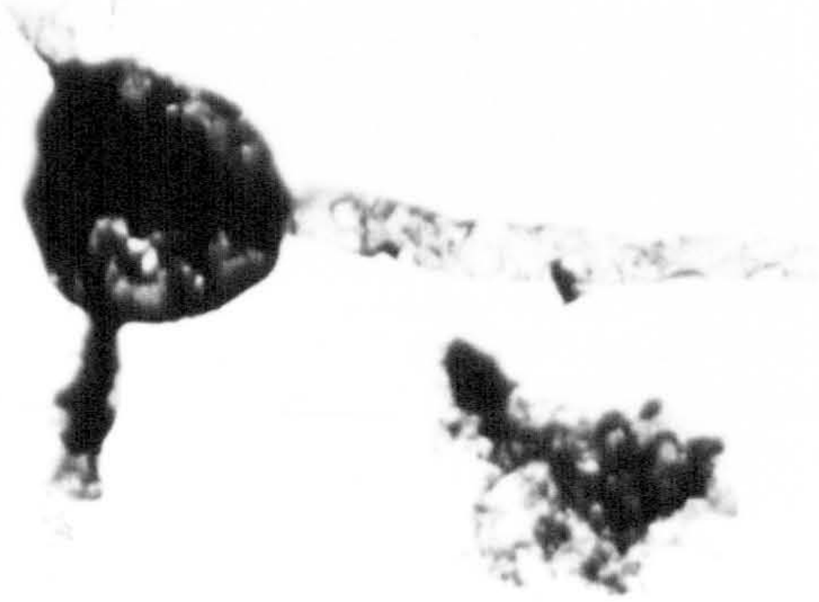

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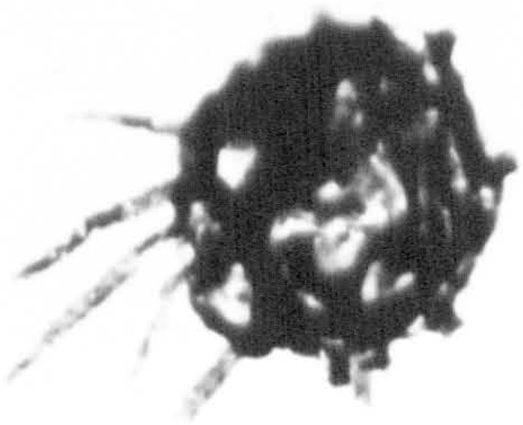

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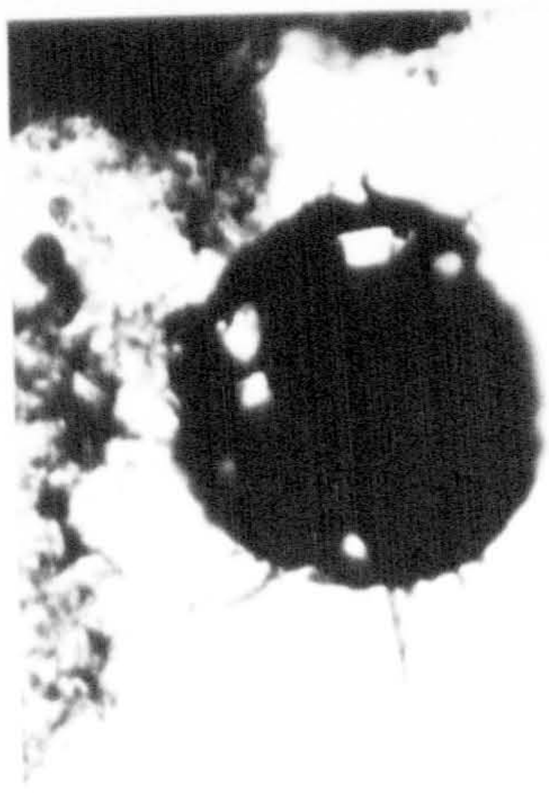

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PLATE 20

Microfloral assemblage from Whitsburn, Shropshire, (Lower Llanvirn)

1.	Frankea longiuscula Burmann, 1970	W1	20	1	0.2	980	336	G43/4
2.	Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b	W1	<20	3	0.1	1116	520	V24/3
3.	Leiofusa sp. A	W1	<20	1	0.1	1039	317	N45/3
4.	Baltisphaera ternata Burmann, 1970	W1	20	5	0.65	1010	426	K34/3
5.	Astropheos celestum Martin, 1969 comb. nov.	W1	20	2	0.2	1004	419	K34/2
6.	Arkonia tenuata Burmann, 1970	W1	20	1	0.2	983	403	H36/2
7.	Peteinosphaeridium aequifurcatum Kjellström, 1971a	W1	20	3	0.65	1045	368	040/1
8.	Uncinisphaera? sp. A	W1	20	3	0.65	1025	487	M27/2

PLATE 20

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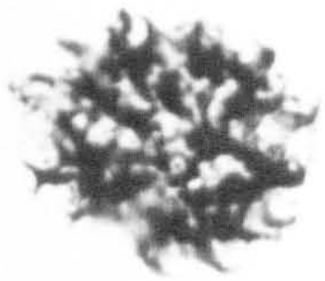

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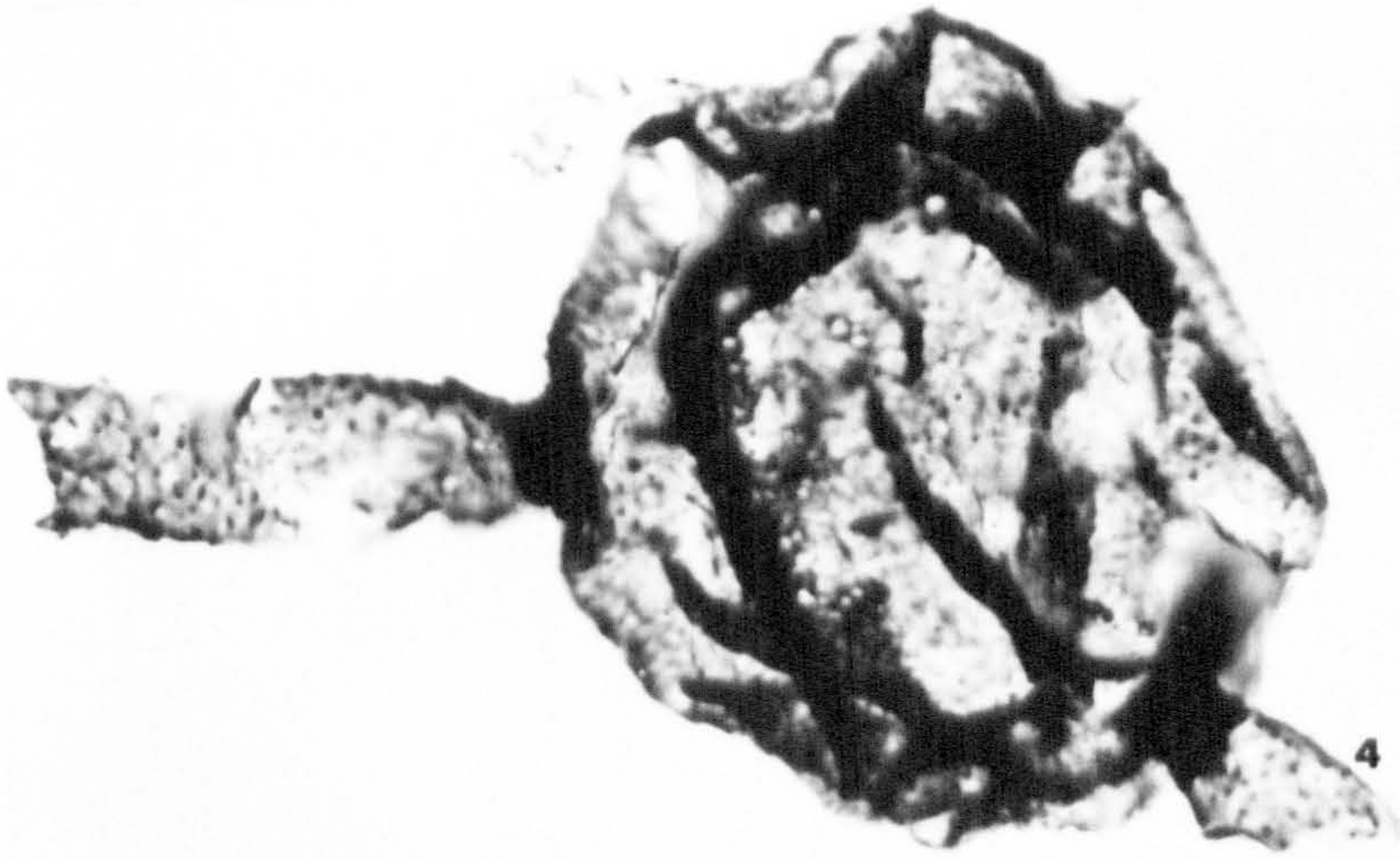

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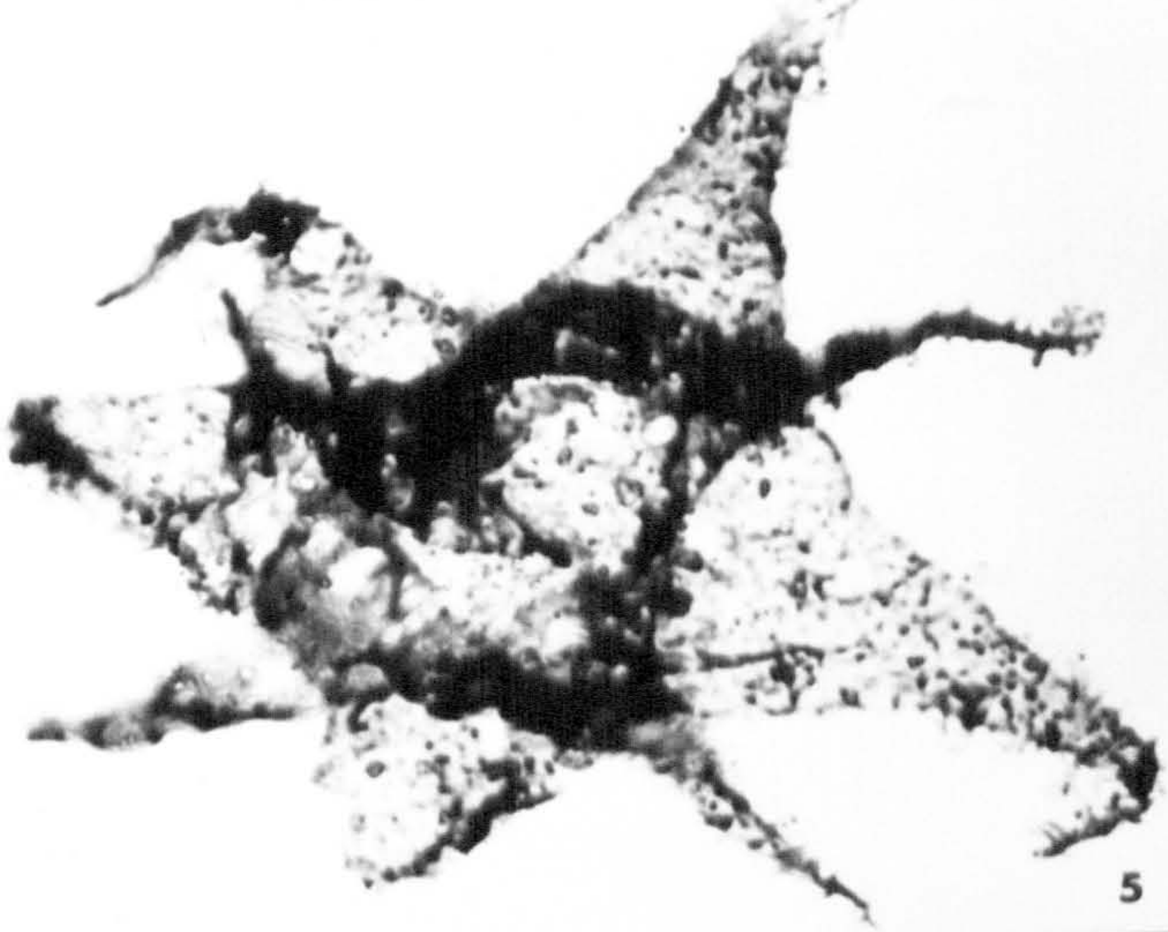

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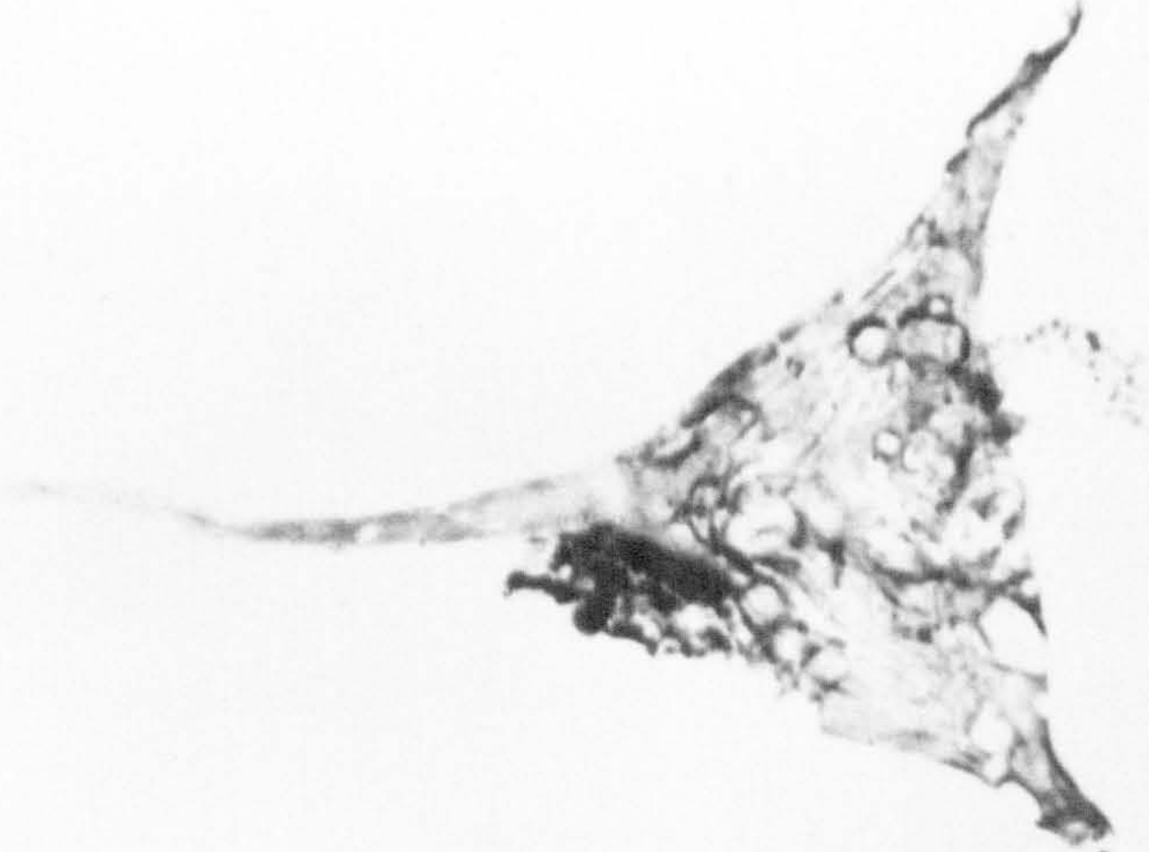

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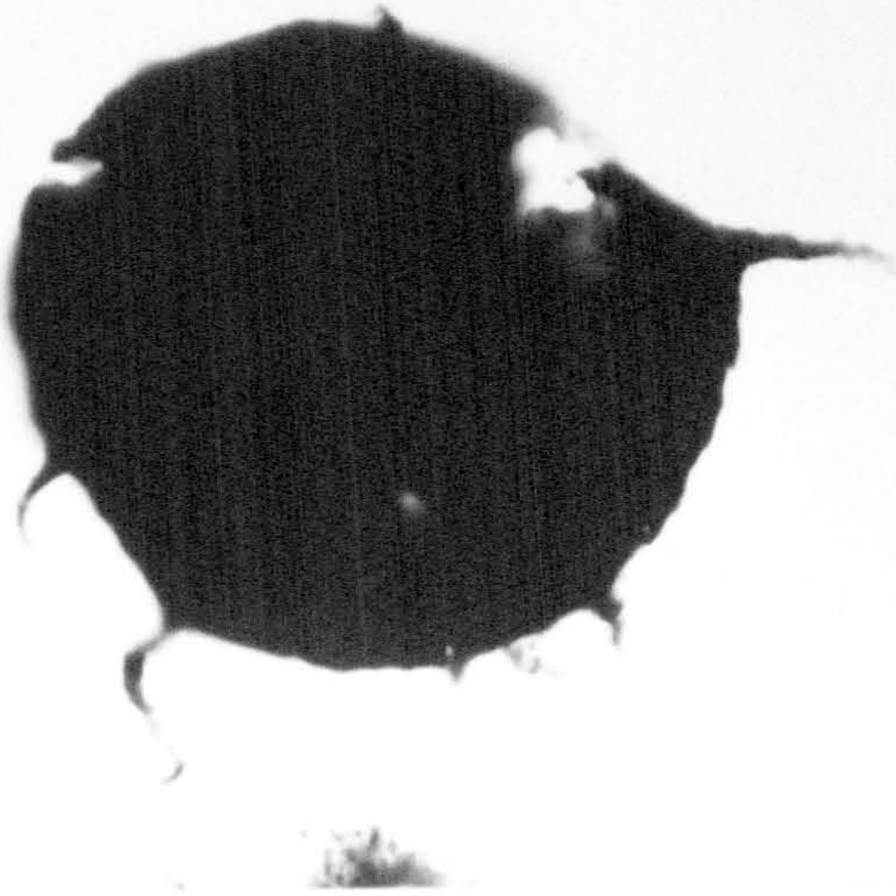

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PLATE 21

Microfloral assemblage from Whitsburn, Shropshire,(Lower Llanvirn)

1. Peteinosphaeridium heteromorphicum Kjellström, 1971a
W1 20 5 0.65 1026 478 M28/2

2. P. velatum Kjellström, 1971a W1 20 5 0.65 1078 298 R47/3

3. Astropheos celestum Martin, 1969 comb. nov.
W1 20 3 0.65 1048 527 023/4

4. Multiplicisphaeridium maroquense Cramer et al., 1974a
W1 20 5 0.65 1090 293 T47/2

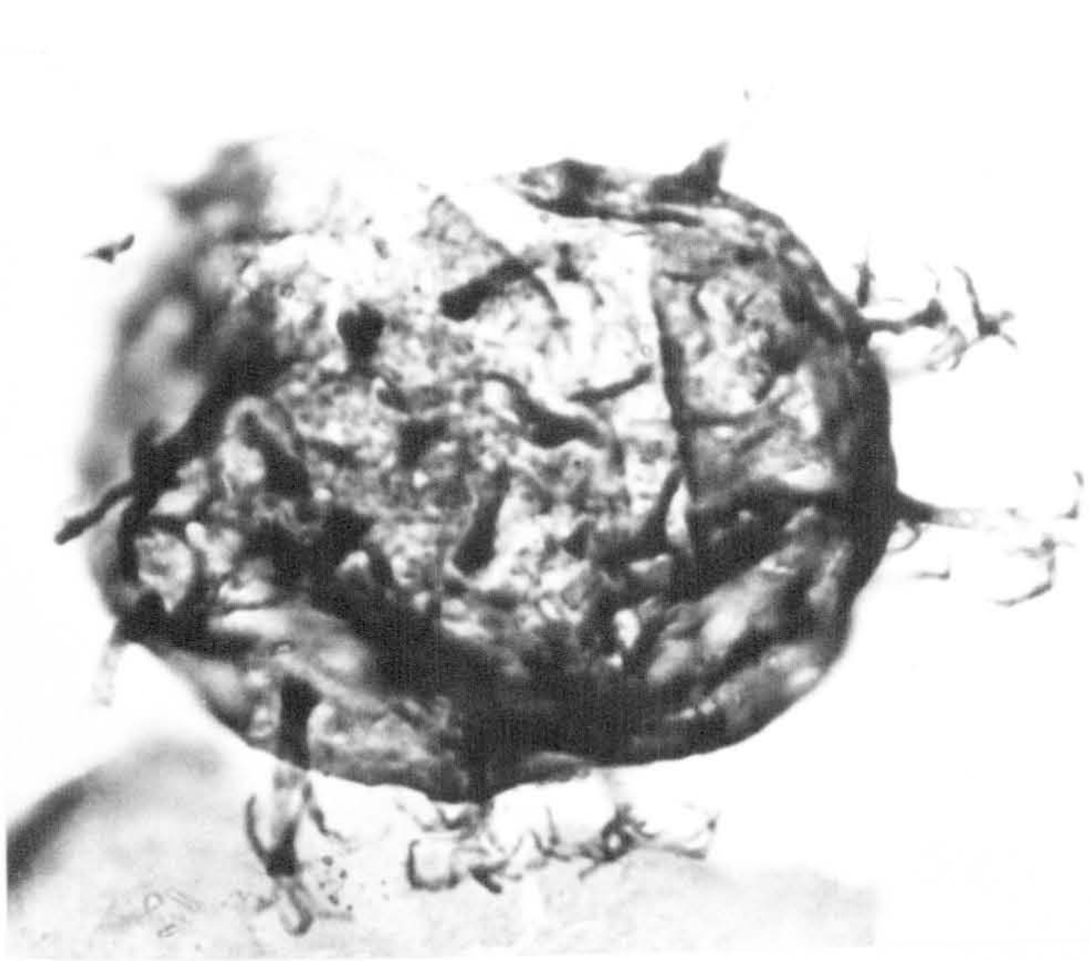
5. Culcitispina brevis gen. & sp. nov.
W1 20 3 0.65 1037 271 N50/3

6. 'Veryhachium' cf. rhomboidium Downie, 1959
W1 20 1 0.2 991 338 H43/3

7. 'Veryhachium' sp. A W1 20 5 0.65 1113 287 V48/2

8. Culcitispina brevis gen. & sp. nov. (Holotype)
W1 20 2 0.2 989 493 H27/3

PLATE 21



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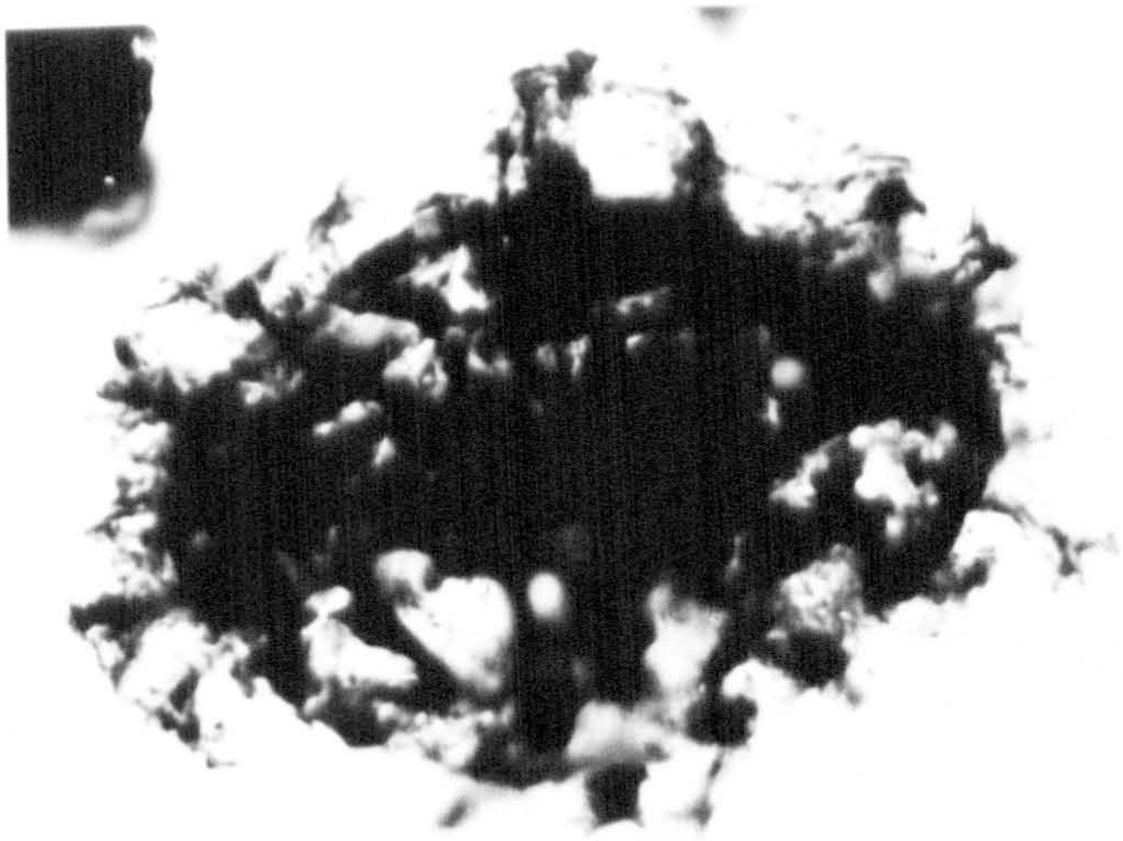

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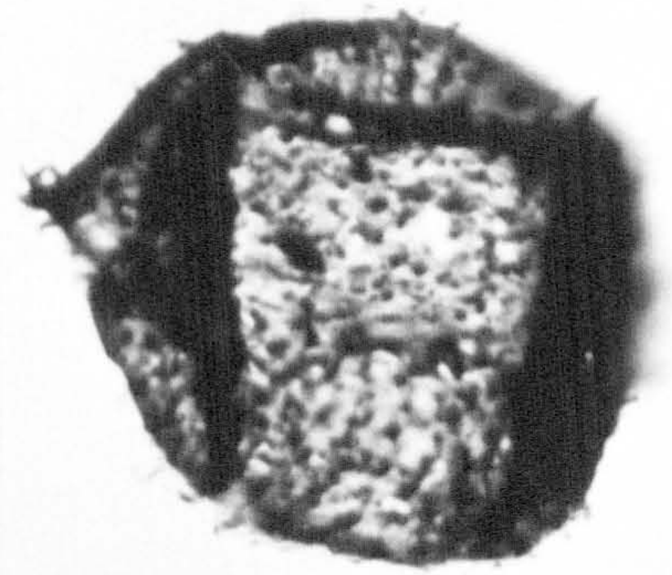

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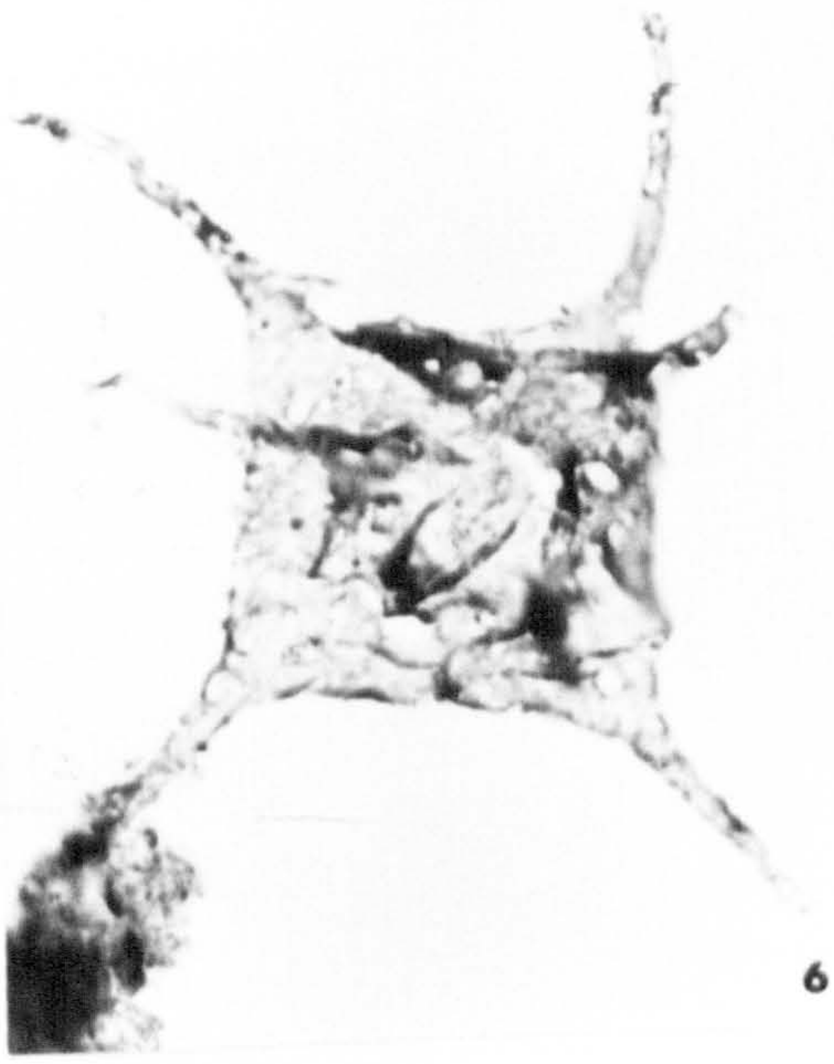

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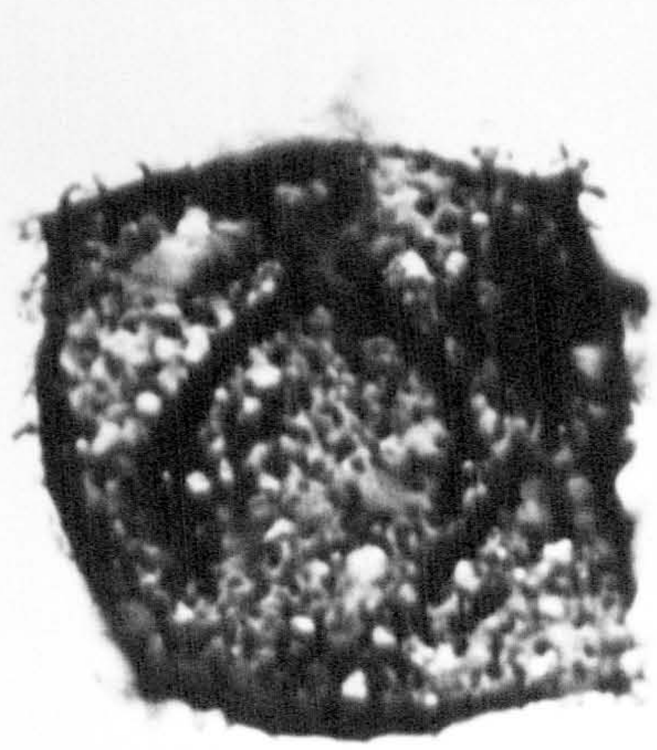

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PLATE 22

Microfloral assemblage from Whitsburn, Shropshire, (Lower Llanvirn)

1. Culcitispina brevis gen. & sp. nov.
W1 20 2 0.2 996 408 J36/1

2. Leiofusa sp. (x 250)
W1 53 2 0.2 1097 279 U49/1

3. Tectitheca contracta Burmann, 1968
W1 20 1 0.2 982 298 G47/3

4. Multiplicisphaeridium sp. W1 20 5 0.65 1106 429 U33/4

5. Baltisphaeridium sp. B (x 500)
W1 53 1 0.2 965 499 F26/2

6. Baltisphaera ternata Burmann, 1970 (x 500)
W1 20 3 0.65 1073 295 R47/2

7. Pirea? sp. B W1 <20 3 0.1 1119 340 V43/3

8. Veryhachium trispinosum Formgroup, Cramer, 1964b
W1 53 2 0.2 963 349 E42/3

9. Pirea sp. A (x 500) W1 20 1 0.2 1061 489 Q27/2

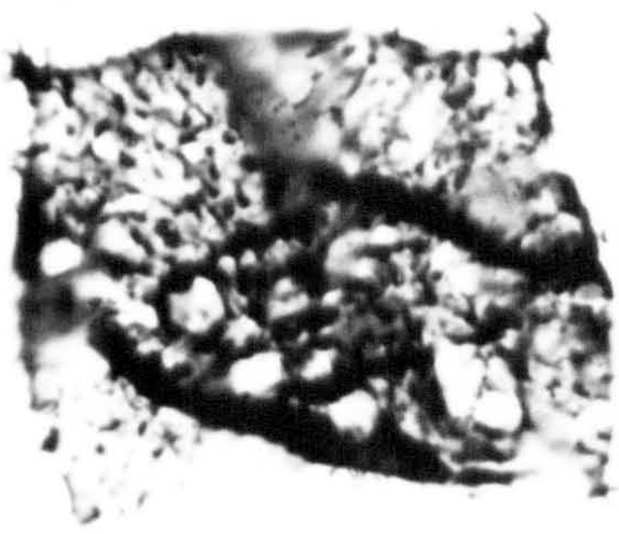
10. Frankea longiuscula Burmann, 1970 (x 500 see also Pl. 20, fig. 1)
W1 20 1 0.2 980 336 G43/4

11. ?Acanthodiacrodium duplicatum Burmann, 1970
W1 20 1 0.2 1019 406 L36/3

12. Pirea cf. dubia Vavrdova, 1972 W1 <20 1 0.1 1030 276 M49/4

13. ?Stelliferidium sp. W1 20 1 0.2 1018 459 L30/4

PLATE 22



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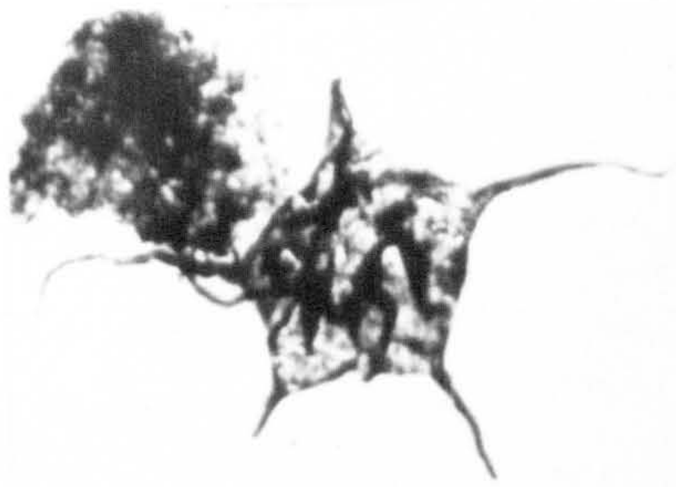

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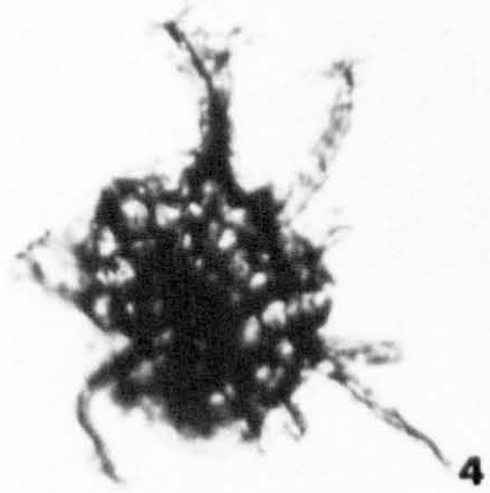

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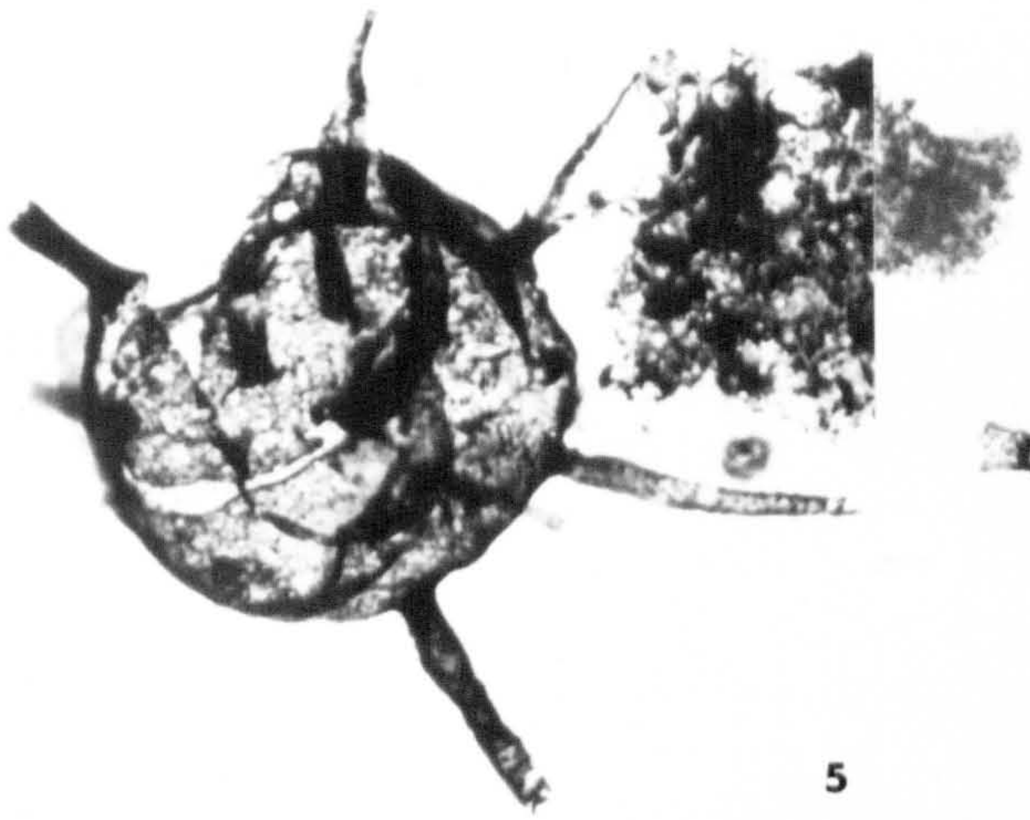

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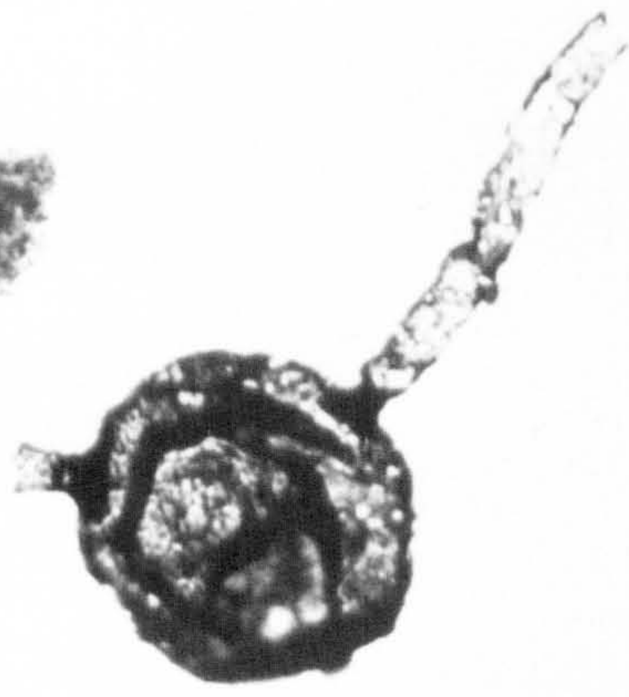

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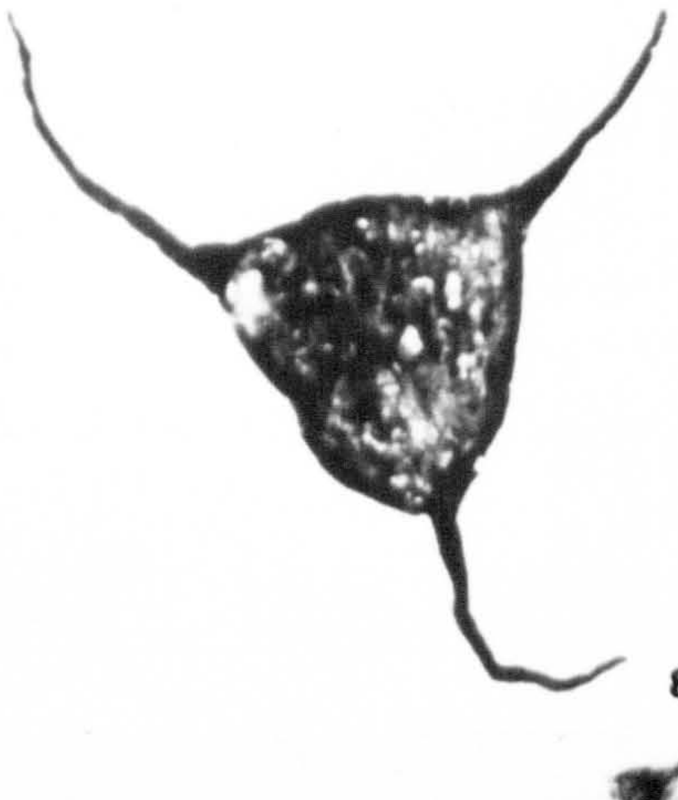

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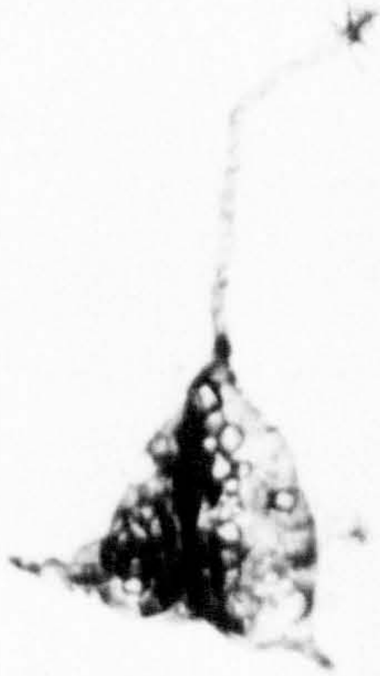

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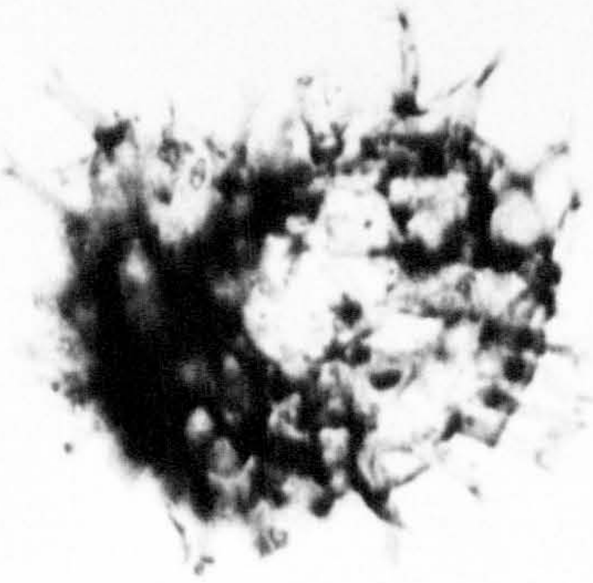

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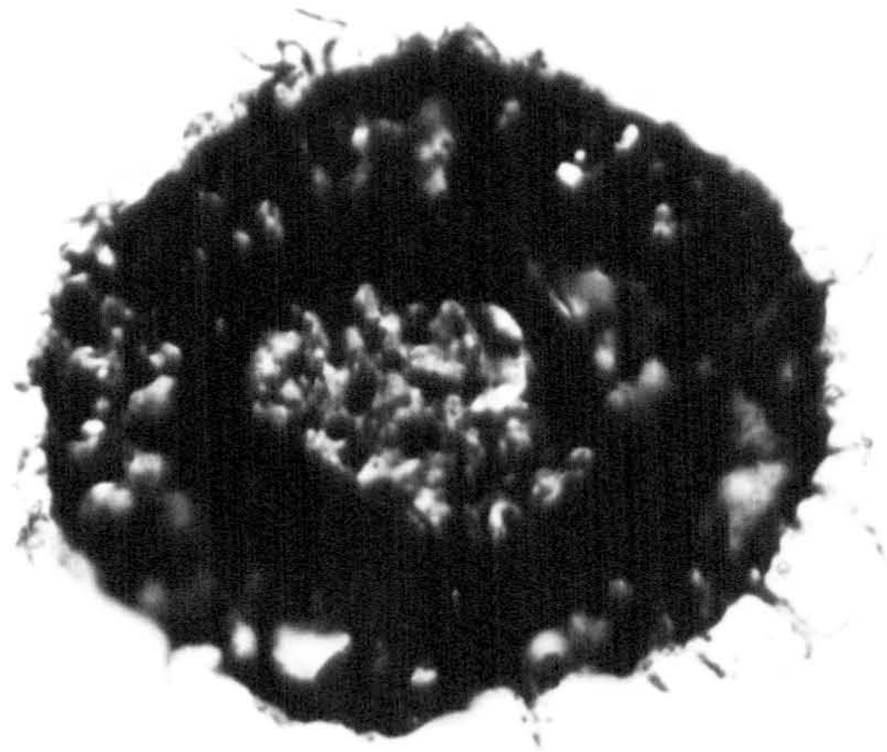
PLATE 23

Microfloral assemblage from Whitsburn, Shropshire,(Lower Llanvirn)

1.	Baltisphaeridium diversum sp. nov.	W1	20	5	0.65	1036 478	N29/1
2.	B. diversum sp. nov. (Holotype)	W1	20	1	0.2	1077 329	R43/3
3.	Striatotheca frequens Burmann, 1970	W1	20	3	0.65	1046 464	030/1
4.	S. quieta (Martin, 1969) Rauscher, 1974	W1	20	3	0.65	1012 492	L27/1
5.	Peteinosphaeridium velatum Kjellström, 1971a	W1	20	2	0.2	1032 416	N35/1
6.	Uncinisphaera? exilis sp. nov.	W1	20	5	0.65	994 486	J28/1
7.	Astropheos sp. A	W1	20	3	0.65	1040 360	N40/4
8.	?Recavisentis uncinatus Downie, 1958 comb. nov.	W1	20	3	0.65	1033 476	N29/1

PLATE 23



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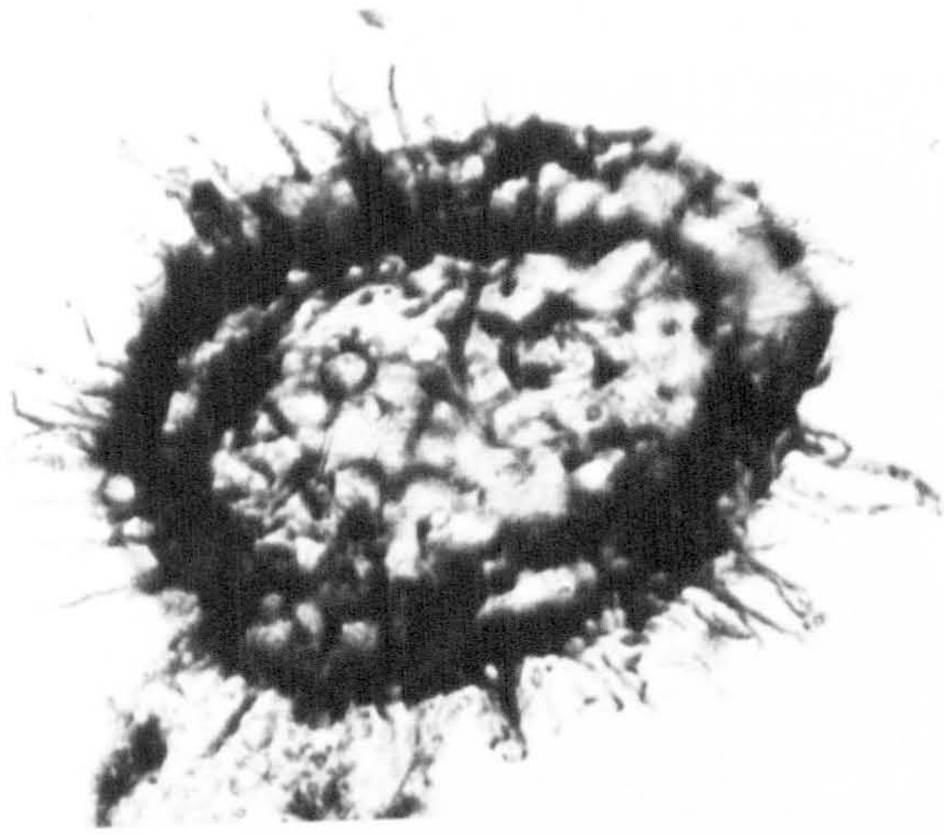

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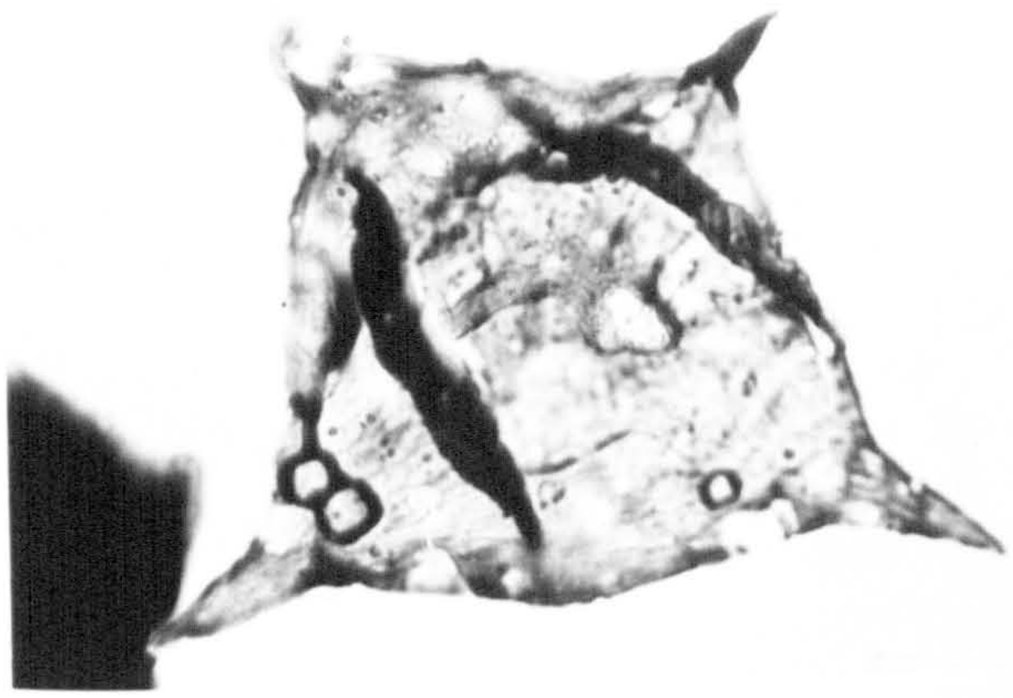

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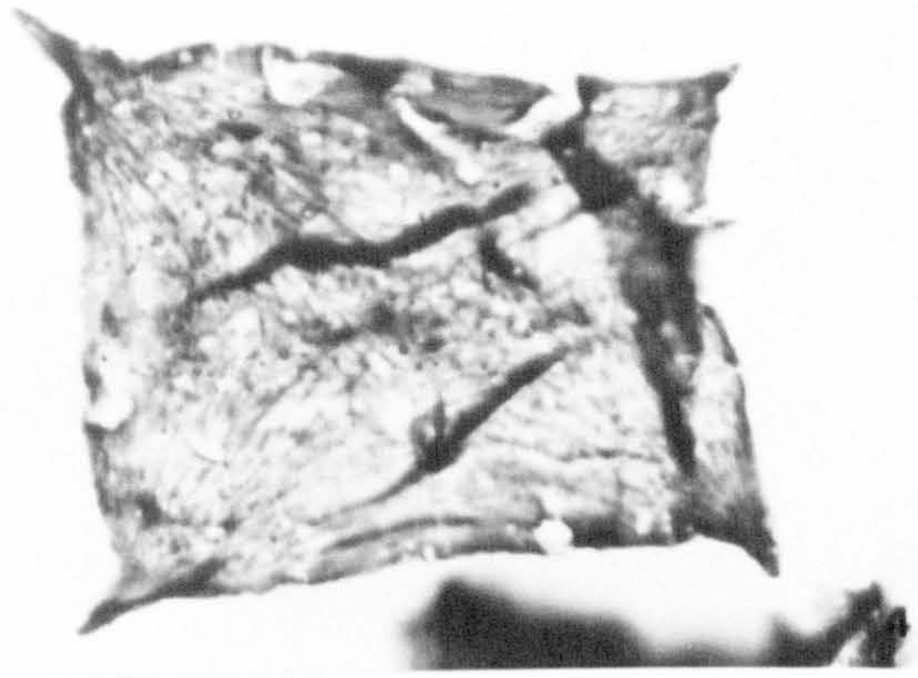

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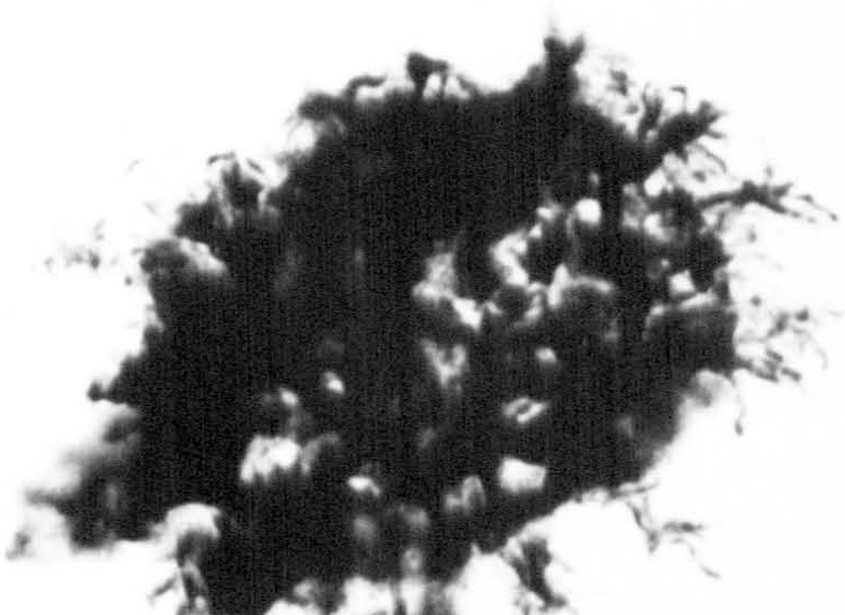

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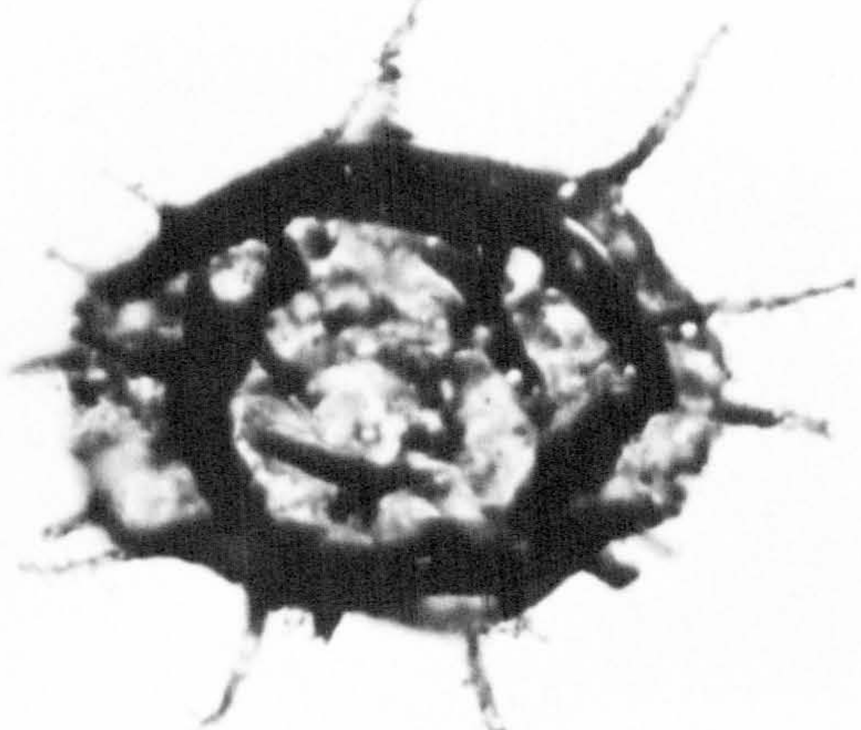

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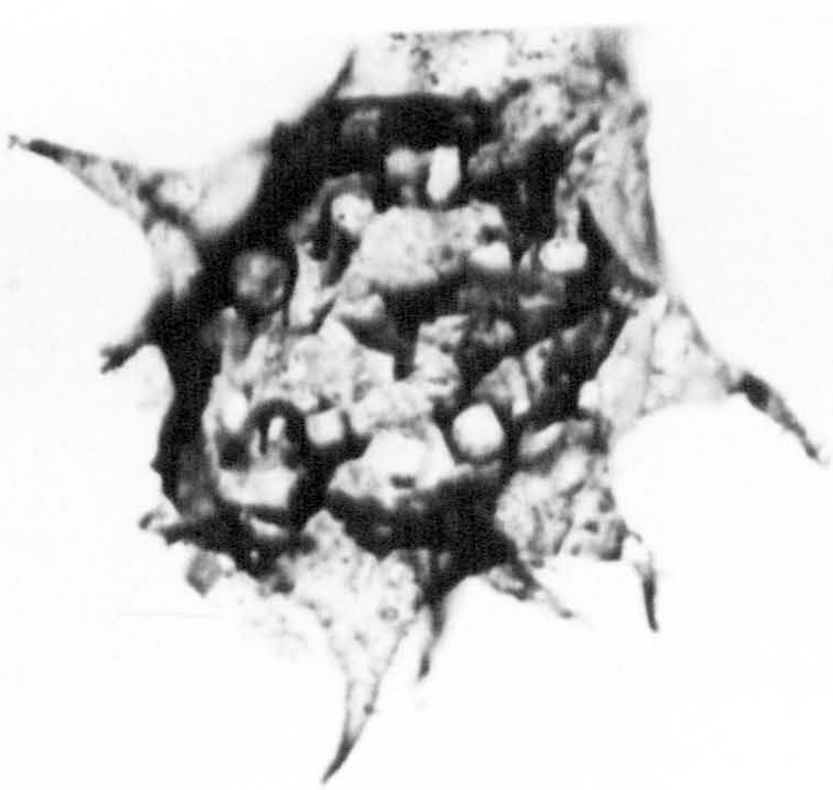

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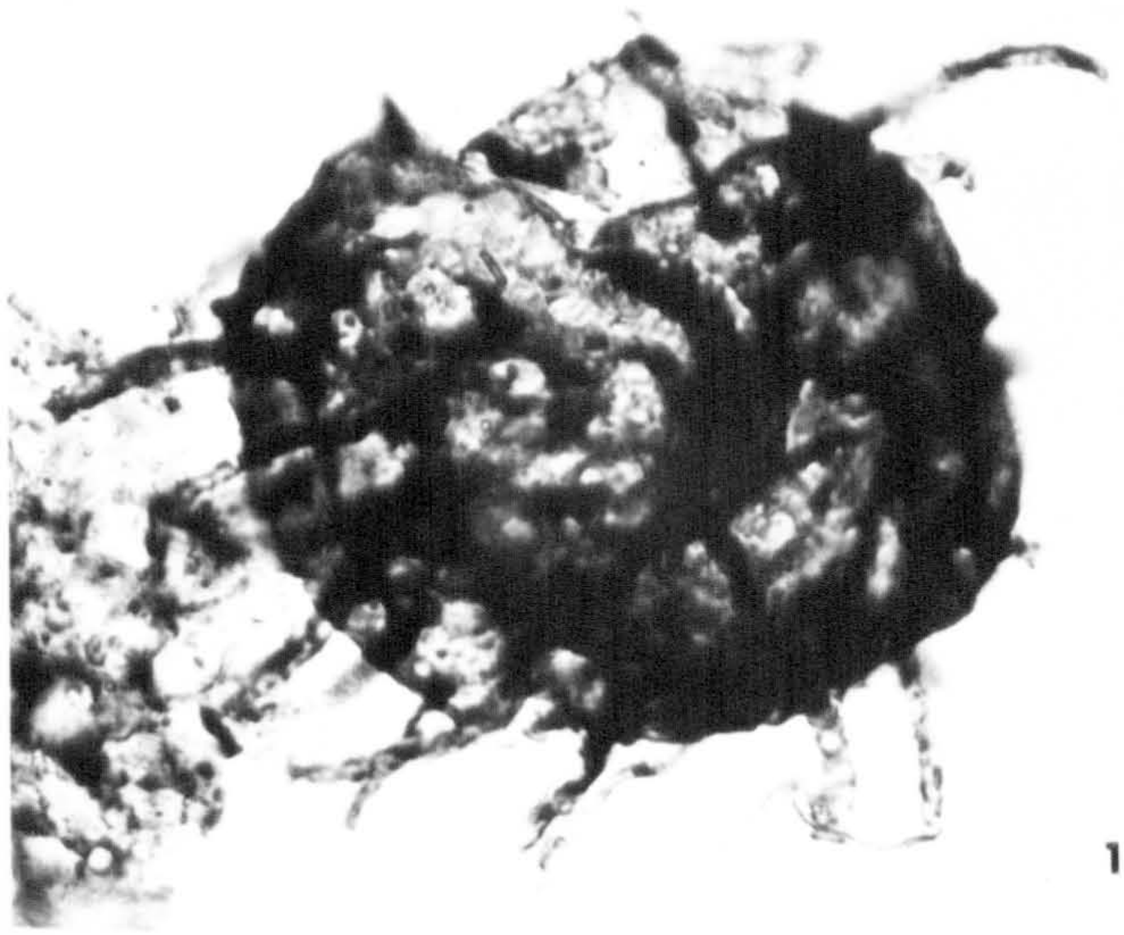
PLATE 24

Microfloral assemblage from Whitsburn, Shropshire,(Lower Llanvirn)

1.	Baltisphaeridium granosum Kjellström, 1971a	W1	20	1	0.2	1026	507	M26/2
2.	Culcitispina cf. fakira Martin, 1969	W1	20	5	0.65	1000	260	J51/1
3.	Baltisphaeridium longispinosum (Eisenack, 1931) Eisenack, 1959, forma longispinosum	W1	20	3	0.65	1050	397	037/3
4.	Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959	W1	20	5	0.65	1008	393	K37/4
5.	?Multiplicisphaeridium maroquense Cramer et al., 1974a	W1	20	3	0.65	1060	328	P44/3
6.	Multiplicisphaeridium sp. B	W1	20	1	0.2	1047	418	035/3
7.	Veryhachium abortivum sp. nov. (Holotype)	W1	<20	4	0.1	1033	251	N52/1
8.	V. abortivum sp. nov.	W1	<20	4	0.1	1039	361	N40/4
9.	V. abortivum sp. nov.	W1	<20	4	0.1	1107	304	U46/4

PLATE 24



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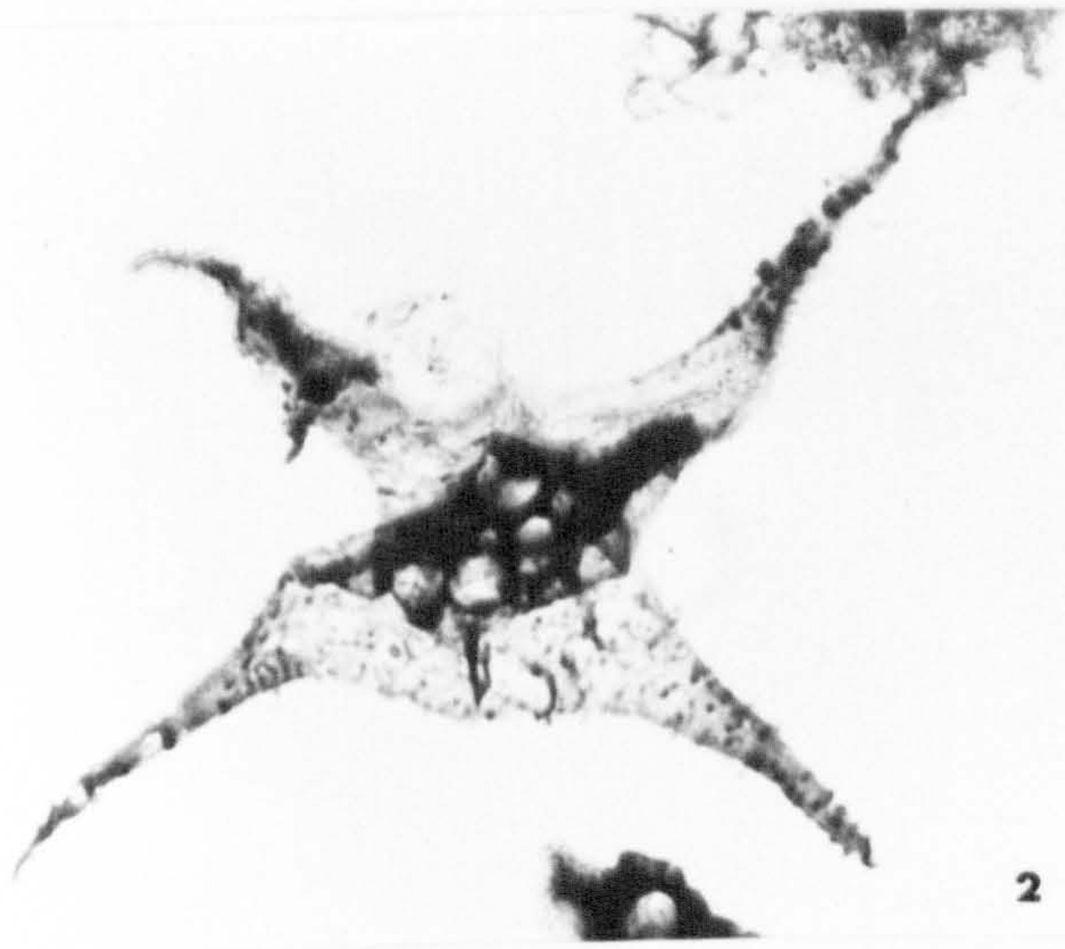

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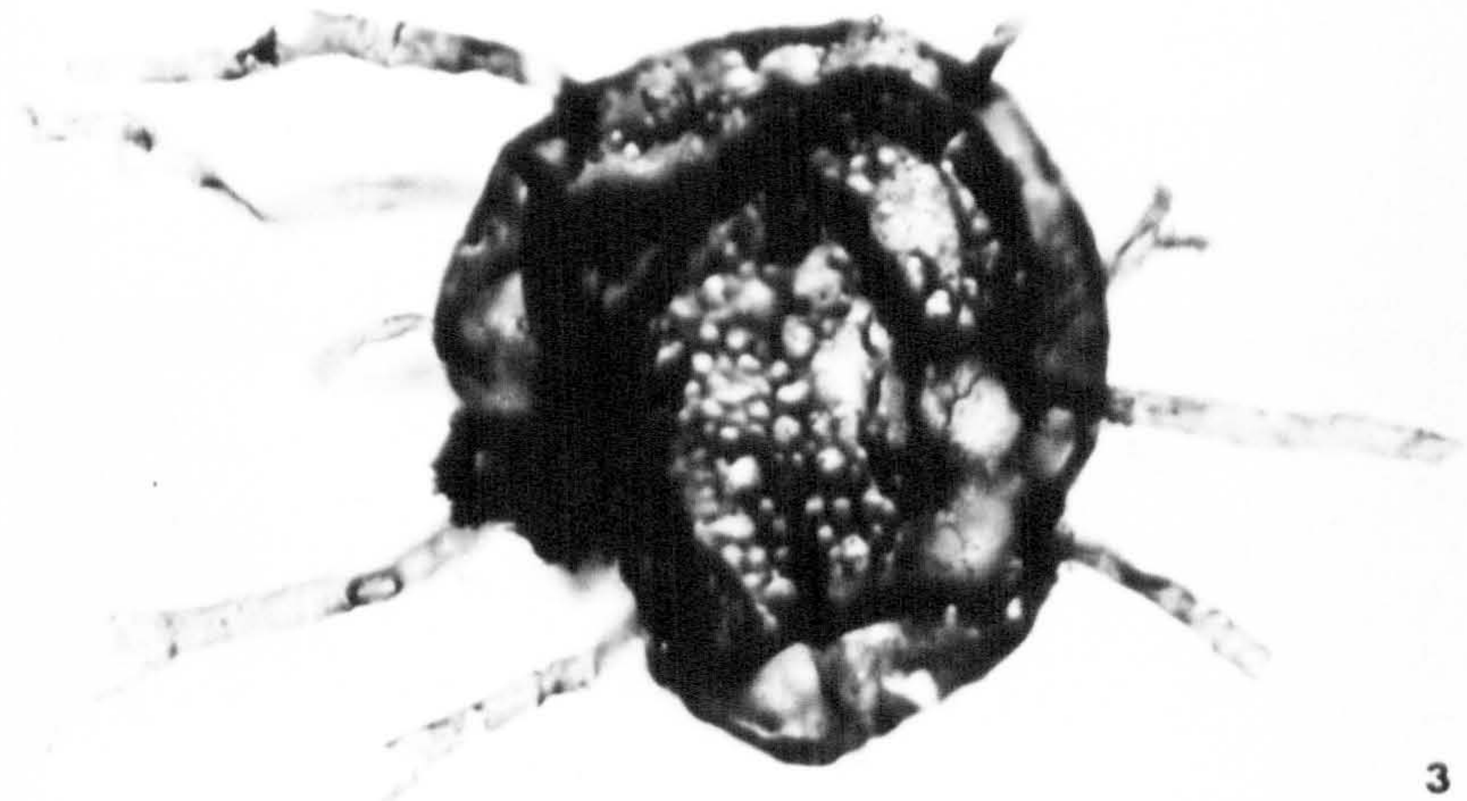

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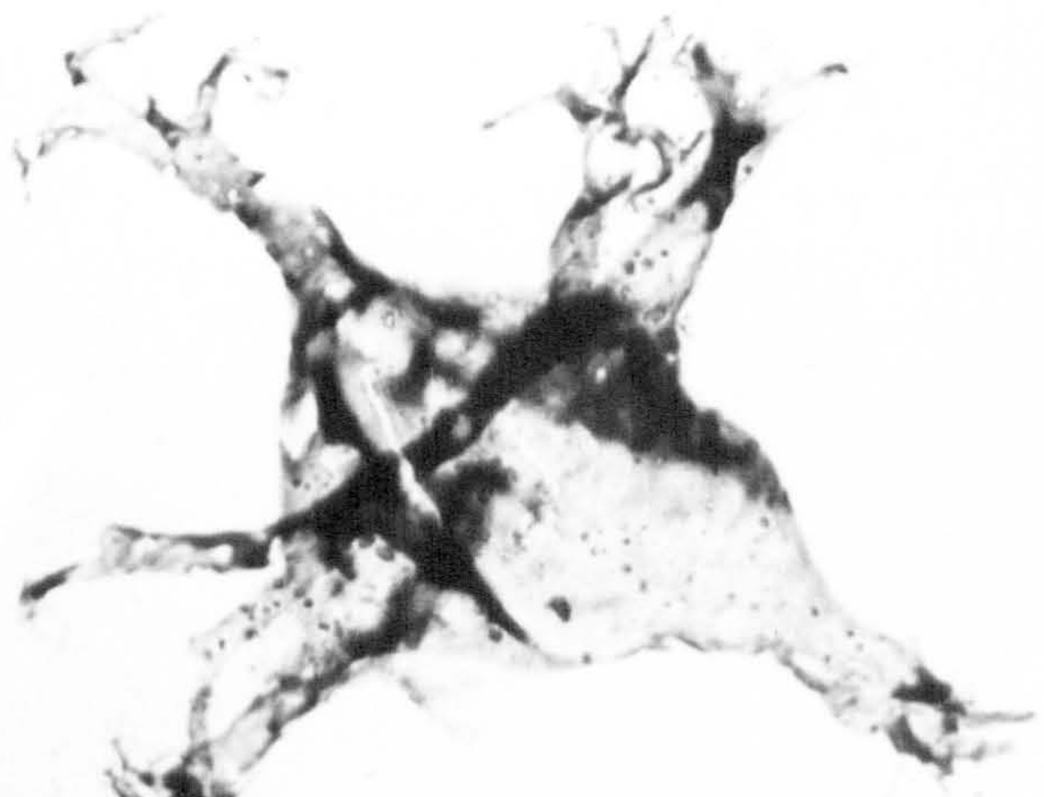

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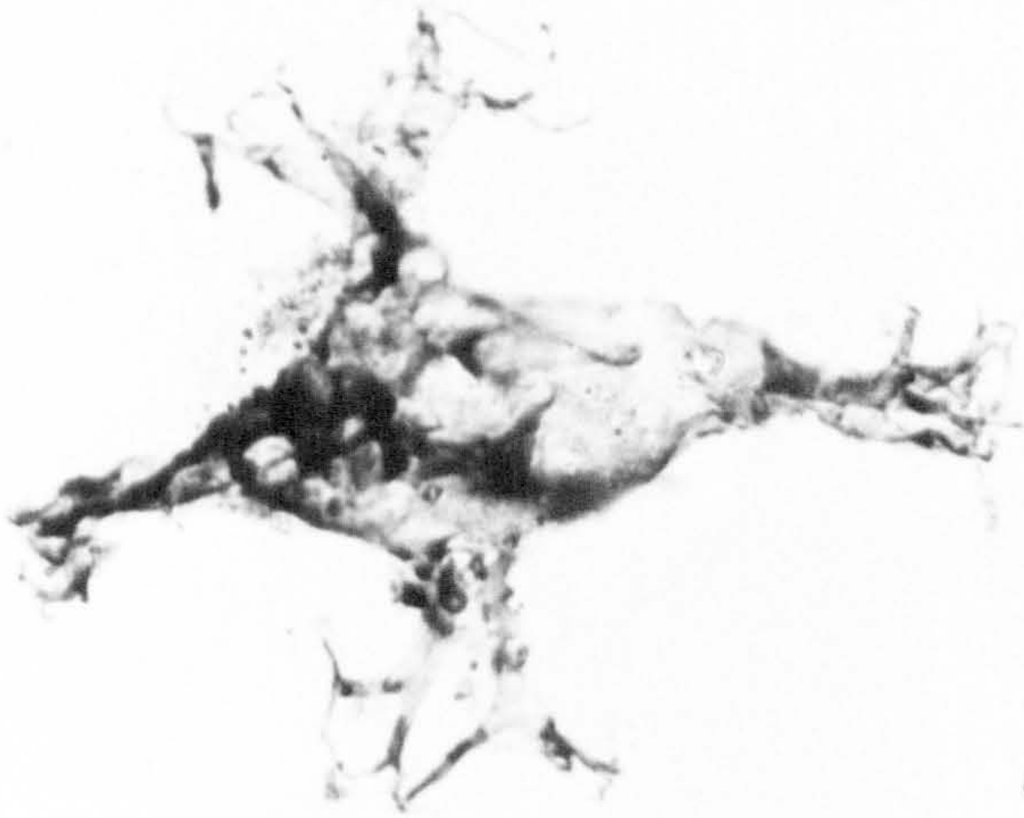

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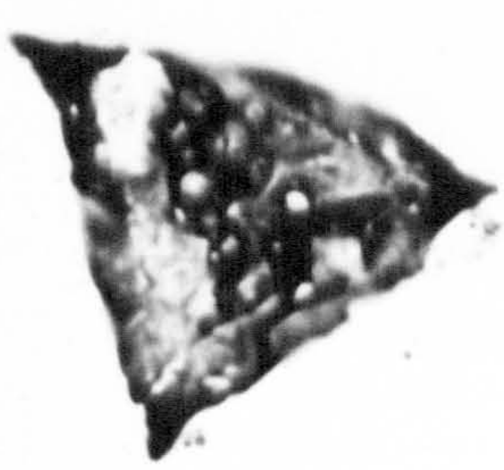

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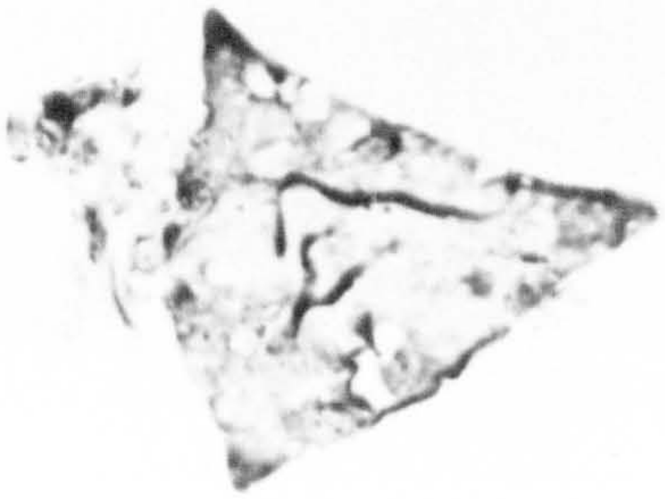

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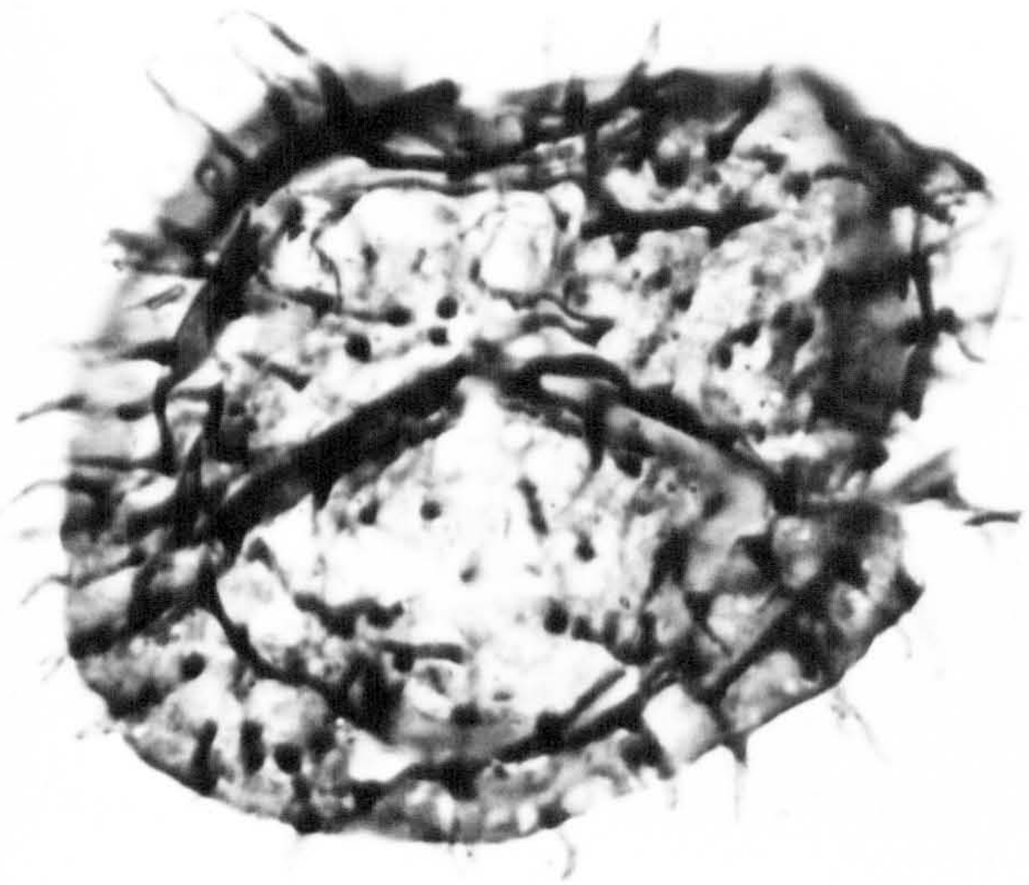
PLATE 25

Microfloral assemblage from Whitsburn, Shropshire,(Lower Llanvirn)

1.	Baltisphaeridium diversum sp. nov.	W3	20	1	0.3	1103	306	U46/1
2.	B. diversum sp. nov.	W3	20	1	0.3	1094	253	T50/4
3.	Baltisphaeridium sp.	W3	20	1	0.3	997	439	J32/2
4.	Uncinisphaera? exilis sp. nov.	W3	20	1	0.3	1001	402	J36/4
5.	Baltisphaeridium granosum Kjellström, 1971a	W3	20	2	0.3	997	376	J39/1
6.	Peteinosphaeridium velatum Kjellström, 1971a	W3	20	2	0.3	997	533	J23/1
7.	Acanthodiacrodium sp. C	W3	<20	1	0.1	993	462	H30/4
8.	Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959	W3	<20	1	0.1	992	359	H30/4
9.	?Stelliferidium distinctum Rasul,1974 comb. nov.	W3	<20	1	0.1	1012	262	K51/3

PLATE 25



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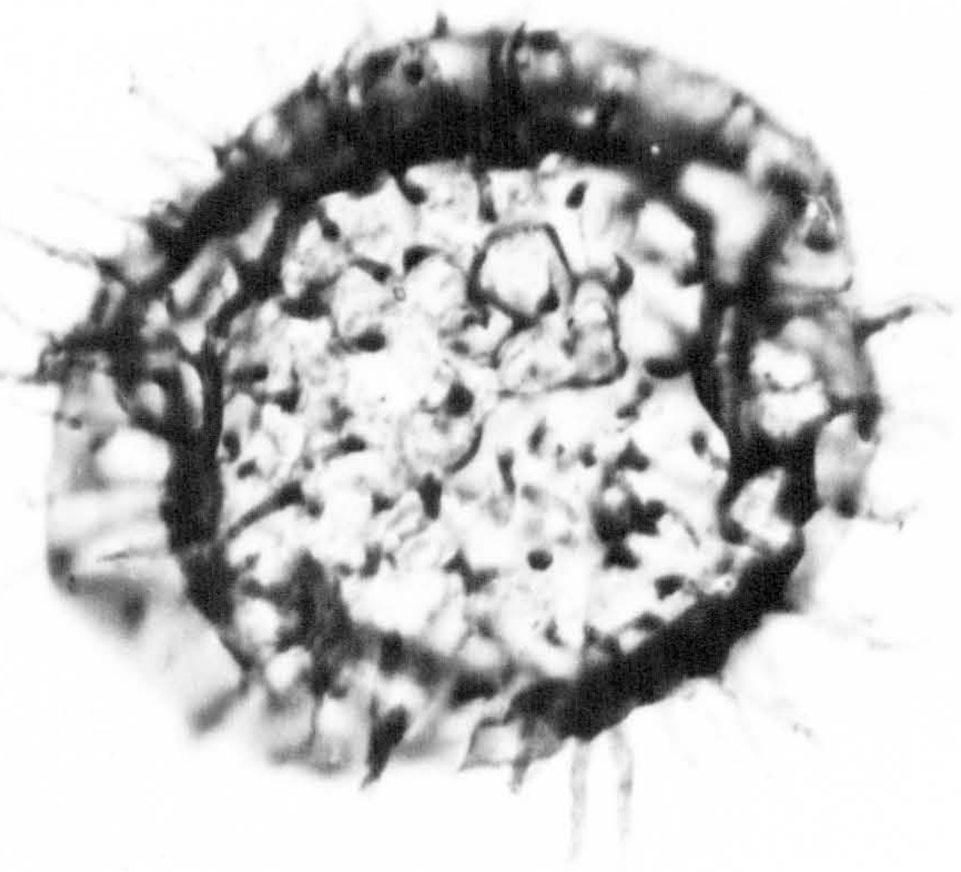

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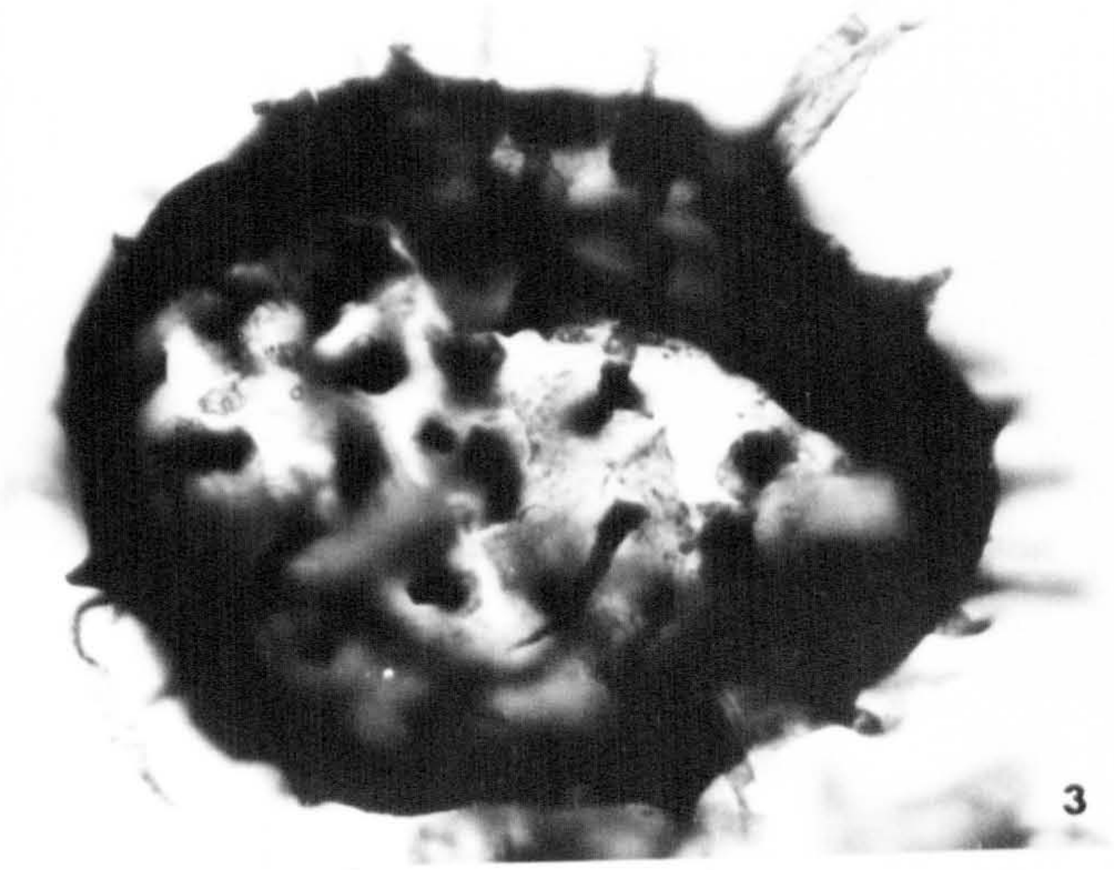

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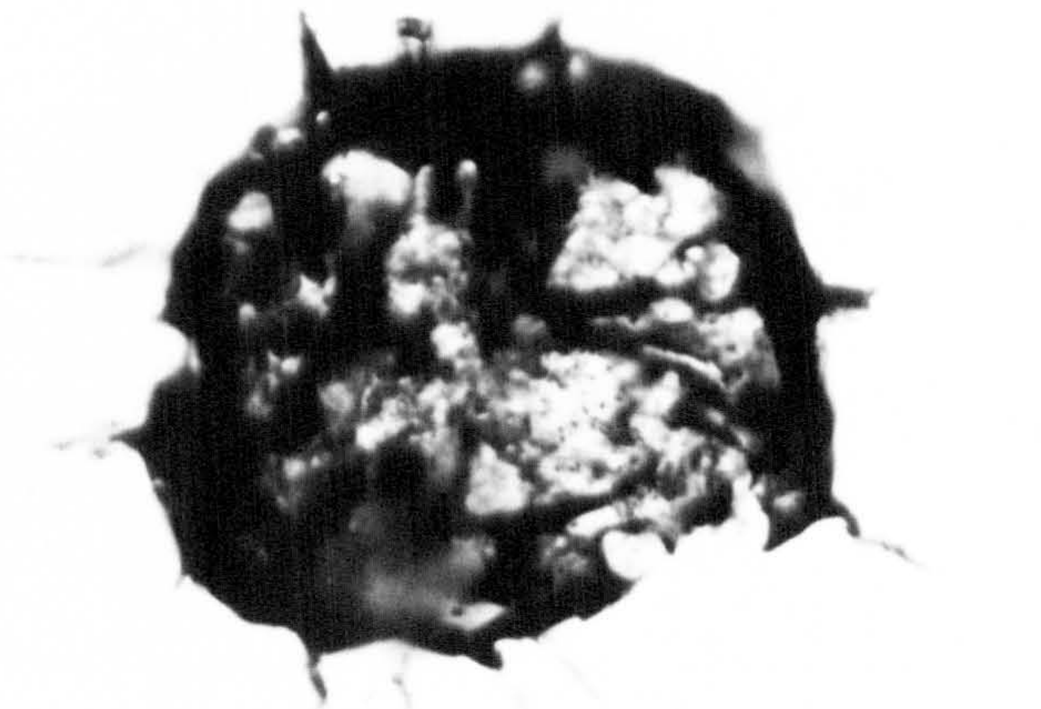

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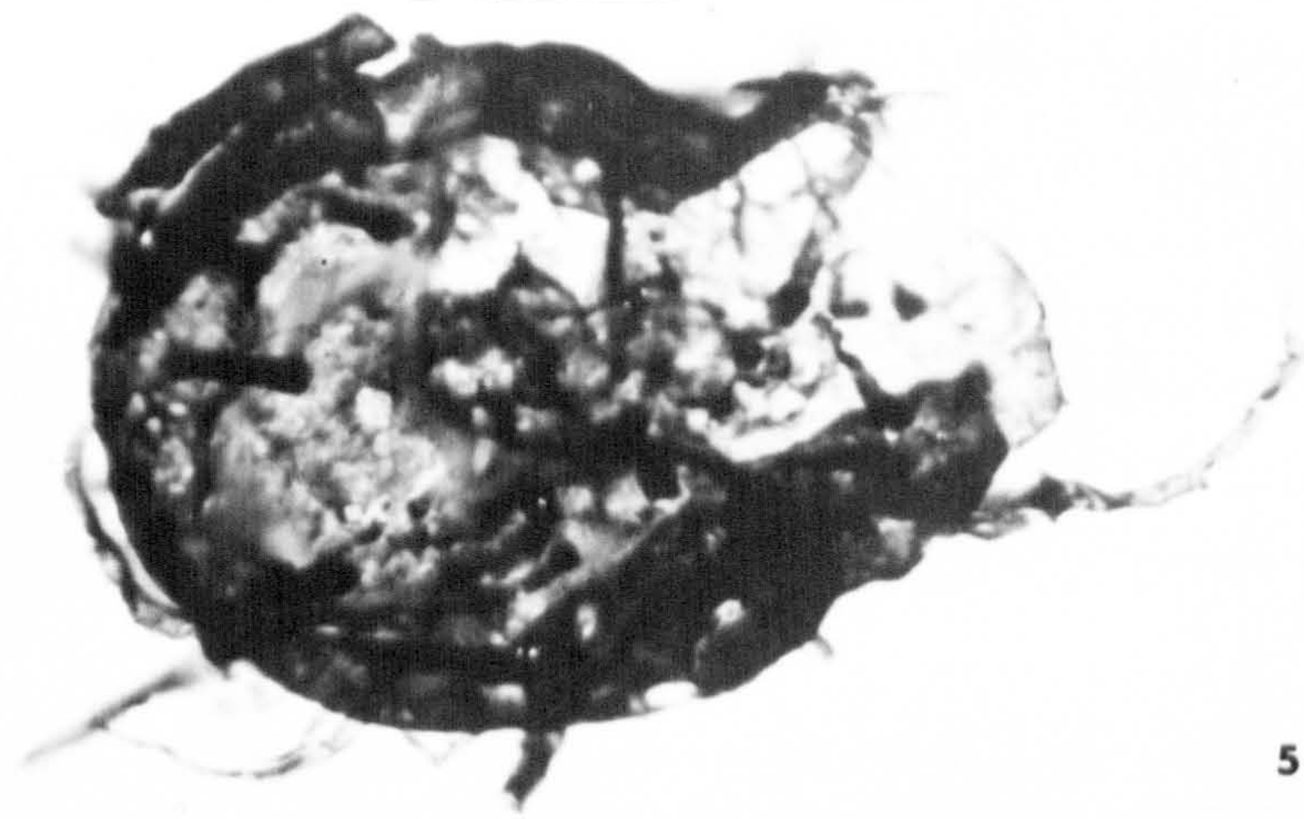

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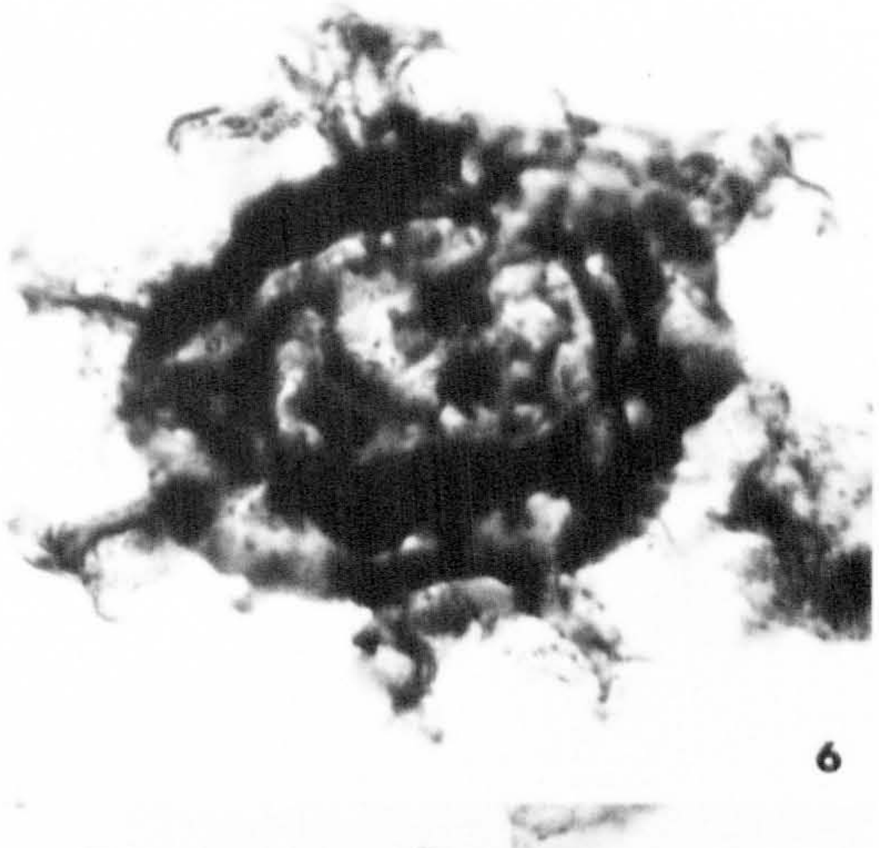

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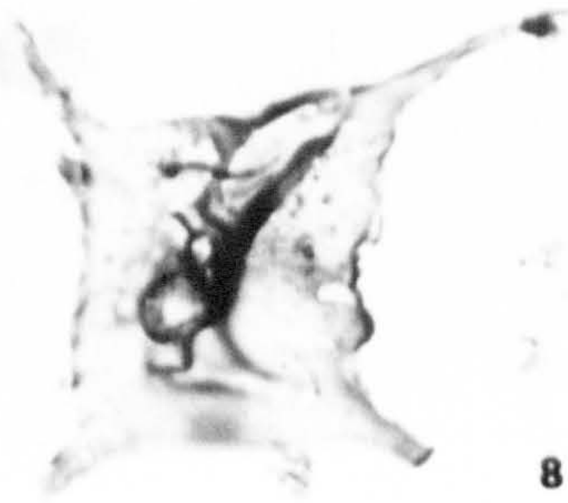

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PLATE 26

Microfloral assemblage from Whitsburn, Shropshire, (Lower Llanvirn)

1. Striatotheca quieta (Martin, 1969) Rauscher, 1974
W3 20 1 0.3 935 382 C38/2

2. S. quieta (Martin, 1969) Rauscher, 1974
W3 20 1 0.3 1095 396 T37/3

3. Baltisphaera procera Burmann, 1970
W3 20 1 0.3 1026 478 M28/2

4. Tectitheca contracta Burmann, 1968
W3 20 1 0.3 1031 433 M33/3

5. ?Dicrodiacrodium normale Burmann, 1968 var. normale nom. nov.
W3 20 2 0.3 998 379 J39/1

6. Astropheos sp. A W3 20 1 0.3 1046 532 023/1

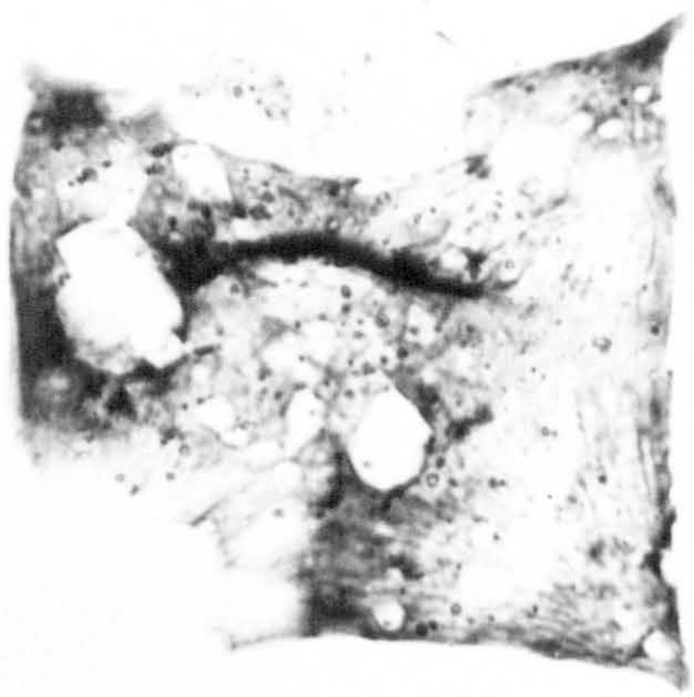
7. Arkonia tenuata Burmann, 1970 W3 <20 1 0.1 1064 311 Q45/2

8. Recavisentis uncinatus Downie, 1958 comb. nov. (x 500)
W3 20 1 0.3 1027 477 M29/1

9. Tectitheca contracta Burmann, 1968 (x 500)
W3 20 1 0.3 1070 427 R34/1

10. Veryhachium trispinosum Formgroup, Cramer, 1964b (x 500)
W3 20 1 0.3 1083 482 S28/1

PLATE 26



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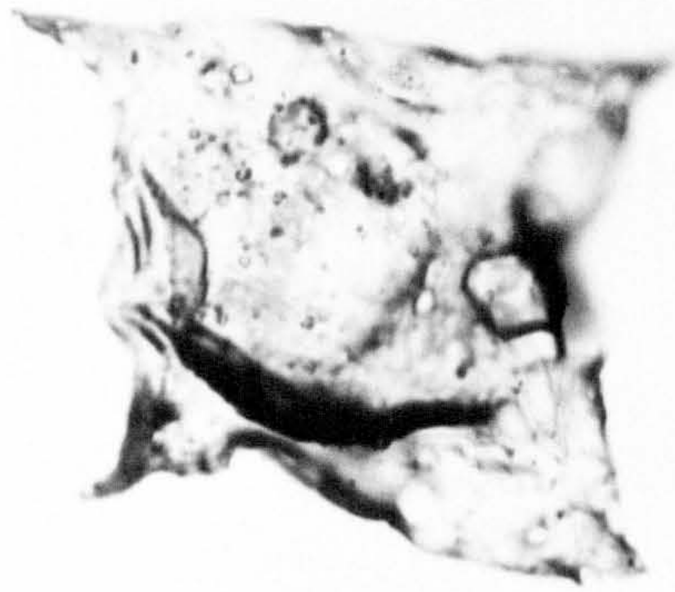

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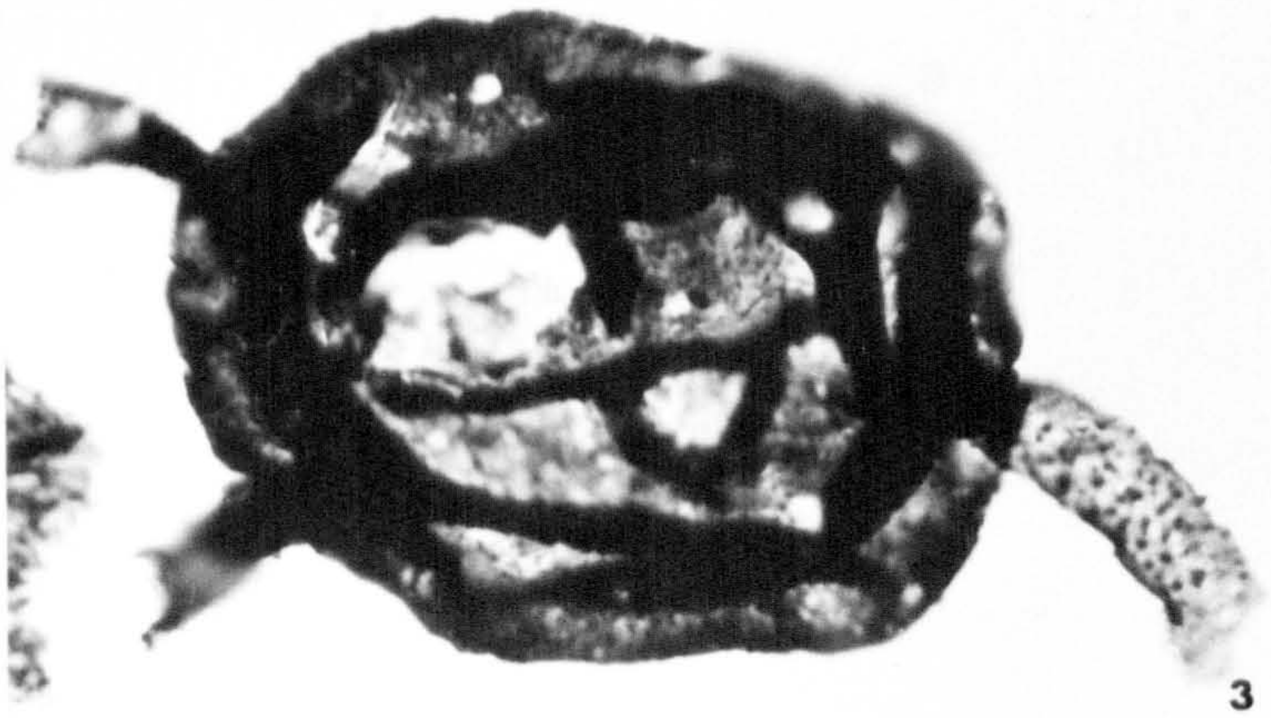

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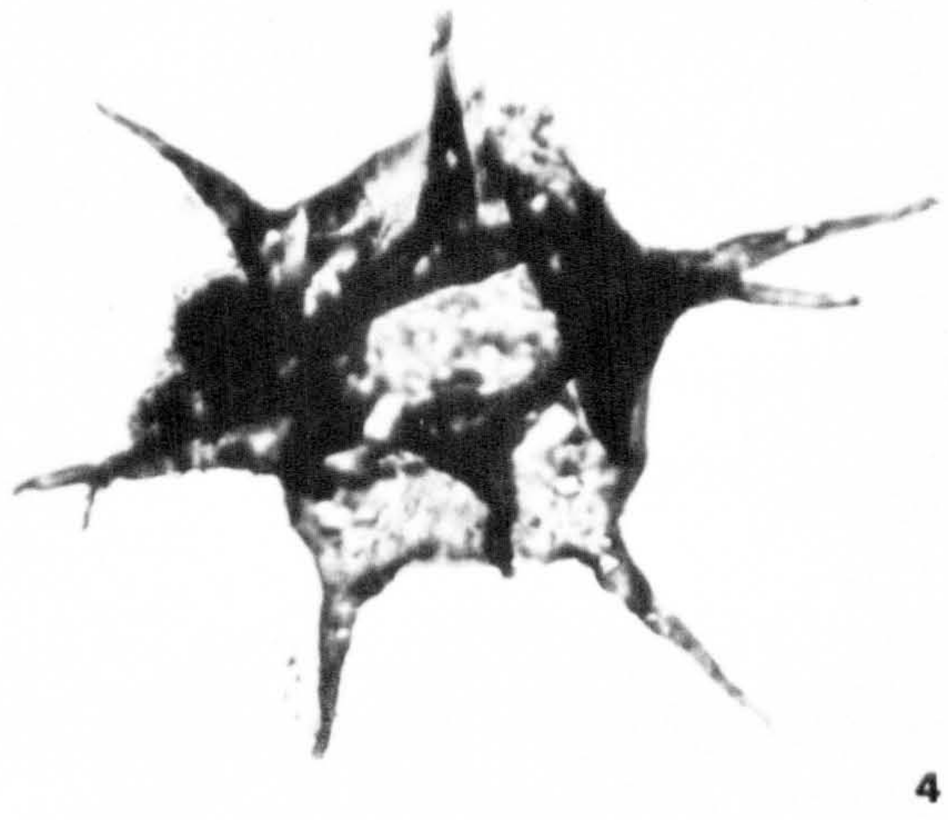

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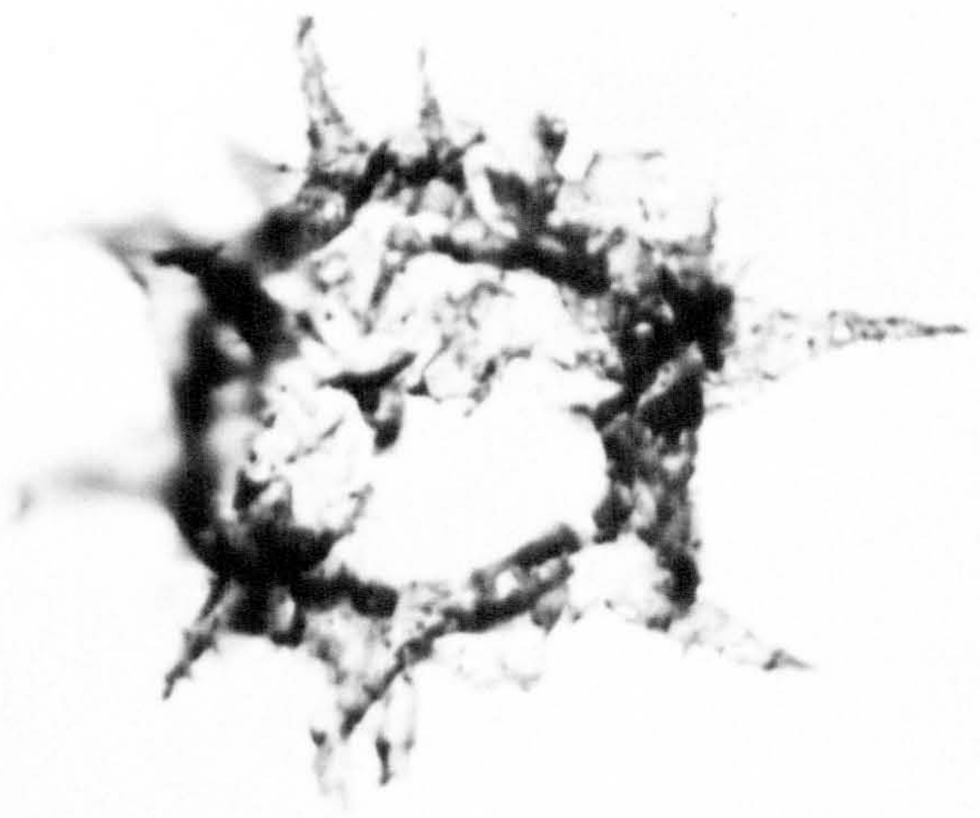

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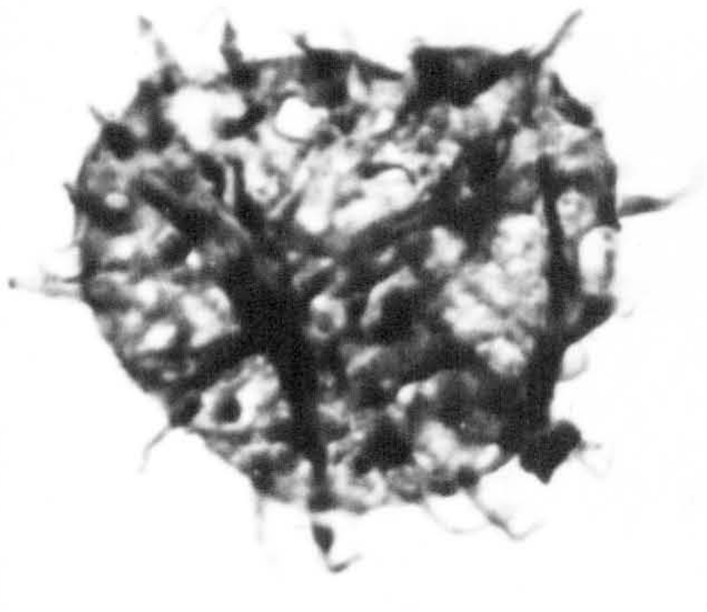
PLATE 27

Microfloral assemblage from Whitsburn, Shropshire, (Lower Llanvirn)

1.	Stelliferidium fimbrium Rasul, 1974 comb. nov.	W3	20	1	0.3	1000	519	J24/2
2.	Peteinosphaeridium velatum Kjellström, 1971a (x 500)	W3	20	1	0.3	1082	358	S41/1
3.	?Acanthodiacrodium concaviusculum Burmann, 1970	W3	<20	1	0.1	998	377	J39/1
4.	A. costatum Burmann, 1968	W3	<20	1	0.1	1019	376	L39/3
5.	Veryhachium abortivum sp. nov.	W3	<20	1	0.1	1059	489	P27/4
6.	Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b	W3	<20	1	0.1	1037	406	N36/3
7.	M. raspum (Cramer, 1964b) Lister, 1970b	W3	<20	1	0.1	1040	365	N40/4
8.	Orthosphaeridium? sp. A	W3	<20	1	0.1	1019	379	L39/3
9.	Orthosphaeridium? sp. A	W3	<20	1	0.1	1034	287	N48/2
10.	Orthosphaeridium? sp. A	W3	<20	1	0.1	1023	358	M51/2
11.	Micrhystridium sp. A	N3	<20	1	0.1	1048	407	036/2
12.	Micrhystridium sp. A	W3	<20	1	0.1	1034	312	N46/1
13.	Leiofusa sp. A	W3	<20	1	0.1	999	398	J37/1
14.	Leiofusa sp. A	W3	<20	1	0.1	1044	317	045/1

PLATE 27



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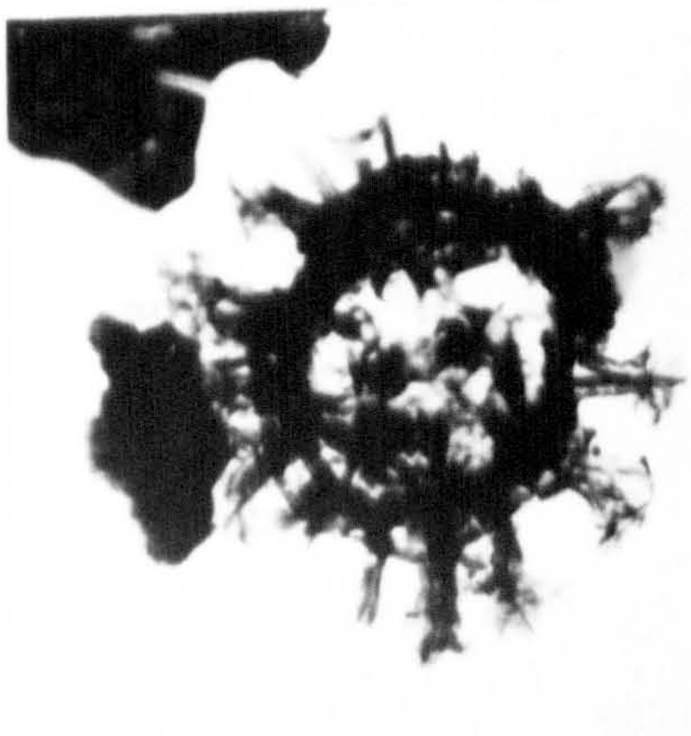

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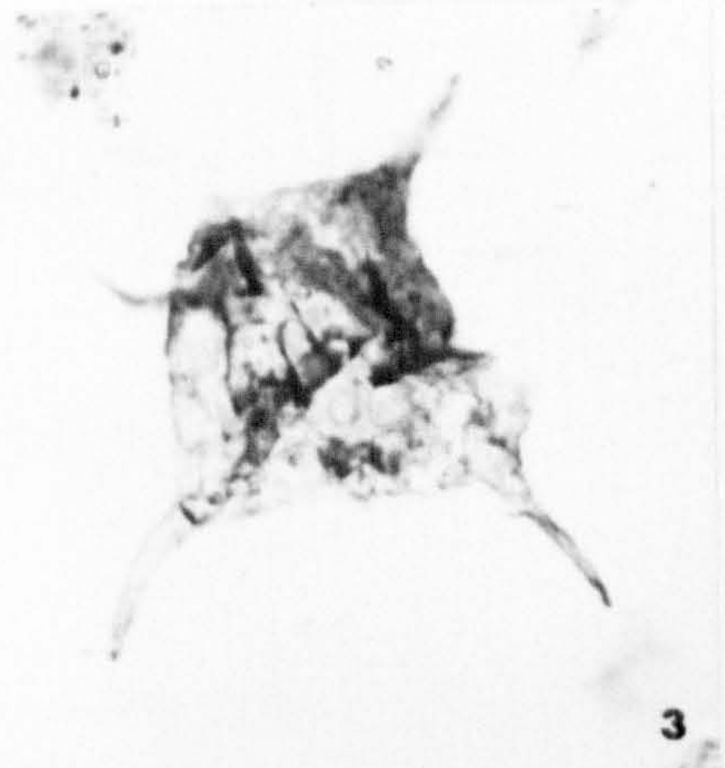

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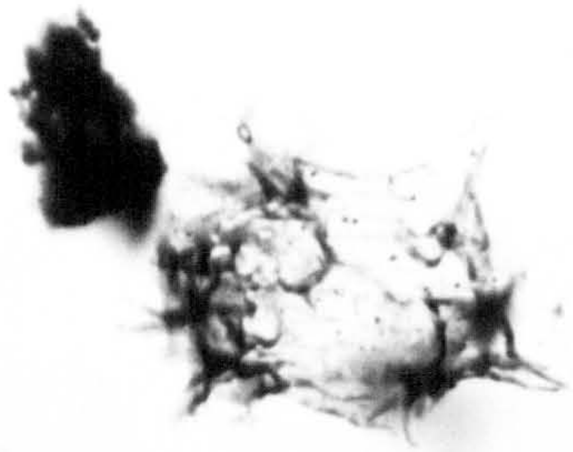

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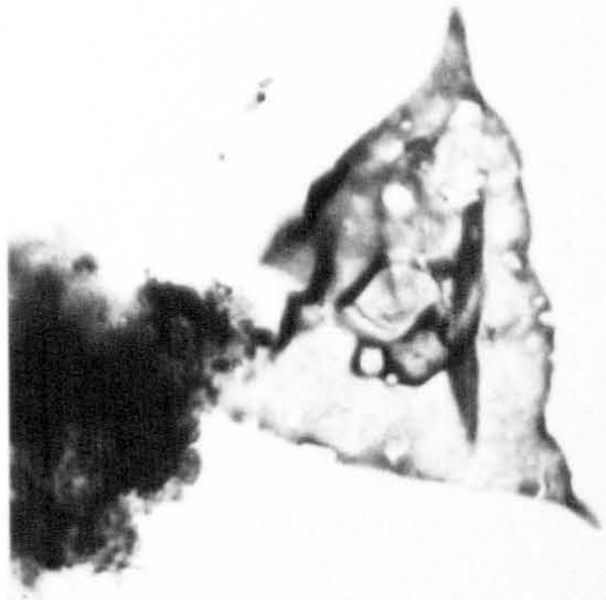

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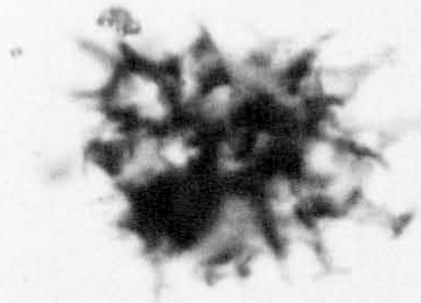

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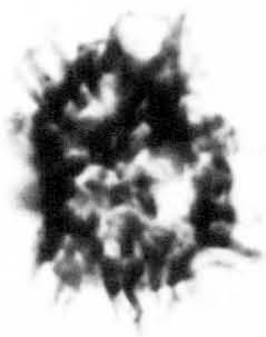

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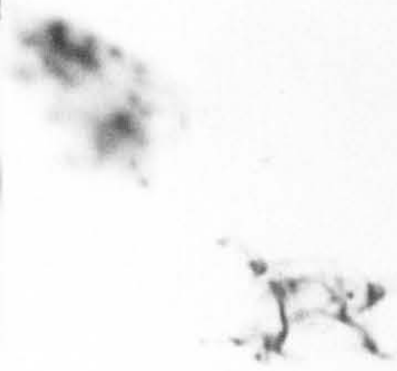

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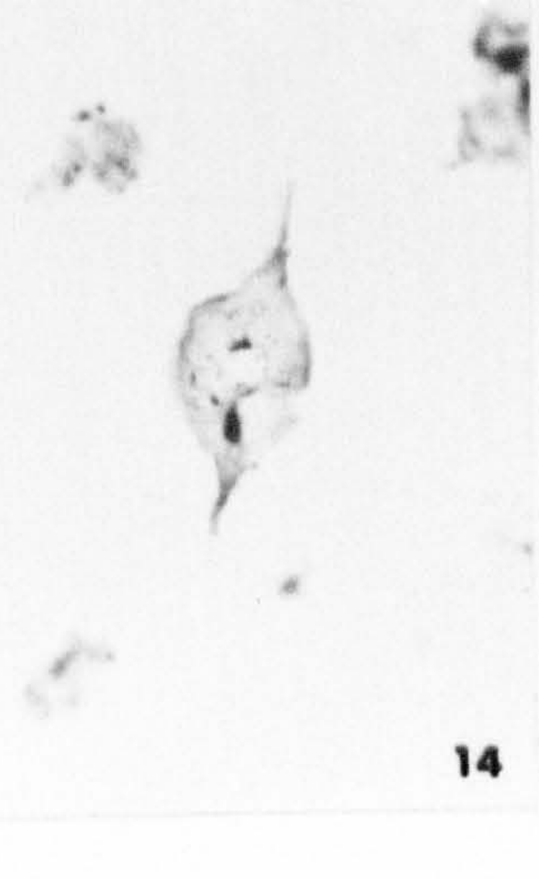

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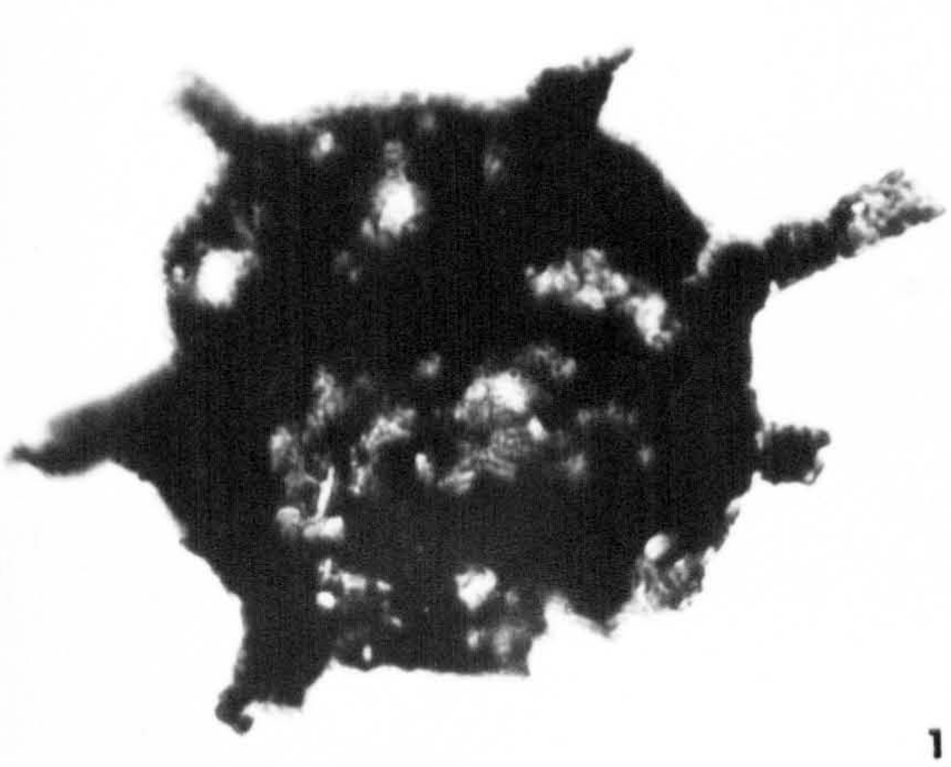
Microfloral assemblage from Rorrington, Shropshire,(Upper Llanvirn)

1.	?Baltisphaeridium sp.	R1	20	1	0	937 227	C55/1
2.	?Baltisphaeridium sp.	R1	20	1	0	1044 251	052/1
3.	?Peteinosphaeridium sp.	R1	20	1	0	1051 442	032/4
4.	?Polygonium sp.	R1	20	1	0	1044 269	050/2
5.	?Striatotheca frequens Burmann, 1970	R1	20	1	0	1050 317	045/4
6.	'Baltisphaeridium' sp.	R1	20	1	0	955 469	E30/1
7.	Acanthodiacrodium sp.	R1	20	1	0	1057 377	P39/3
8.	'Baltisphaeridium' sp.	R1	20	1	0	991 273	H50/3
9.	'Baltisphaeridium' sp.	R1	20	1	0	1052 487	028/3
10.	'Baltisphaeridium' sp.	R1	20	1	0	985 295	H48/1
11.	'Baltisphaeridum' sp.	R1	20	1	0	1064 462	Q30/2
12.	'Baltisphaeridium' sp.	R1	20	1	0	965 284	F49/1

PLATE 28



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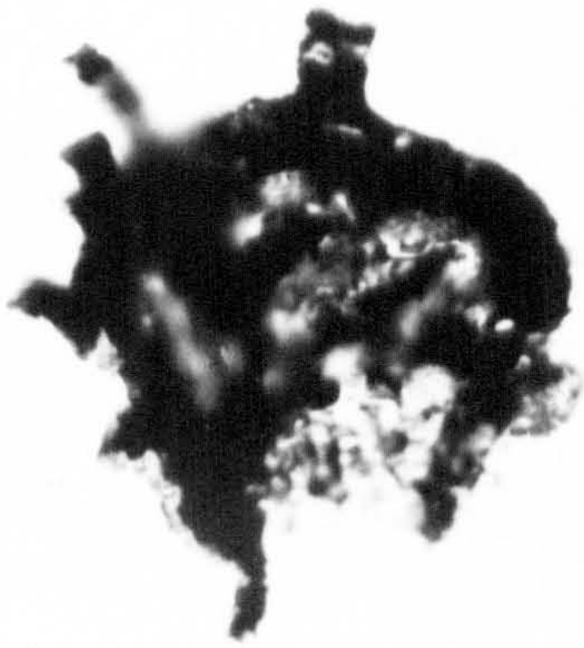

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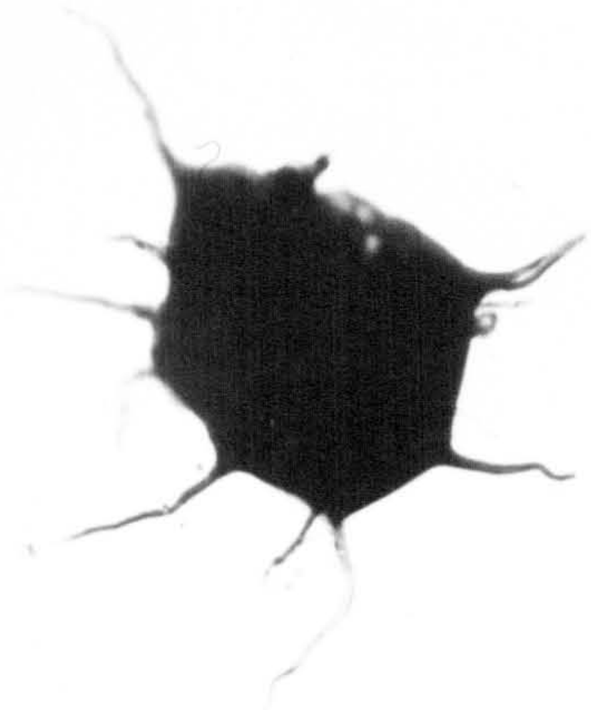

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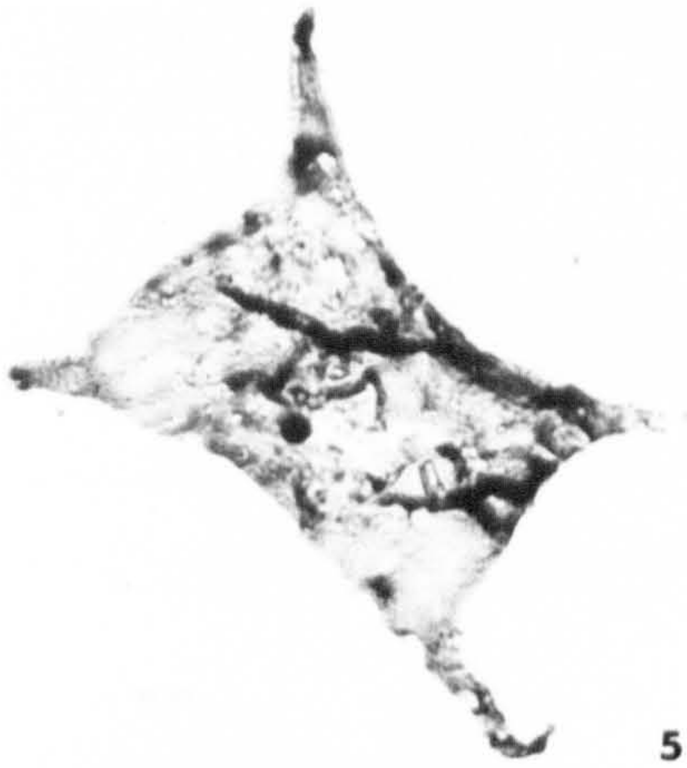

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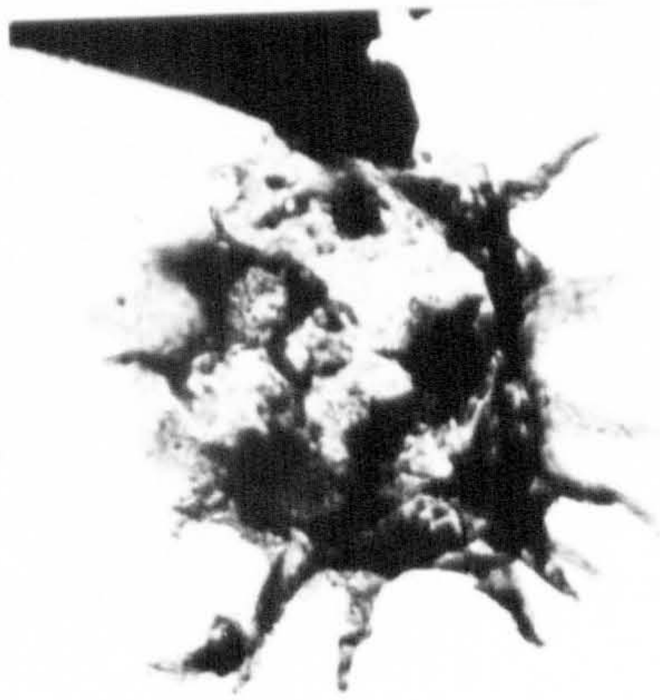

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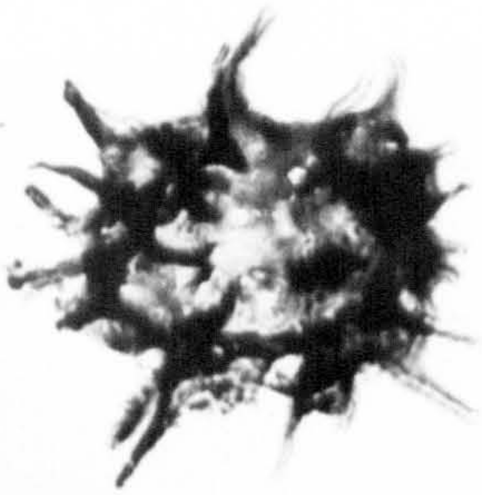

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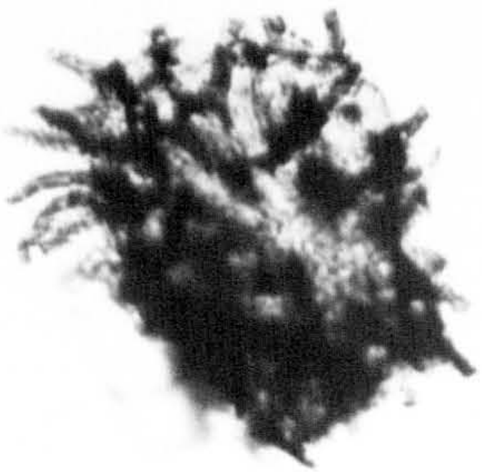

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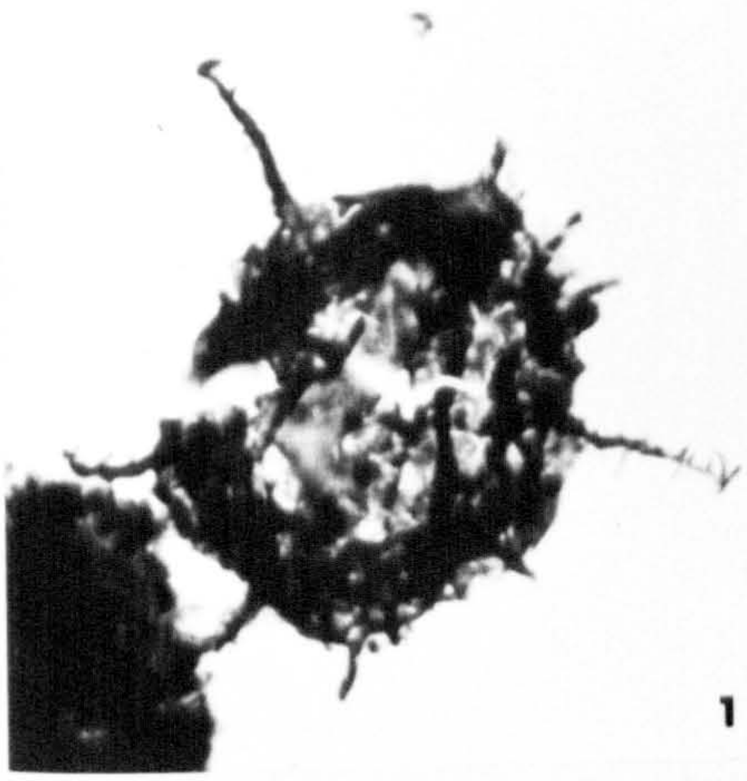
PLATE 29

Microfloral assemblage from the Tailbert-Llanshaw tunnel, Lake District, (Lower Llanvirn)

1.	Uncinisphaera? exilis sp. nov.	SAL 389	20	1	0	1053	382	P41/2
2.	Veryhachium trispinosum Formgroup, Cramer, 1964b	SAL 389	20	1	0	1093	385	T38/1
3.	Arkonia virgata Burmann, 1970	SAL 389	20	2	0	979	400	G37/3
4.	?Culcitispina brevis gen. et sp. nov.	SAL 389	20	1	0	1099	253	U52/1
5.	Striatotheca quieta (Martin, 1969) Rauscher, 1974	SAL 389	20	1	0	1095	312	T45/4
6.	?S. quieta (Martin, 1969) Rauscher, 1974	SAL 389	20	2	0	1034	386	N38/2
7.	S. frequens Burmann, 1970	SAL 389	20	1	0	936	357	C41/2
8.	Stelliferidium distinctum Rasul, 1974, comb. nov.	SAL 389	20	2	0	1048	423	034/4
9.	Coryphidium bohemicum Vavrdova, 1972	SAL 389	<20	1	0	929	401	B36/2
10.	C. bohemicum Vavrdova, 1972	SAL 389	<20	1	0	1043	385	038/1
11.	C. bohemicum Vavrdova, 1972	SAL 389	<20	1	0	1006	235	K54/1
12.	Multiplicisphaeridium raspum (Cramer, 1964b) Lister, 1970b	SAL 389	<20	1	0	1023	476	M29/1

PLATE 29



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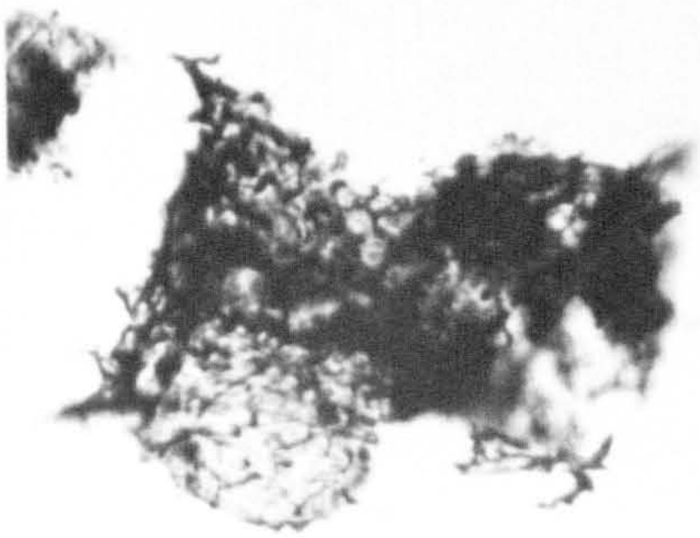

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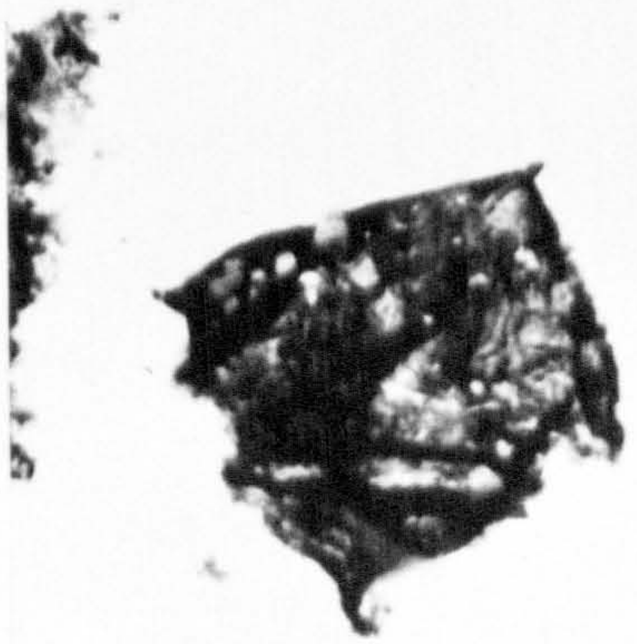

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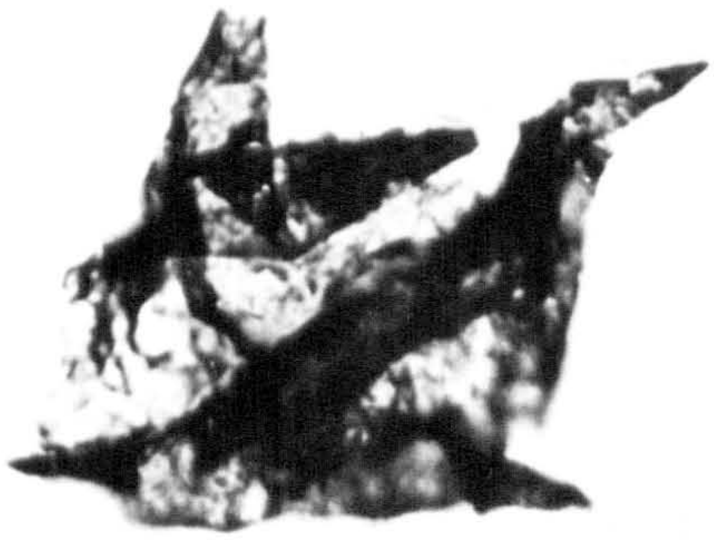

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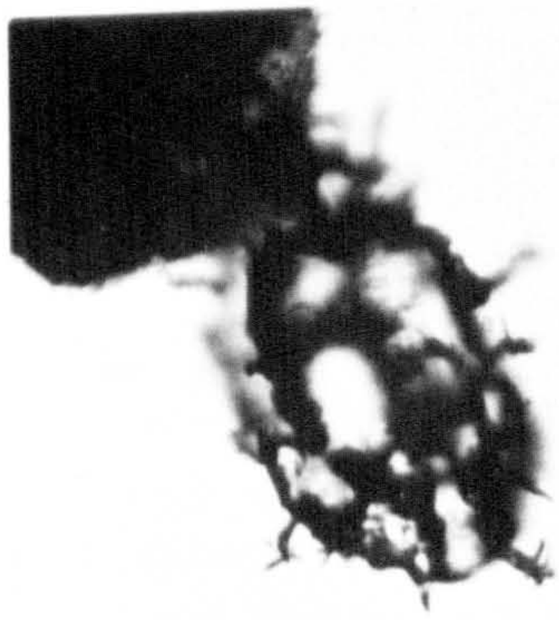

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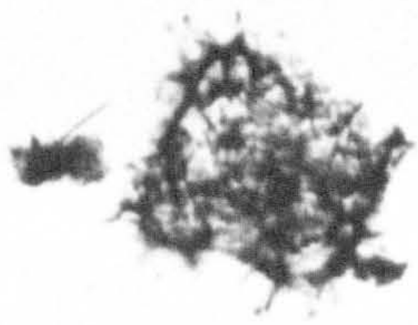

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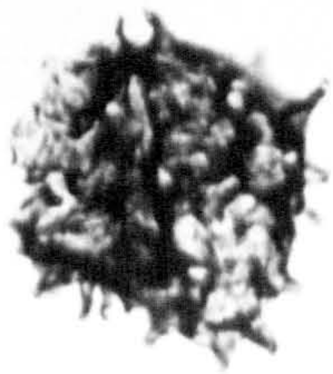

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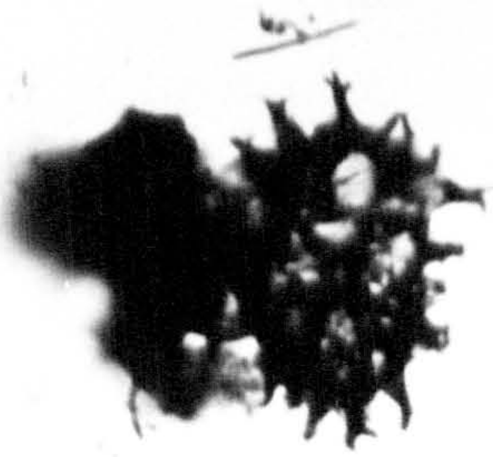

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Microfloral assemblage from the Tailbert-Llanshaw tunnel, Lake District, (Lower Llanvirn)

1.	Uncinisphaera? sp. A	SAL 390	20	1	0	1106	432	U33/1
2.	Peteinosphaeridium? sp. D	SAL 390	<20	1	0	986	416	H35/1
3.	Peteinosphaeridium? sp. D	SAL 390	<20	1	0	975	338	G43/1
4.	Peteinosphaeridium? sp. D	SAL 389	<20	1	0	945	523	D24/1
5.	Peteinosphaeridium? sp. D	SAL 389	<20	1	0	1014	379	L39/1
6.	Frankea sartbernardense (Martin, 1966) Burmann, 1970	SAL 389	<20	1	0	1071	459	R30/2
7.	?Frankea hamata Burmann, 1970	SAL 389	<20	1	0	1066	312	Q46/3
8.	?Micrhystridium nannacanthum Deflandre, 1942 ex Deflandre, 1945	SAL 389	<20	1	0	1020	370	L46/3
9.	Multiplicisphaeridium sp.	SAL 389	<20	1	0	961	320	E45/3
10.	?Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.	SAL 389	<20	1	0	1067	357	Q41/3
11.	Elektoriskos? sp. A	SAL 389	<20	1	0	1019	399	L37/3
12.	Elektoriskos? sp. A	SAL 390	<20	2	0	1038	482	N28/4
13.	?Veryhachium minutum Downie, 1958	SAL 390	<20	2	0	1012	253	L52/1
14.	Micrhystridium sp.	SAL 390	<20	1	0	944	230	D54/2
15.	Micrhystridium sp. B	SAL 389	<20	1	0	1077	313	R45/4

PLATE 30

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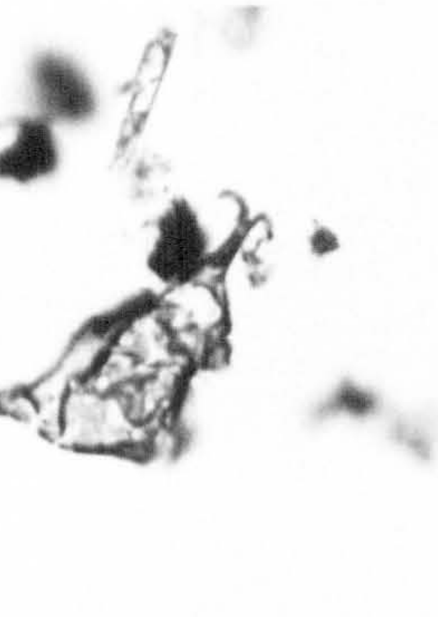

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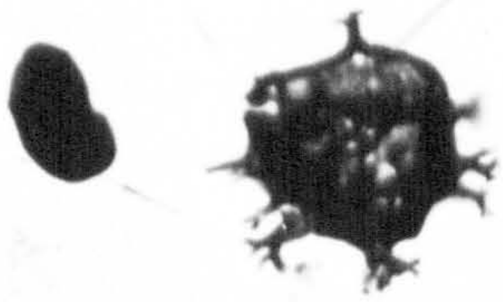

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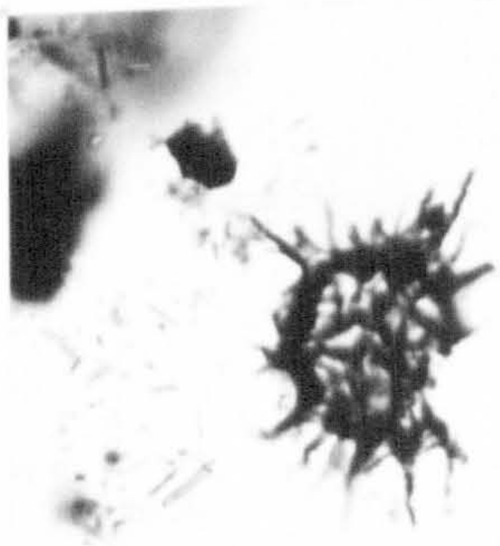

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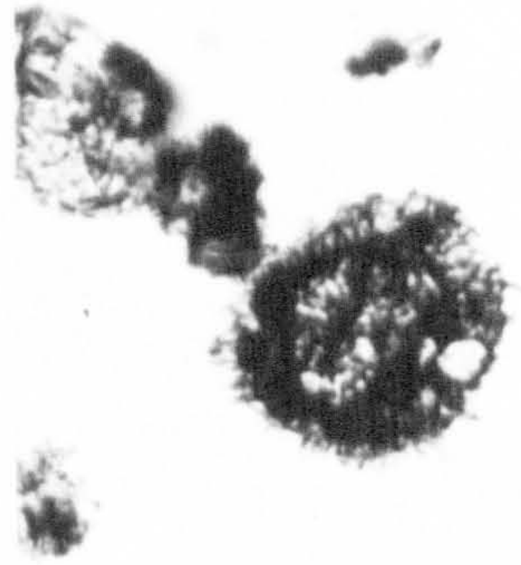

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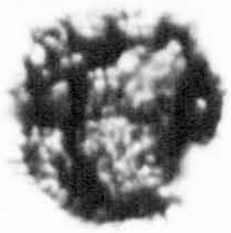

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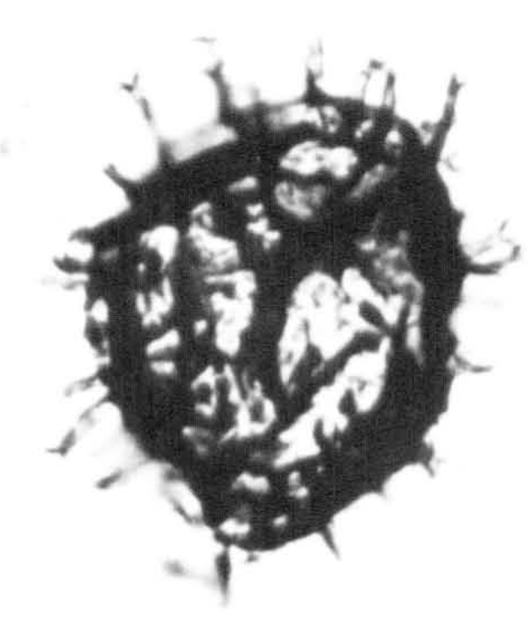
Microfloral assemblage from the Tailbert-Llanshaw tunnel, Lake District, (Lower Llanvirn)

1.	Stelliferidium distinctum Rasul, 1974 comb. nov.	SAL	390	20	2	0	1083 444	S32/1
2.	S. distinctum Rasul, 1974 comb. nov.	SAL	390	20	3	0	985 399	H37/1
3.	S. distinctum Rasul, 1974 comb. nov.	SAL	390	20	2	0	1070 480	Q28/4
4.	Recavisentis uncinatus Downie, 1958 comb. nov.	SAL	390	20	1	0	980 471	G29/4
5.	Polygonium gracile Vavrdova, 1966 emend.	SAL	390	20	2	0	1002 313	K46/1
6.	Polygonium cf. pungens Timofeev, 1959 comb. nov.	SAL	390	20	2	0	1018 361	L41/3
7.	Arkonia virgata Burmann, 1970	SAL	390	<20	1	0	1125 440	W32/4
8.	Veryhachium trispinosum Formgroup, Cramer, 1964b	SAL	390	20	1	0	1056 393	P37/4
9.	Arkonia tenuata Burmann, 1970	SAL	390	<20	1	0	1006 440	K32/2
10.	Striatotheca principalis Burmann, 1970 var. principalis nom. nov.	SAL	390	20	1	0	979 343	G42/4
11.	S. quieta (Martin, 1969) Rauscher, 1974	SAL	390	20	2	0	1037 347	N42/3
12.	S. frequens Burmann, 1970	SAL	390	20	3	0	967 260	F51/1

PLATE 31



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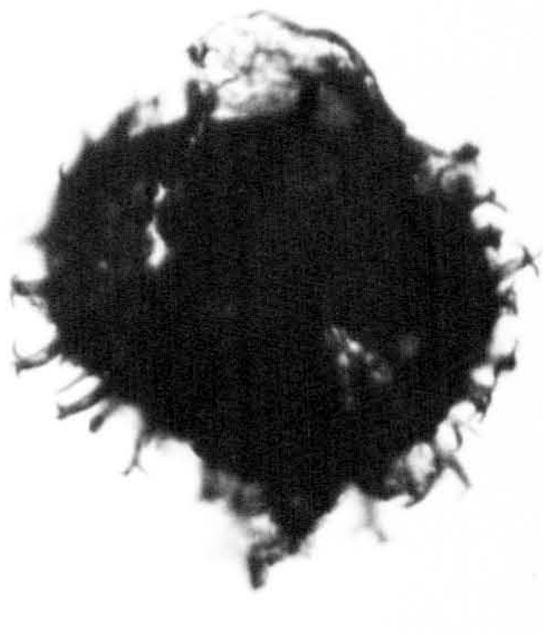

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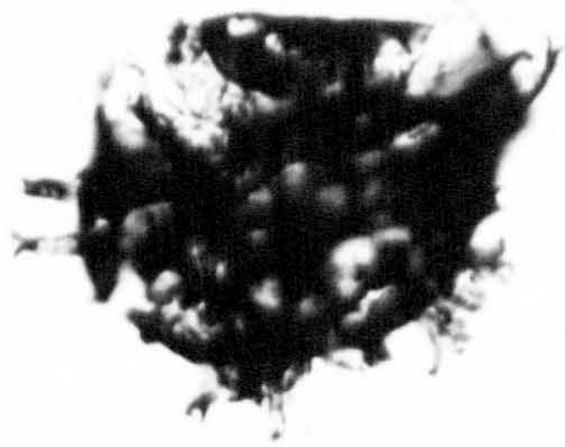

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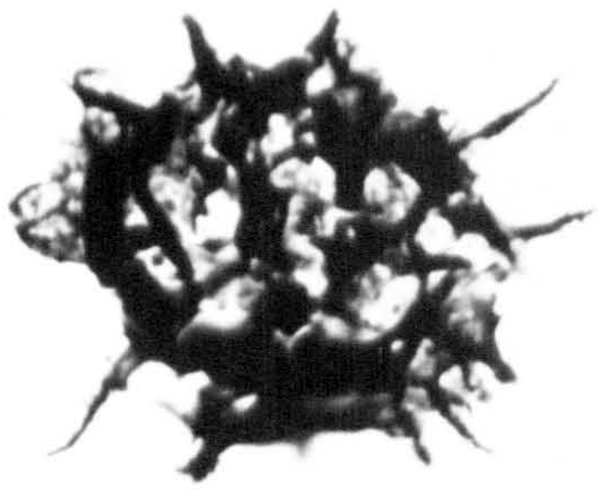

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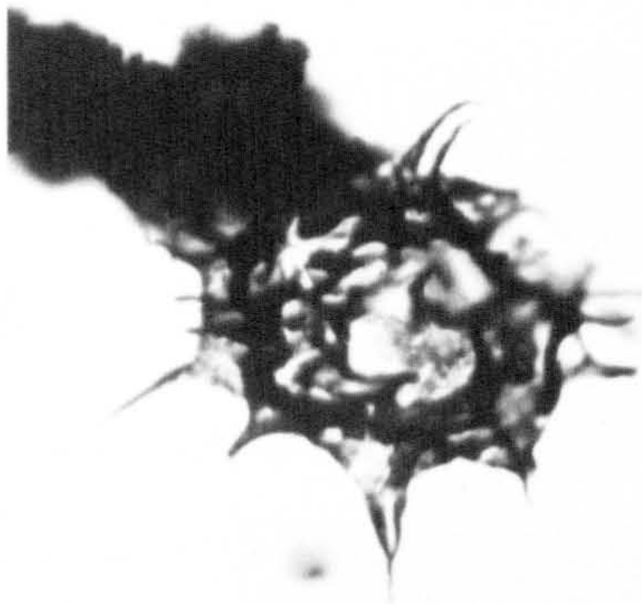

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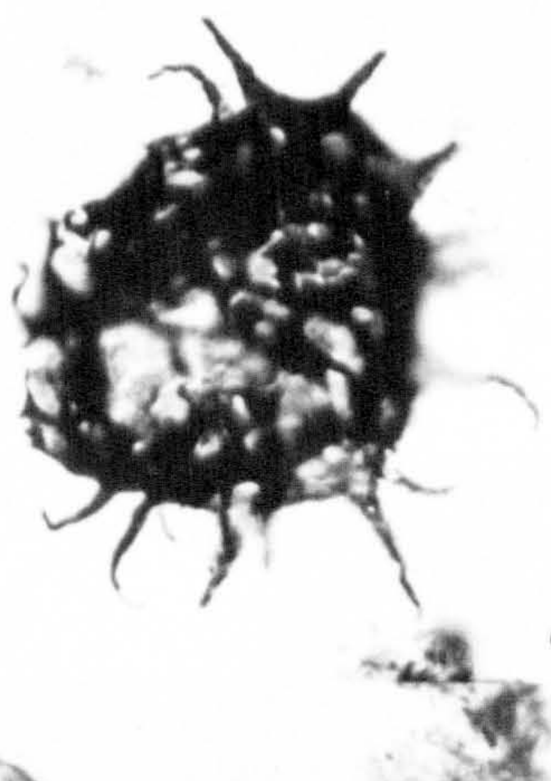

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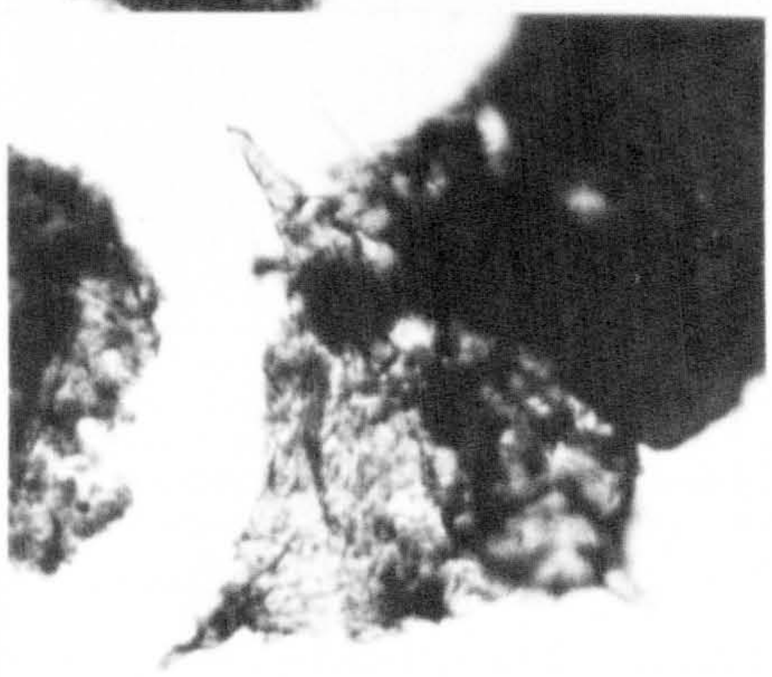

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PLATE 32

Microfloral assemblage from the Tarn Moor tunnel, Lake District, (Upper Llanvirn)

1.	Frankea longiuscula Burmann, 1970	SAL 2778	20	1	1	961	359	E41/3
2.	Veryhachium trispinosum Formgroup, Cramer, 1964	SAL 2778	20	1	1	1069	394	
3.	?Diacrodium ancoriferum var. minutum Burmann, 1968	SAL 2778	<20	1	1	1010	354	K41/4
4.	Frankea sartbernardense (Martin, 1966) Burmann, 1970	SAL 2778	<20	1	0.5	999	511	J25/1
5.	?Veryhachium minutum Downie, 1958	SAL 2778	<20	1	0.5	1036	490	N27/2
6.	?Elektoriskos? sp. A	SAL 2778	<20	1	0.5	1010	285	K48/4
7.	Baltisphaeridium? sp. A	SAL 2778	20	1	1	1019	488	L27/4
8.	Uncinisphaera? sp. A	SAL 2778	20	1	1	1104	488	U27/2
9.	Uncinisphaera? exilis sp. nov.	SAL 2778	20	1	1	1048	466	030/8
10.	Striatotheca cf. trigonia Burmann, 1970	SAL 2778	20	1	1	989	247	H52/4
11.	Nothoidium sp. A	SAL 2778	20	1	1	1046	477	029/1
12.	Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959	SAL 2778	20	1	1	1087	452	S31/4

PLATE 32

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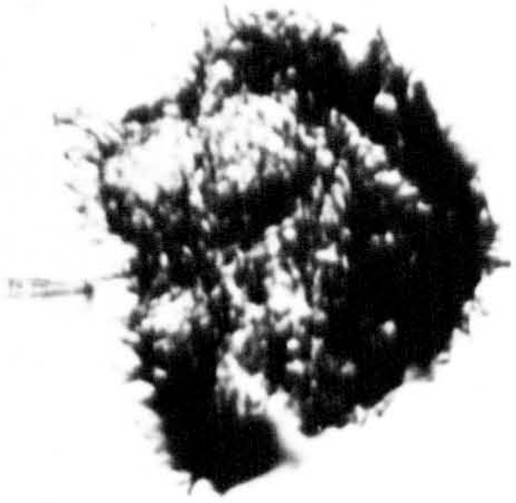

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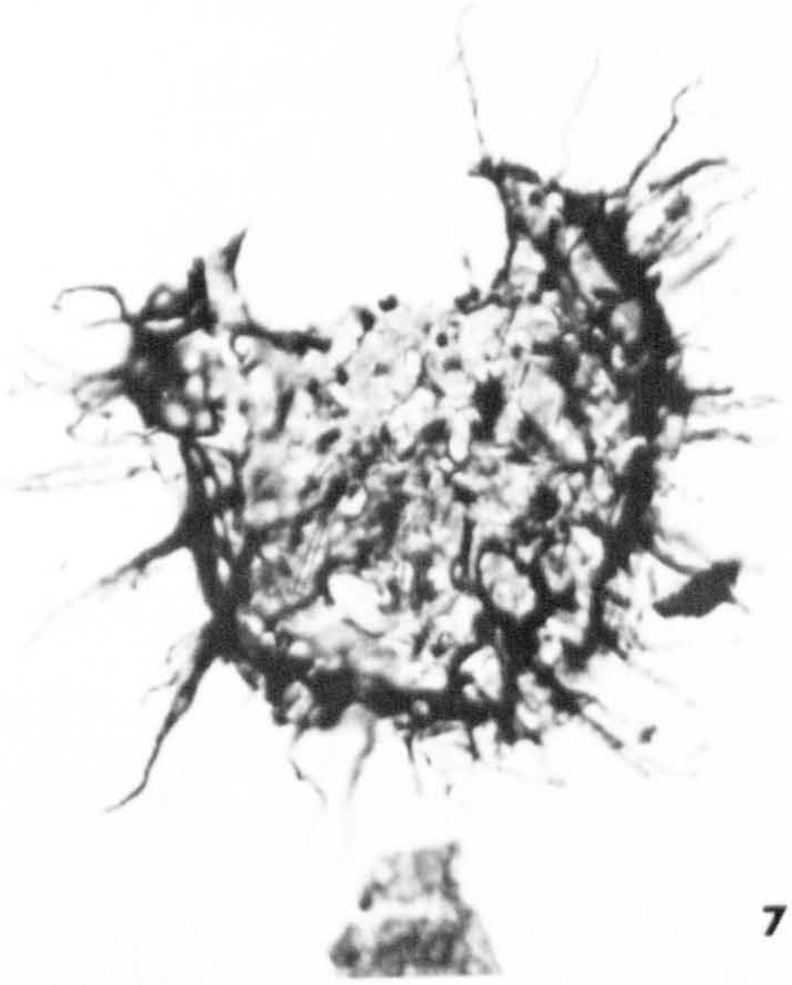

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PLATE 33

Microfloral assemblage from the Tarn Moor tunnel, Lake District, (Upper Llanvirn)

1. Multiplicisphaeridium maroquense Cramer et al., 1974a
SAL 2778 20 1 1 986 496 H27/1

2. M. maroquense Cramer et al., 1974a
SAL 2778 20 1 1 953 367 D40/3

3. Recavisentis uncinatus Downie, 1958 comb. nov.
SAL 2778 20 1 1 1026 352 N42/1

4. Dicrodiacrodium normale Burmann, 1968 var. normale nom. nov.
SAL 2778 20 1 1 945 349 D42/1

5. D. normale var. doliiforme Burmann, 1968
SAL 2778 20 1 1 1026 392 M37/2

6. D. normale var. doliiforme Burmann, 1968
SAL 2778 20 1 1 939 441 C32/2

7. Astropheos celestum Martin, 1969 comb. nov.
SAL 2778 20 1 1 1030 440 M32/4

8. Astropheos sp. A SAL 2778 20 1 1 996 276 J49/4

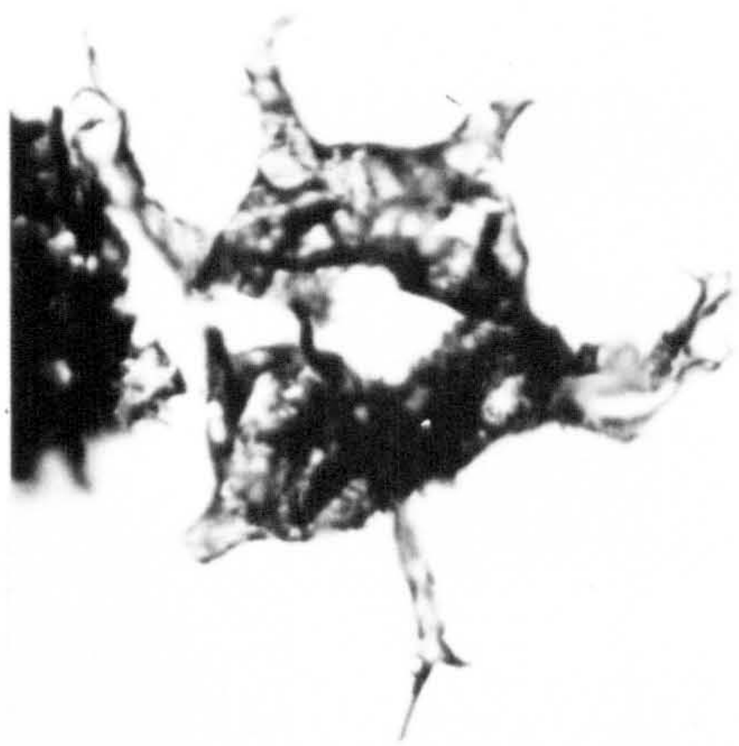
9. ?Tectitheca contracta Burmann, 1968
SAL 2778 20 1 1 950 491 D27/2

10. Stelliferidium distinctum Rasul, 1974 comb. nov.
SAL 2778 <20 1 1 1050 382 038/4

11. Striatotheca quieta (Martin, 1969) Rauscher, 1974
SAL 2778 20 1 1 1048 464 050/4

12. Villosacapsula cf. piliferum Martin, 1969 comb. nov.
SAL 2778 20 1 1 991 438 H33/3

PLATE 33



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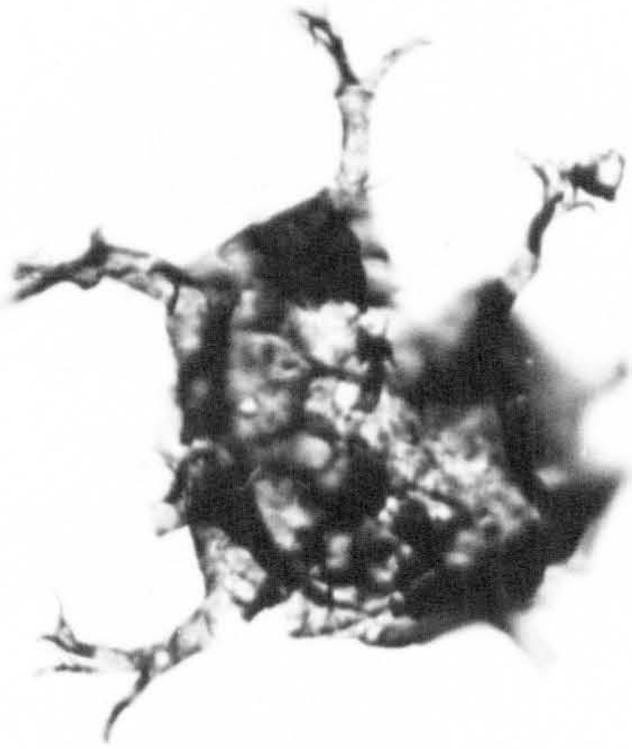

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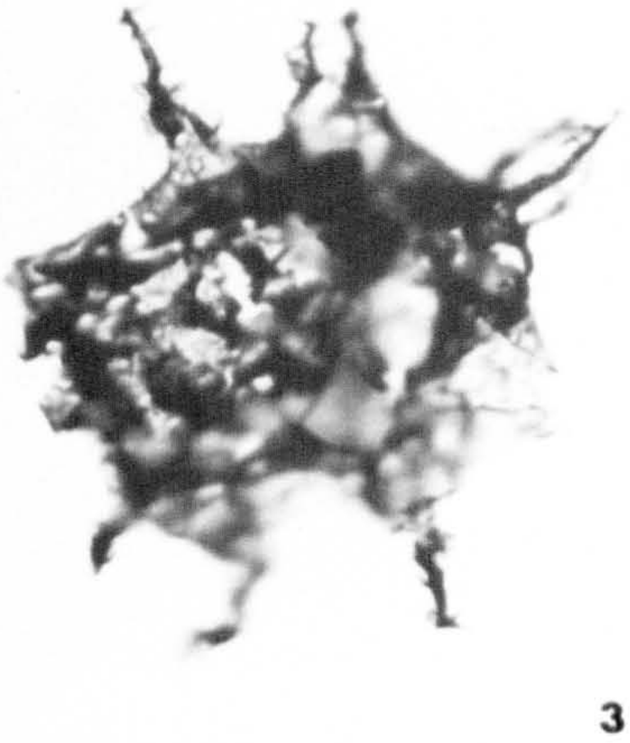

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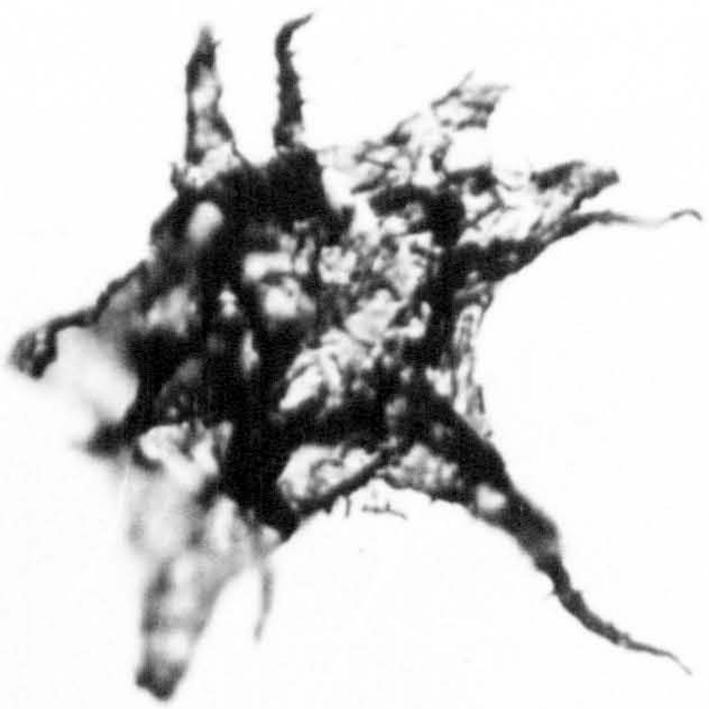

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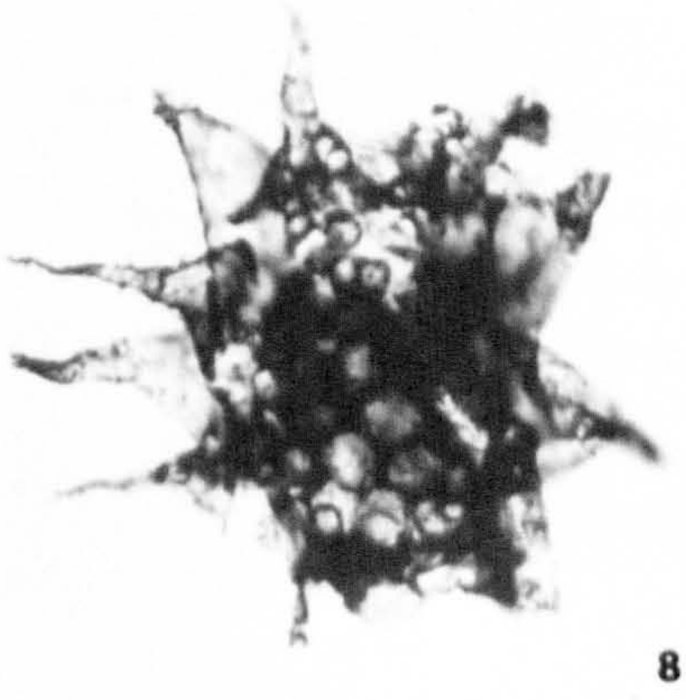

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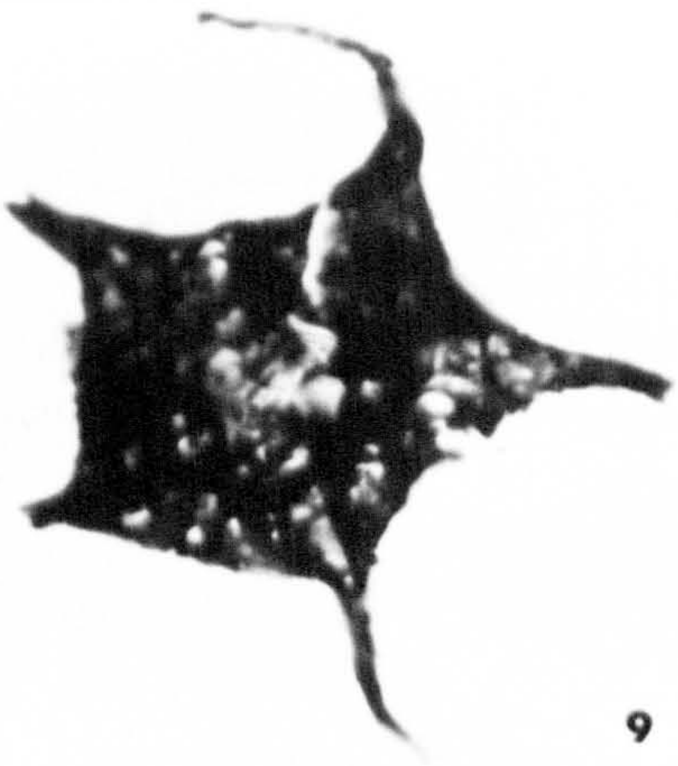

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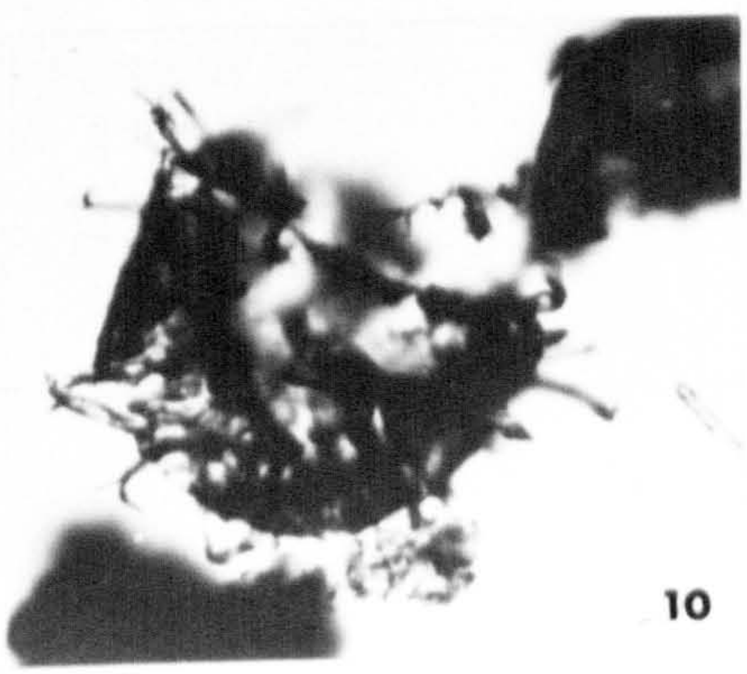

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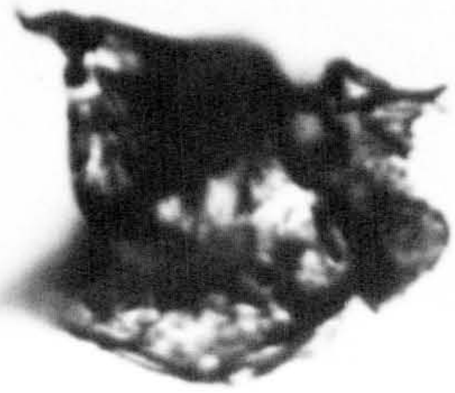

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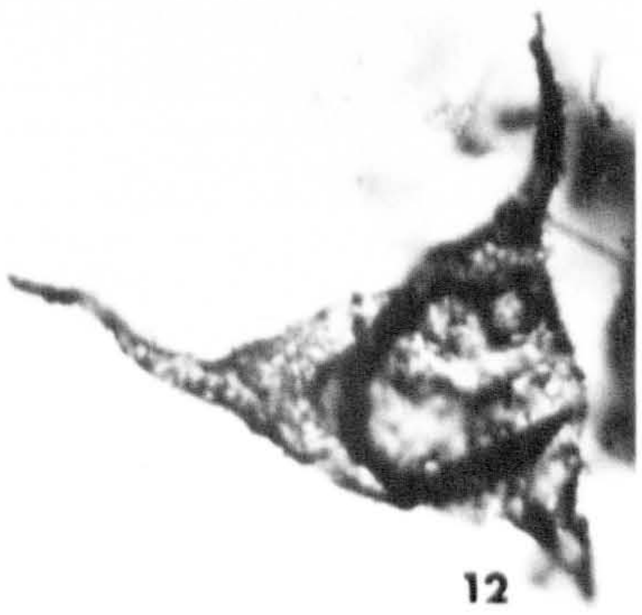

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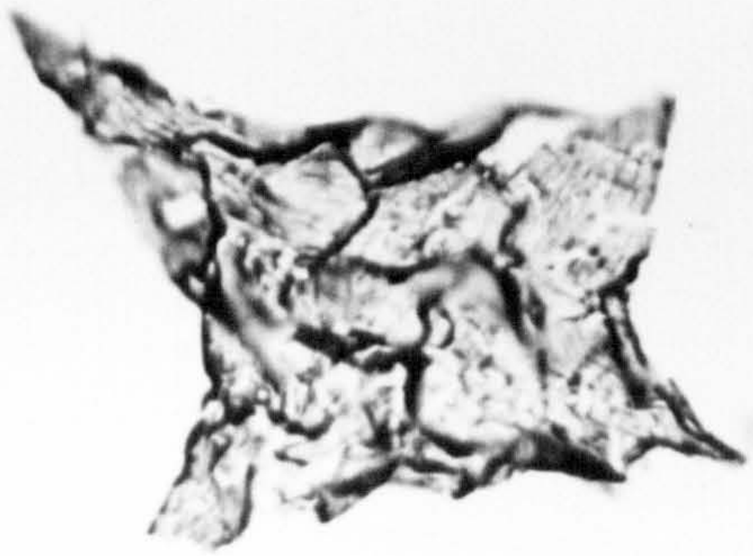
Microfloral assemblage from the Tarn Moor tunnel, Lake District, (Upper Llanvirn)

1.	Striatotheca frequens Burmann, 1970	SAL	2781	20	4	0	1084 299	S47/1
2.	Striatotheca quieta (Martin, 1969) Rauscher, 1974	SAL	2781	20	4	0	1050 314	045/4
3.	Elektoriskos? sp. A	SAL	2781	<20	1	0	1026 468	M29/2
4.	Uncinisphaera? exilis sp. nov.	SAL	2781	20	4	0	999 293	J48/3
5.	Veryhachium lairdii (Deflandre, 1946) ex Deunff, 1959	SAL	2781	20	1	0	1052 351	P42/1
6.	Nothooidium sp. A	SAL	2781	20	4	0	977 328	G44/1
7.	Dicrodiacrodium normale cylindricum Burmann, 1968	SAL	2781	20	4	0	969 461	F30/4
8.	Baltisphaera ternata Burmann, 1970	SAL	2781	20	1	0	1045 525	024/1
9.	?Stelliferidium distincta Rasul, 1974 comb. nov.	SAL	2781	<20	1	0	941 362	C41/3
10.	?Micrhystridium aremoricanum Paris & Deunff, 1970 comb. nov.	SAL	2781	<20	1	0	1041 515	N25/3
11.	Veryhachium minutum Downie, 1958	SAL	2781	<20	1	0	1049 265	050/4
12.	Micrhystridium sp. C	SAL	2781	<20	1	0	994 527	J23/2

PLATE 34



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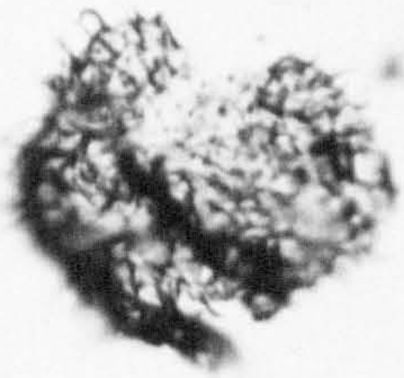

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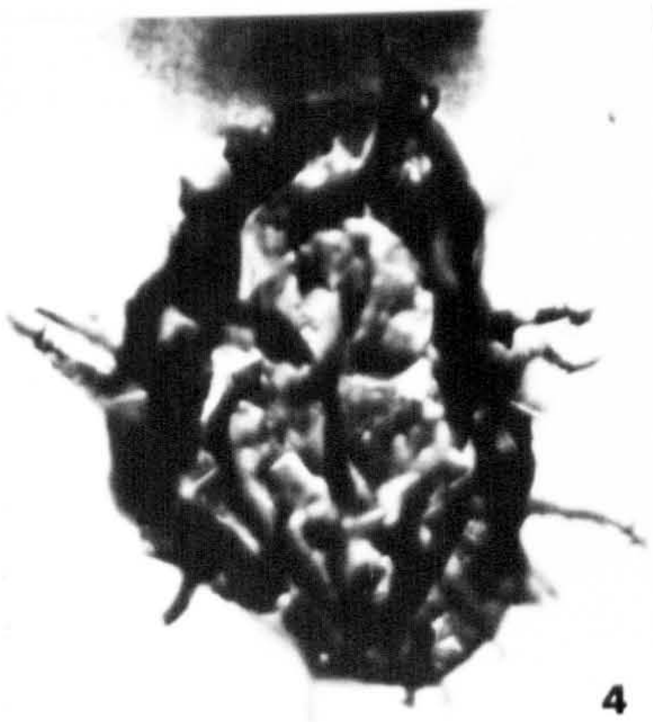

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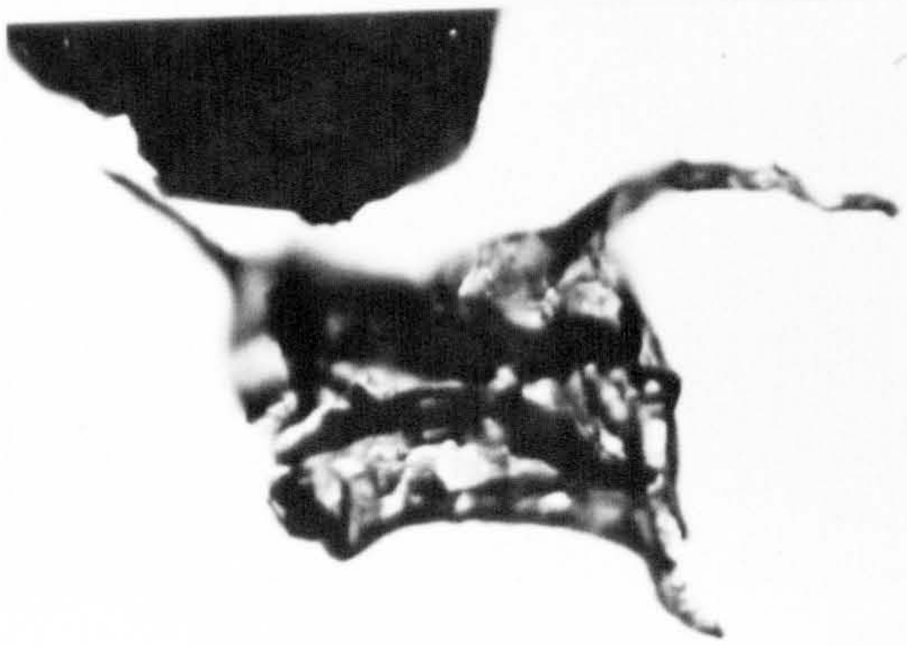

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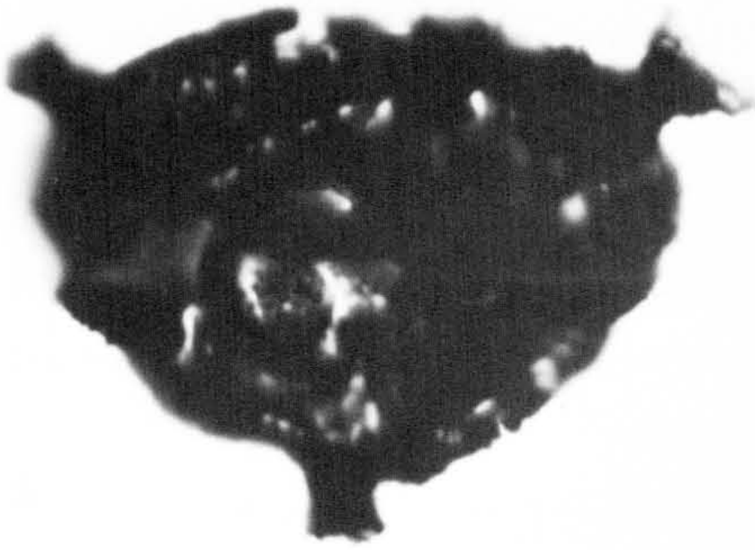

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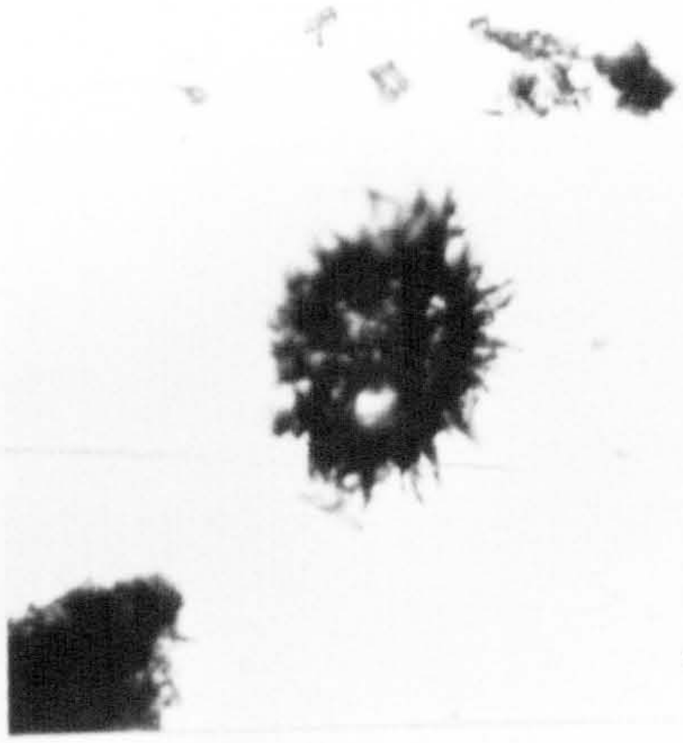

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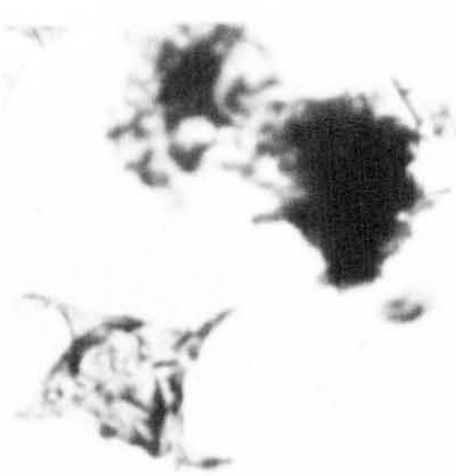


11

12

Microfloral assemblage from the Tarn Moor tunnel, Lake District, (Upper Llanvirn)

1. Astropheos celestum Martin, 1969 comb. nov.
SAL 2781 20 4 0 1100 329 U44/1

2. Frankea longiuscula Burmann, 1970
SAL 2781 20 1 0 1046 443 032/2

3. Recavisentis uncinatus Downie, 1958 comb. nov.
SAL 2781 20 4 0 1028 360 M41/3

4. Stelliferidium distinctum Rasul, 1974 comb. nov.
SAL 2781 20 4 0 961 446 E32/3

5. Stelliferidium fimbrium Rasul, 1974 comb. nov.
SAL 2781 20 4 0 1016 287 L48/2

6. Astropheos sp. A SAL 2781 20 4 0 1071 341 R43/1

7. Culcitispina? sp. A SAL 2781 20 4 0 1067 405 Q36/3

8. Stelliferidium sp. SAL 2781 20 4 0 1111 509 V25/2

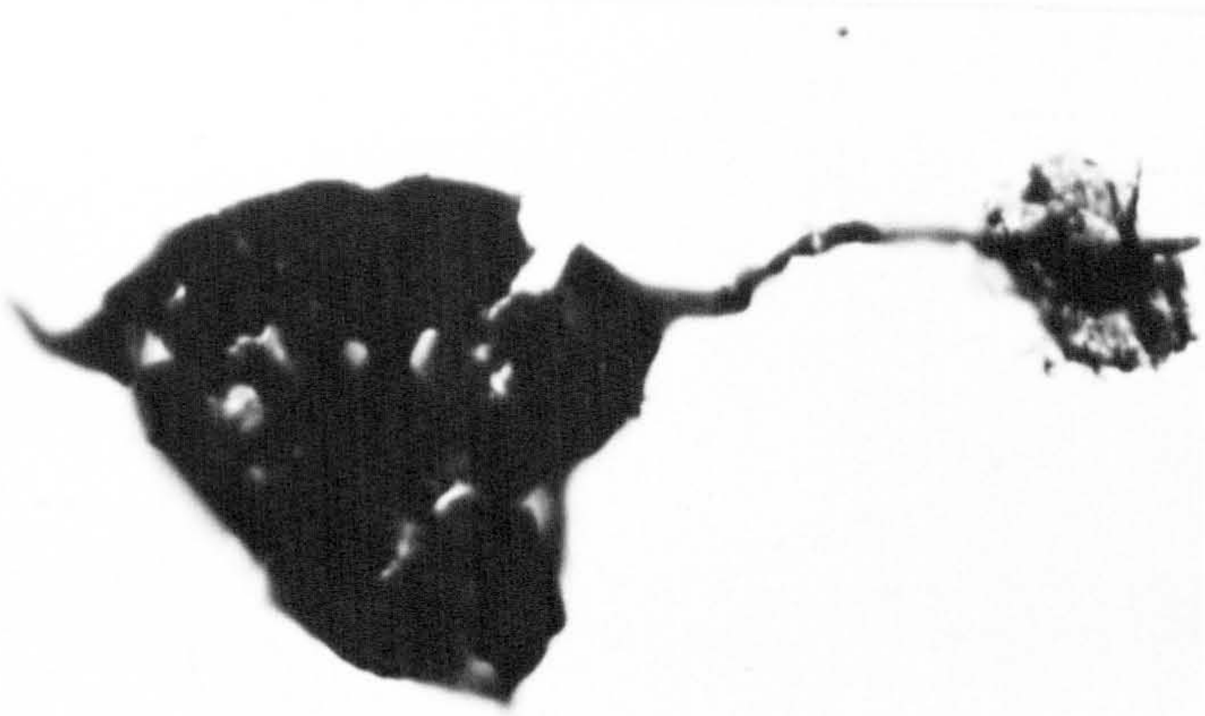
9. ?Multiplicisphaeridium maroquense Carmer et al., 1974a
SAL 2781 20 1 0 1013 451 L31/2

10. Frankea hamulata Burmann, 1970
SAL 2781 <20 1 0 1043 421 034/2

11. Veryhachium trispinosum Formgroup, Cramer, 1964b
SAL 2781 20 4 0 1058 398 P37/3

PLATE 35

1



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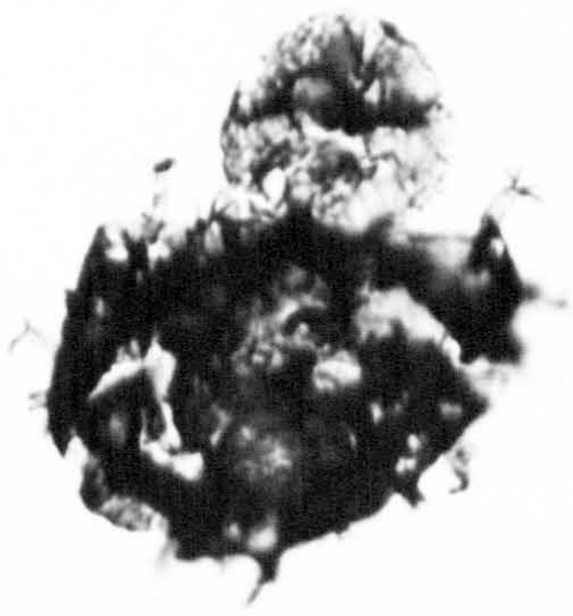

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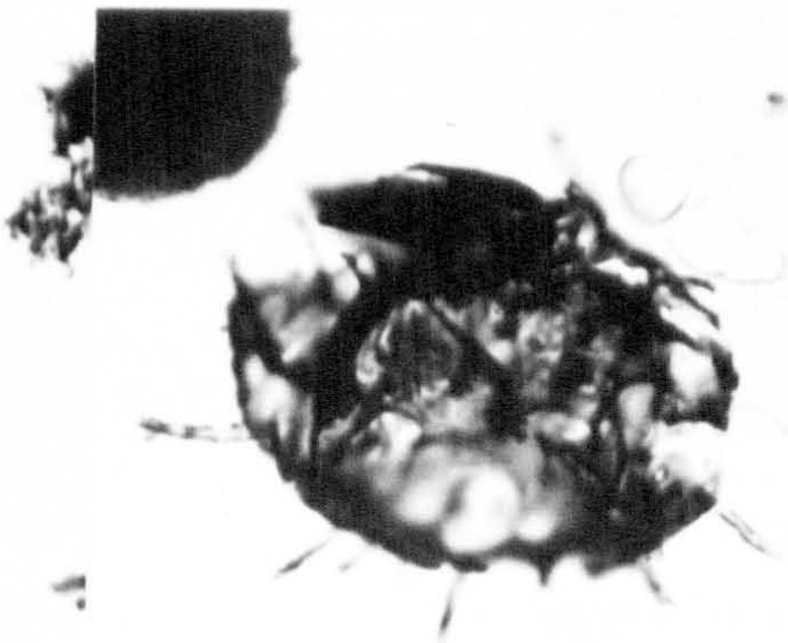

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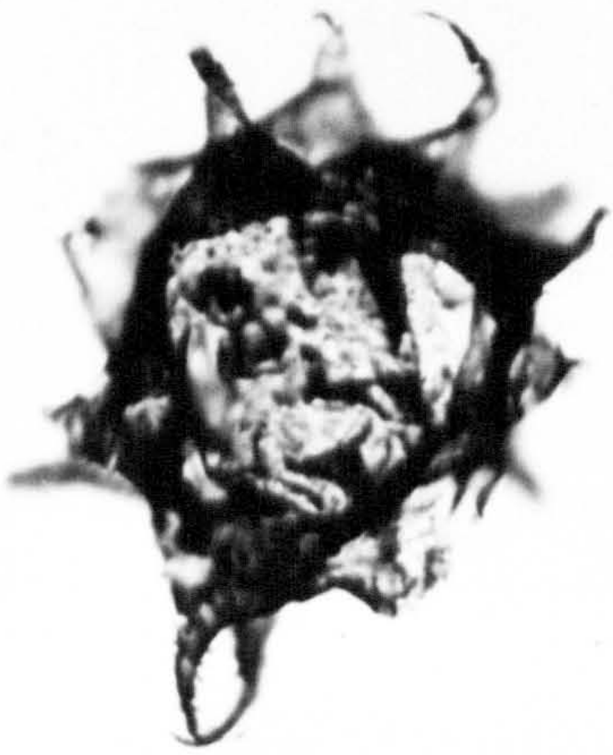

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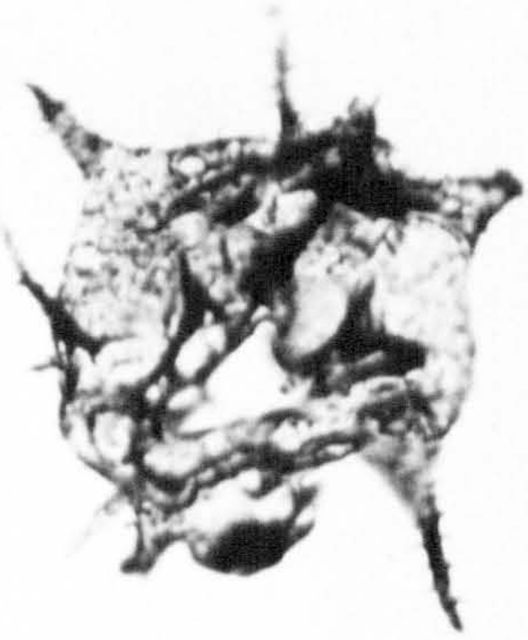

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