A Proterozoic Microbiota from the Roper Group, Australia

by

Christopher John Peat

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Abstract

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The Roper Group (c.1400 x 10^6 yr old) is a shallow water sequence of sandstones, siltstones and shales, with minor carbonates and sub-economic oolitic ironstones. The depositional environments of the Group range from fluvial through deltaic to estuarine or marine.

Core samples of shales from the McMinn Formation at the top of the Group have yielded a diverse assemblage of organic-walled microfossils (OWMs) which includes many new forms. Some of these OWMs excyst to release endospores and were probably eukaryotic while others show evidence of life cycles. These new microfossils show that many OWM taxa previously considered to be unrelated could be degradational or developmental forms of the same organism. It is also clear that indistinguishable OWMs could be produced by the fossilisation of fundamentally different living organisms.

Current approaches to the classification of OWMs are reviewed, and it is argued that OWMs cannot be classified in the same system as living microorganisms because they do not show the necessary characters. Morphological characters useful for the classification of OWMs are evaluated and ranked, and these characters are used to develop keys and a new system of classification.

A computerised data base system (Foscat) has been developed to deal with information on the occurrence, distribution, classification and nomenclature of fossils. The structure and operation of Foscat are described, and it has been used to produce a comprehensive catalogue of relevant material.

Foscat has been instrumental in reviewing the status and nomenclature of known OWM taxa. These taxa have been critically evaluated and classified with the new Roper Group microfossils according to the new system suggested here. These studies allow the Roper Group assemblage to be seen in perspective, and can be expected to result in a radical reassessment of Precambrian evolution, and to contribute substantially to the development of a practical Precambrian biostratigraphy.

To Irene

"

'So careful of the type'? but no.
From scarped cliff and quarried stone
She cries, 'A thousand types are gone:
I care for nothing, all shall go.'

"

In Memoriam
Tennyson

Acknowledgments

The palaeontological potential of the Roper Group was first recognised by Dr. M. D. Muir, who arranged support for this project and supervised my work. In return for her kindness, practical advice and effervescent enthusiasm I can only say 'Thanks Boss' and hope that this report is up to the standards you set.

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Chapter 1

Introduction

The aim of this study is to describe the fossil microbiota of the McMinn Formation of the Roper Group, Northern Territory, Australia and to compare it with other Precambrian fossil assemblages.

This work has led to a review of Precambrian fossil occurrences, a new approach to the classification of organic-walled fossil microorganisms and an assessment of the potential use of organic-walled microfossils in Precambrian biostratigraphy.

The McMinn Formation of the Roper Group was drilled and cored by the Broken Hill Proprietary Company Limited (BHP) in 1958 and 1961 while prospecting the Sherwin Ironstone Member (Bennett, 1959; Vivian, 1962). The greater part of this core is stored in a shed at the former Gum Creek camp at Sherwin Creek (c. 14°43'S, 134°17½'E) and has been presented to the Northern Territory Department of Mines (NTDM). Stratigraphic columns were drawn up by K. A. Plumb in 1959 (Bureau of Mineral Resources (BMR), Darwin office, now NTDM) from unpublished company reports and core logs (Appendix 1) while some scientific observations on the ironstones were published by Cochrane & Edwards (1960).

Samples of the black shales were collected for organic geochemical studies (Hoering, 1967; McKirdy, 1971, 1974) and one sample (DDH-U37-120'-166' *) yielded a "moderately abundant assemblage of somewhat corroded microfossils, dominated by sphaeromorph acritarchs" (Norvick, 1970). This discovery was not pursued and in 1972 a further 14 samples

* This sample numbering convention is used throughout and means Diamond Drill Hole number U37, sample from depth interval 120'-166'.

were collected by K. A. Plumb (BMR) and sent to M. D. Muir, Royal School of Mines, London, who realised the significance of the assemblage and arranged for further studies to be made.

Most presently known assemblages of Precambrian fossils come from diagenetic cherts in stromatolitic carbonate sequences. These sediments have given very little information about the Precambrian planktonic microbiota and it was hoped that the McMinn shales and mudstones would provide new comparative data. This hope has been realised, though the variety and advanced nature of the biota has at this stage led me to speculate more about the reliability of the radiometric dating of the Roper Group than to consider any radical reassessment of Precambrian evolution (See Chapters 2, 9 and 10).

To try to obtain more information on the ultrastructure and composition of the fossils, some new techniques have been developed. The most useful of these makes it easy to examine the same microfossil by light microscopy (LM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) (See Chapter 4).

So far there have been no detailed studies on the classification of microfossils of the type described here. This is because such fossils have hardly been used in post-Cambrian stratigraphy, and because their potential for Precambrian stratigraphy is only just being investigated.

Because of the simple structure of some genuine fossils, there are many reports in which abiogenic structures, preparational artifacts and contaminating microorganisms have been described as the remains of Precambrian microorganisms. Some spherical fossils have been referred to

the sphaeromorph acritarchs while other spheres and morphologically different forms have been questionably treated as relatives of living microorganisms. Fossils of this general type have also been encountered throughout the geological column and have often been described as new genera with inadequate descriptions and comparisons. This fragmented approach has produced a plethora of overlapping taxa, often with names of uncertain validity.

These problems have been attacked by reviewing current approaches to the classification of organic-walled microfossils (OWMs) and reconsidering the biological and palaeontological information the OWMs convey. It is argued that OWMs cannot be classified in the same system as living organisms because they do not show the necessary characters. A morphological scheme of classification in which OWMs are divided into acritarchs and cryptarchs is suggested (See Chapter 5). Morphological characters that could be used in the classification of cryptarchs are reviewed and discussed, and arranged in a hierarchy (See Chapter 6). This hierarchy is then used to subdivide the cryptarchs and to develop a set of keys to morphologically similar groups of taxa. A number of cryptarch taxa have been critically evaluated and are classified together in a unified system for the first time (See Chapter 7).

An attempt has also been made to catalogue previously reported Precambrian fossils and other relevant OWM taxa with the object of reviewing their interpretation, nomenclatural standing and synonymies, and of assessing their potential usefulness as time markers in Precambrian stratigraphy (See Chapter 8 & microfiche inside back cover).

Finally, the Roper Group microbiota is described and classified according to the principles developed here. These studies allow the Roper Group microfossils to be seen in perspective and can be expected to result in reassessments of Precambrian evolution and the way in which OWMs are interpreted. They can also be expected to contribute substantially to the development of a practical Precambrian biostratigraphy.

Chapter 2

Geology

A. General

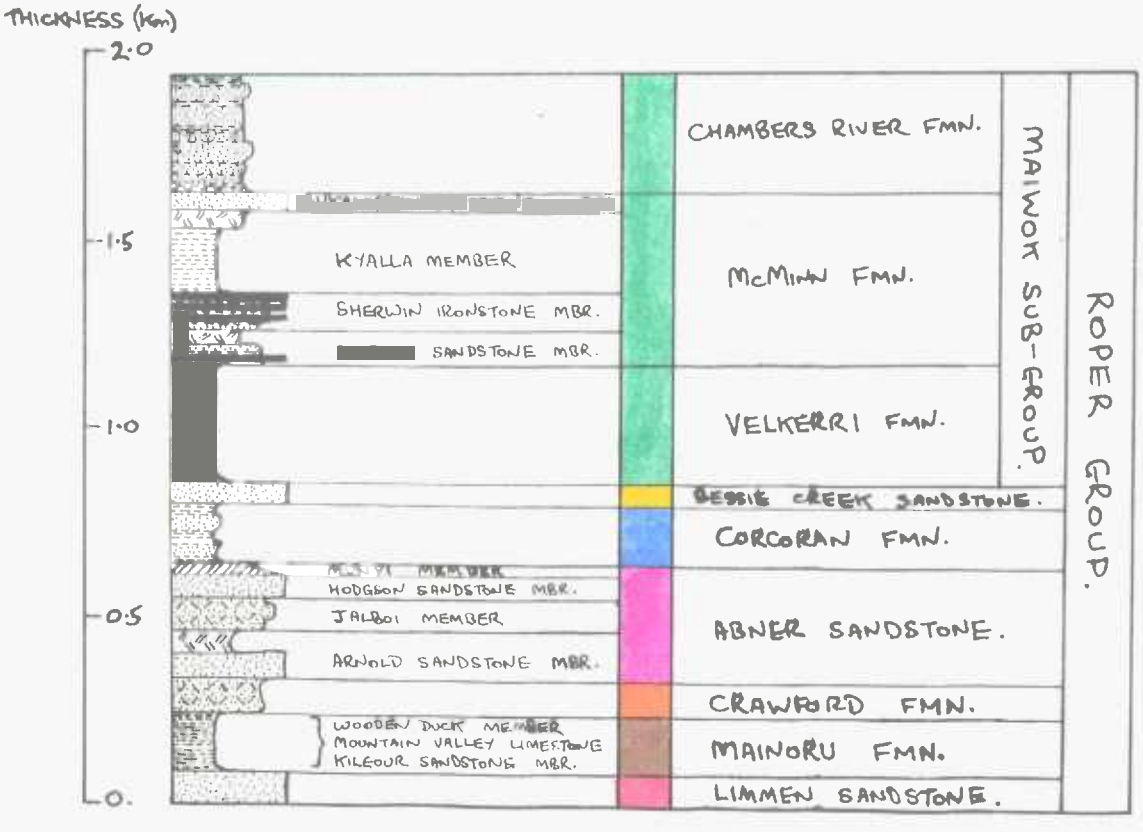
The sediments of the Roper Group outcrop over the area shown in Figure 1. This area is covered by BMR 1:250,000 geological maps with explanatory notes from which the data for Figures 1-4 have been taken (Dunn, 1963a, 1963b, 1963c; Dunnet, 1965; Paine, 1963; Plumb & Paine, 1964; Plumb & Rhodes, 1964; Plumb & Roberts, 1965; Randal, 1963; Rix, 1965; Roberts & Plumb, 1965; Roberts, Rhodes & Yates, 1963; Smith, 1964; Yates, 1963).

The sequence is mainly sandstone, with one thin carbonate member (Mountain Valley Limestone) near the bottom and with more shale towards the top. No stromatolites have been found. I saw no shale sequences thicker than 1m, and the shale usually occurs as thin (0.5-3cm) laminae separated by medium grained sandstones. In outcrop the shales soon weather out, leaving sandstone slabs. The Velkerri Formation is described as a continuous shale section, but has weathered so badly that its presence in the field is inferred by white (as opposed to red or brown) termite mounds (K. A. Plumb, pers.comm.). However, this formation does have a distinctive air photograph pattern, and in fact all of the other rock units show up clearly on air photographs. The sandstone units are easily distinguished in the field by their characteristic joint patterns and weathering.

FIGURE 1

ROPER GROUP: OUTCROP AREA AND STRATIGRAPHIC COLUMN





AFTER K.A. PLUMB.

SANDSTONE
SHALE SILTSTONE.
QUARTZ GREYWACKE.
CHAMOSITIC. OR SIDERITIC. SANDSTONE
DOLERITE INTRUSIVES
OOLITIC. HAEMATITE HAEMATITIC. SANDSTONE

Figure 2 was constructed by rotating the 1:250,000 sheet grid by 45° and plotting vertically the thickness of the various formations of the Roper Group in the centre of each grid square. To give a better fit and three-dimensional effect, the base of the Mainoru Formation was taken as the datum level. The Bauhinia Downs Sheet has three constructions as thickness estimates for West, centre and East of the sheet area were given (Smith, 1964, Table 3).

It is immediately apparent that the Roper Group represents a basin which subsided more rapidly in the South. This picture is consistent with sedimentation to the North and West of the Batten Trough following the deposition of the McArthur Group to the South (Plumb & Derrick, 1976; Plumb, 1979).

To the North and East of Fig.2 the Roper Group disappears under the late Proterozoic/early Palaeozoic of the Arafura Basin, while to the West it lies under relatively thin Cretaceous cover. The Northern half of the outcrop lies in the Arnhem Land aboriginal reserve which prevents casual access. In the South the Roper Group disappears under a flat semi-desert of Cenozoic sands and lateritic soils with occasional limited outcrops of Cambrian strata. Nothing is known of the rocks beneath the Cambrian in this region.

The relationships of the Roper Group to nearby rock units are shown in Fig.3. The Proterozoic geology of northern Australia has been reviewed by Plumb & Derrick (1976) and the general tectonic situation by Plumb (1979). A general account of Australian Proterozoic geology is given by Brown et al (1968, Chap.1.). The following account of the general geology and depositional environment of the fossiliferous part of the McMinn Formation is based on Peat et al (1978).

FIGURE 2: EXTENT OF ROPER GROUP SEDIMENTS

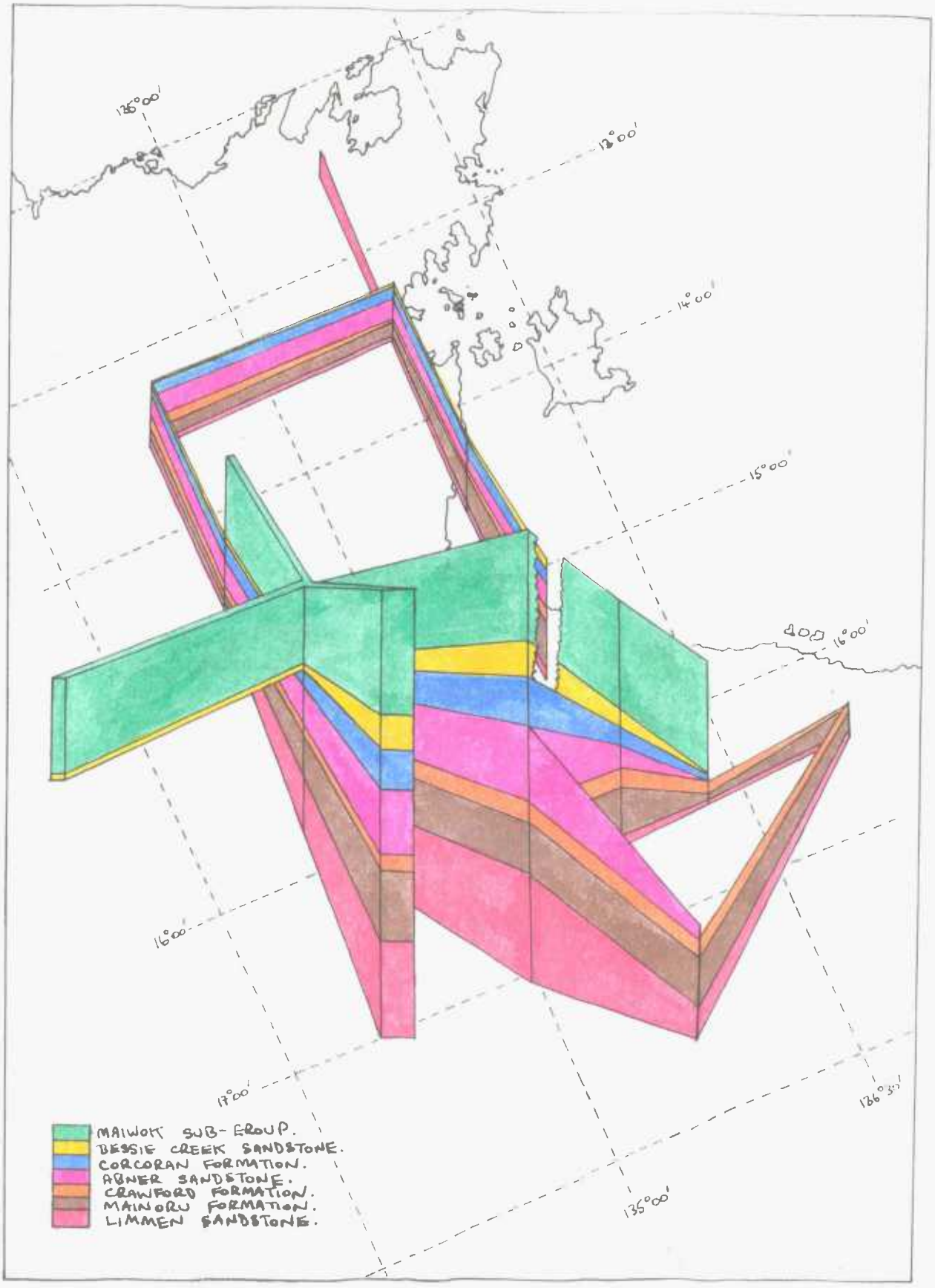
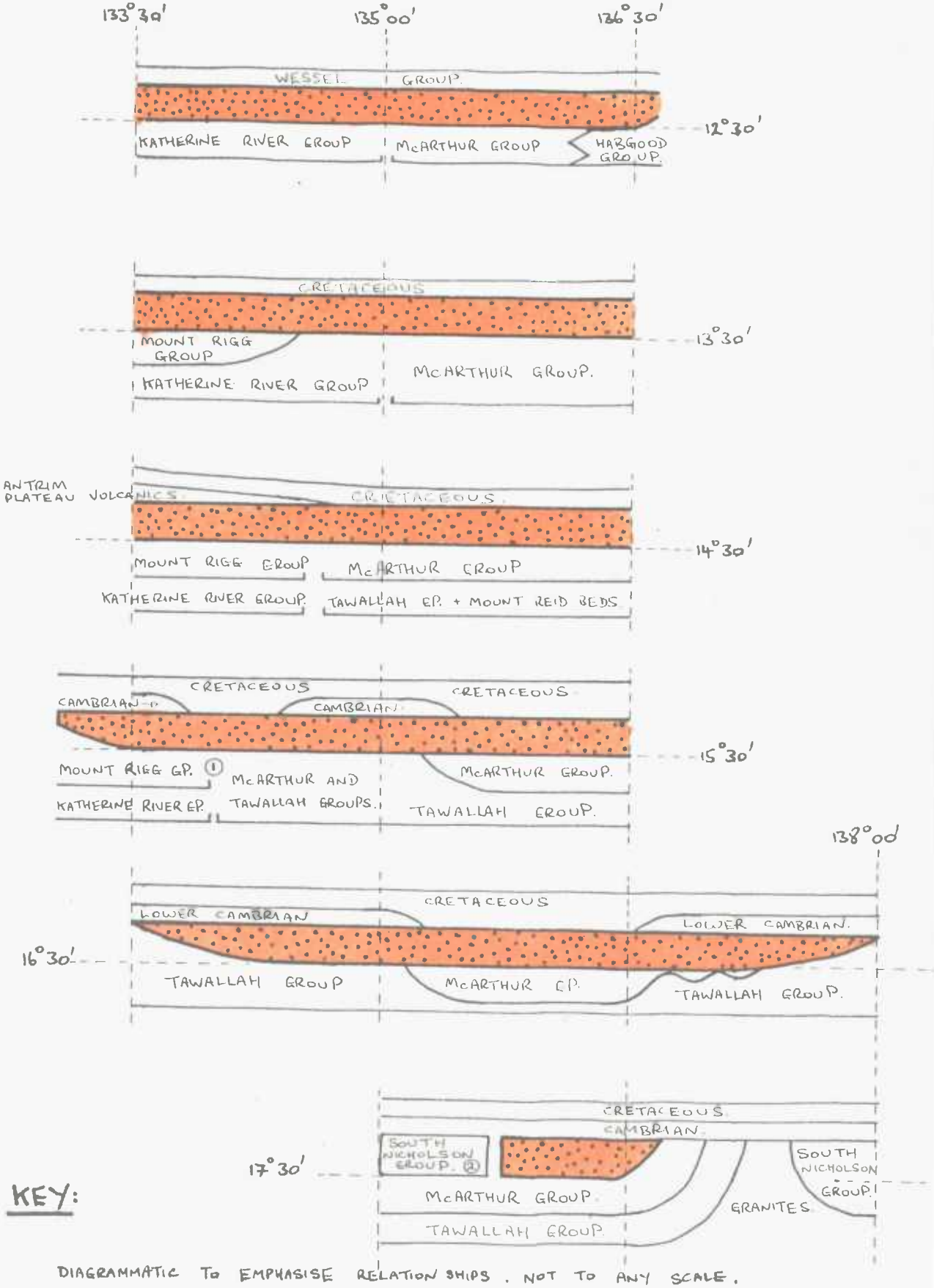


FIGURE 3: STRATIGRAPHIC POSITION OF THE ROPER GROUP



KEY:

DIAGRAMMATIC TO EMPHASISE RELATIONSHIPS. NOT TO ANY SCALE.

: ROPER GROUP.

: UNCONFORMITY.

① : STRANGEWAYS FAULT.

② : THE SOUTH NICHOLSON GROUP IS LATERALLY EQUIVALENT TO THE ROPER GROUP, BUT ONLY OUTCROPS IN THE EXTREME SOUTH OF THIS AREA.

The Roper Group represents the upper succession of the McArthur Basin and unconformably overlies the carbonate-rich McArthur Group, which in turn rests on the quartz-arenite/ basic volcanic suite of the Tawallah Group and its equivalents. The McArthur Group is a rich source of microfossils from various facies (Croxford et al, 1973; Muir, 1974, 1976; Hamilton & Muir, 1974; Oehler, J. H. 1977; Oehler, D. Z. 1978) and contains a wide variety of stromatolites.

The Roper Group comprises an unstable shelf association of mica-rich siltstones, shales and quartz greywackes, alternating with well sorted pure quartz sandstones. The quartz sandstones are characterised by abundant medium scale high-angle cross beds and ripple and rill marks. The interbedded quartz/greywacke/ siltstone sequences have a spectacular abundance and variety of sedimentary structures - medium to small-scale low angle cross-beds, ripple marks, rill marks, swash marks, shale clasts, mud cracks, flute casts, brush and tool marks, braided channel casts, step moulds, current scours (toroids), crystal casts and slump folds (See Chapter 3). Glauconite is a common constituent. Thick shales and siltstones are generally laminated, may have calcareous interbeds, and range through black, grey, grey-green, olive-green and brown in colour.

The major rock units are continuous over wide areas, but while the quartz sandstones are relatively uniform the other units show significant lateral facies changes. The microfossils described here come from the Kyalla and Moroak Sandstone Members of the McMinn Formation which comprises flaggy interbedded variegated grey, olive-green and brown to black shales, micaceous siltstones and fine to medium grained sandstones. Interbeds of blocky sandstone and black carbonaceous shale (sometimes pyritic) occur near the base, and there are localised occurrences of carbonate towards the top.

Discontinuous bands of sub-economic ironstone at or near the base of and interfingered with the Kyalla Member are mapped together as the Sherwin Ironstone Member. Up to three major bands of ironstone are found, comprising combinations of haematite oolites, greenalite oolites, chamosite and quartz grains set in a matrix of siderite. A fourth minor ironstone band is present within the Moroak Sandstone Member; air photo interpretation has probably resulted in the mapping of adjacent iron-stained sandstones as ironstone outcrop around 15°10'S 133°55'E.

The siderite partially replaces the greenalite and haematite and in weathered outcrop is itself replaced by silica (Cochrane & Edwards, 1960). Interbeds of fine grained chloritic sandstone and black micaceous-pyritic-carbonaceous shale, studded with greenalite granules occur within and separating the ironstone bands. Cross beds are present in the haematite oolite beds and intraformational ironstone conglomerates are found locally.

Detailed sedimentological studies have not yet been carried out on the Roper Group, but the overall association of mineralogical textures and sedimentary structures suggests alternating shallow-marine, transitional and fluviatile environments for the Group as a whole.

The regional setting of the basin (Plumb & Derrick, 1976) is that of a broad epicontinental shelf (of the order of 400 x 600 km), probably bordered by land on most sides. A variety of local environments is to be expected in such a setting, from open shelf, barrier systems, tidal channels and flats to lagoons, estuaries, rivers and lakes. Local areas of restricted circulation are common in estuaries, lagoons and sea-floor depressions.

The repeated upward-fining sequences and the structures indicating strong current action and periodic desiccation suggest a fluviatile origin for the Moroak Sandstone Member. The degree of sorting and paucity of coarse material indicates a distant source area and the most likely environment would seem to be near the outer limit of fluvial influence, perhaps extending into tidal channels. In comparison, the types of lutite in the Kyalla Member and their regularly interbedded rock types, laminations and desiccation features indicate restricted or transitional marine environments (barred basins, lagoons or tidal flats). The vertical progression of facies therefore points to the Sherwin Ironstone Member being deposited in a shallow restricted marine environment at or near to the interface with terrestrial or fluvial influence.

The Sherwin Ironstone Member contains all four facies of iron formation - sulphide, carbonate, silicate and oxide - described by James (1954), and they are all closely interbedded and intermixed. For example, oxides (haematite) and silicates (greenalite) occur in carbonate (siderite) cement, and silicate (greenalite) occurs in sulphide (pyritic black shale). These facies were each supposed to require distinctly different physico-chemical conditions for their precipitation, but recent studies (Curtis, 1977) have shown that the facies could easily be the result of changing rates of sedimentation and differential diagenesis.

The microfossils are best preserved within black pyritic carbonaceous and micaceous shales; most of the organisms probably lived as free-floating plankton and were then transported and dropped into their present position with other detritus. A few colonies are preserved in their positions of growth but most of the other forms, judging by their attitudes in the sediment and varied preservation, had been washed around or recycled for some time before final deposition took place.

B. Radiometric Age

The age of the Roper Group is generally taken to be about 1,400 Ma on the basis of various radiometric age determinations reported and reveiwed by McDougall et al (1965). Glauconites from the Crawford Formation gave ages of 1100-1280 Ma (K-Ar) and 1270-1390 Ma (Rb-Sr). Leakage of radiogenic strontium was suspected, and 1390 Ma was taken as a minimum age for the formation. Samples of dolerites intruding the Roper Group gave ages of 1220 and 1280 Ma (K-Ar) from plagioclase and 1150 Ma from a pyroxene.

Although not competent to criticise the methodology of these age determinations, I have treated these numbers with some reserve. My reasons are

1. The microflora of the McMinn Formation (Chapter 5) most resembles the late Precambrian biotas of Scotland (Torridonian), Eastern Europe (Baltic Stage) and Russia (Vendian), and these biotas are consistently dated as 800-900 Ma.
2. The Wessel Group, which lies unconformably above the Roper Group was "clearly" dated as Precambrian on one glauconite sample which gave ages of 770 Ma (K-Ar) and 790 Ma (Rb-Sr). 780 Ma was taken as a minimum age, despite the occurrence of Scolithus in the bottom unit. The discovery of a middle Cambrian trilobite fauna in the upper part of the Wessel Group (Plumb, Shergold & Stefanski, 1976) makes the radiometric age about 230 Ma too old. A similar error in the Roper Group determinations would make it about 1000 Ma.
3. The internal consistency of the Roper Group dates led to the acceptance of supportive but less reliable ages and the rejection of some dates which did not fit the Roper Group story. For example, a single glauconite sample from the underlying Mount Rigg Group gave ages of 1210 Ma (K-Ar) and 1255 Ma (Rb-Sr), while a model lead age on a galena sample gave about 1260 Ma. If the Mount Rigg Group was only 1250 Ma

old, the Roper Group would be unlikely to be older than 1100 Ma.

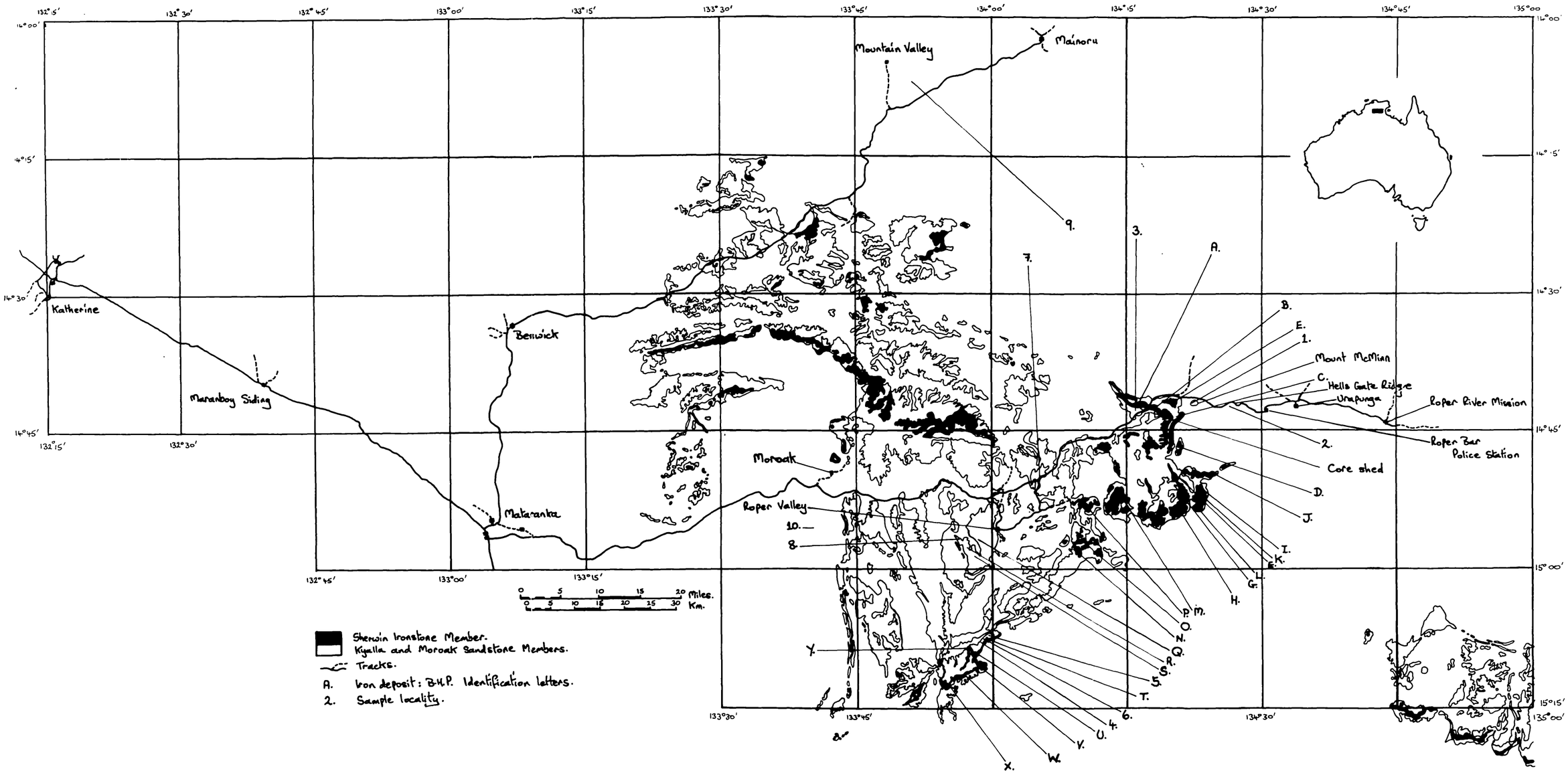
4. All the Roper Group age determinations were made on surface samples, some of which are of uncertain provenance, and all of which could have been severely affected by weathering.
5. The work reported in McDougall et al (1965) was done in the late fifties and early sixties before dating methods achieved their present sophistication.

A recent attempt to obtain a direct estimate of the age of the fossiliferous shales was unsuccessful (Webb, 1973) but almost the whole of DDH-B7 has now been transferred to the Australian National University for radiometric studies by M. Kvalile, a postgraduate student of W. R. Compston (M. D. Muir, pers.comm. 1978). Until new reliable data become available, it will be clear from the points raised above that I favour an age of around 1000 Ma for the Roper Group, more from an intuitive feeling that the fossils are too advanced to be older than on any firm data. However, some of the radiometric ages in the area have been shown to be rather mysterious and for the present it seems best to treat them all with caution.

C. Field Observations

Routes and sampling localities are shown in Fig.4: this area is covered by the Urapunga and Hodgson Downs sheets (Dunn, 1963a, 1963b). The whole of this northern part of Australia was submerged and peneplaned during the Cretaceous period, and subsequent uplift, erosion and slight warping have produced a dissected table land where gently dipping resistant beds form prominent strike ridges (Dunn, 1963a, 1963b; Fig.5).

FIGURE 4 : LOCALITY MAP



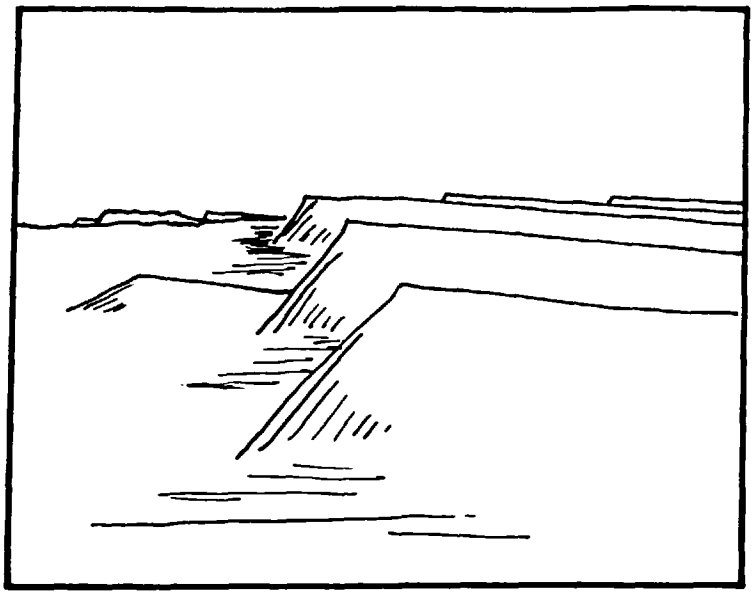


FIGURE 5 : DISSECTED TABLE LAND

The climate is now monsoonal: only the largest rivers flow during the dry season while in 'the wet' most of the land is under water and access impossible. Roads and water courses change their position every year, so topographic maps are of little use though air photographs and geological maps make navigation reasonably straightforward. The road from Mataranka Siding to Roper Bar is now intermittently sealed and hence semi-permanent as far as the Strangeways River, and it has been improved and well graded all the way to Roper Bar. Its course is not as shown on the Urapunga sheet map (Dunn, 1963b) but cuts from Boomerah Lagoon just South of MacDougall Bluff to the small East-West fault 2.5 km SE of Mount Eleanor. The most prominent landmarks along the route to Roper Bar are Mount McMinn ($14^{\circ}42\frac{1}{2}'$S, $134^{\circ}22\frac{1}{2}'$E, Plate 1A), followed by the Hells Gate Ridge (Hodgson Sandstone, Pl.1B,1D).

The best time of year for fieldwork is May-August when the vegetation is tropical semi-arid bush; isolated gum trees with a ground cover of drying grasses and termites. Steeper rockier hillsides are sometimes covered with the much denser 'ti-tree scrub'. The underbrush is periodically burned off

to provide better cattle grazing and this makes fieldwork much easier, though camping becomes trying when the fires get out of control.

Tropical weathering has been prolonged, and although scree slopes below ridges provide magnificent displays of weathered-out sedimentary structures, the shales and silts are totally oxidised and outcrop samples would be of little use for palynological work. In roadcuts only two or three years old and 10m deep, weathering had oxidised Kyalla Shale more than 2m into the rock face: drilling or blasting would seem to be the only answers to this collecting problem. Cores of Kyalla Shale show weathering down to 20m but these were taken on the top of a scarp where weathering can be expected to be at its most severe.

The aims of the fieldwork were to examine and sample the DDH core in detail and to look at all of the formations of the Roper Group in the field. A brief diary and route are given in Table 1; all formations except the Velkerri were found in outcrop, many of them well exposed in new road cuttings. The roads do not follow the courses marked for them on the 1:250 000 geological maps.

My general geological observations add little to those of Dunn (1963a, 1963b). New quarries for roadstone have now left useful exposures of the Mountain Valley Limestone East of the turn off to Mountain Valley Homestead ($14^{\circ}7'S$, 133° 50'E). At this locality the limestone forms thin flat plates, often in pavements with rhomboidal fracture lines (Plate 1C).

There are no surface indications of ironstone within 8 km of localities 4-6 (See Fig.4), and although cores here (Deposits T-X) seem to show a thin bed of ore, the deposit could be a series of lenses. Even if the ore is a continuous bed it is hardly thick enough to produce surface outcrops as extensive as those mapped. Extensive leaching of ochreous ore to leave only quartz with some grains of crystalline haematite

TABLE 1. Fieldwork diary

May 18	Flew to Katherine.
May 19	Provisioning in Katherine.
	Drove to locality 7.
May 20	Found core shed. Began core logging.
May 20-24	Core logging and sampling at core shed.
May 25	Drove to Roper River Mission, examining roadside outcrops. Landrover stranded in Wilton River.
May 26	Hells Gate Ridge section. Roadside outcrops.
May 27	Road cuts between core shed and Mataranka.
May 28	Difficult scrub driving to localities 4-6. Preliminary traverses along ridge.
May 29	Traverses across ridges of localities 4-6.
May 30	Drove from localities 4-6 to Mataranka and then to Mainoru Homestead. Road cuttings.
May 31	Roadside outcrops driving SW. Landrover bogged near Flying Fox Creek.
June 1	Walked up Flying Fox Creek to contact between Limmen Sandstone and Dook Creek dolomite. Unsuccessful search for fossil jellyfish.
June 2	Drove back to Katherine.
June 3	In Katherine, packing and posting samples.
June 4	Left Katherine for home.

was noted by Cochrane & Edwards (1960,p.147) and would partly explain the lack of iron seen in outcrop.

The disparity between map and field is probably due to photointerpretation, the host facies of the ironstone having been mapped as the ironstone unit.

38 outcrop samples were collected and sent to K. A. Plumb (BMR) for storage pending further study. They are listed and briefly described in Tables 2 and 3, and some of them are shown in Plates 1E-H,2 & 3.

The presence of metazoa in Roper Group times has been suggested on dubious grounds. M. D. Muir and I found no evidence of trace fossils or sedimentary structures at the probable original locality (along the East bank of Flying Fox Creek between 14°7'S 133°43'E and 14°9'S 133°14'E) for Dunn's (1964) Beltanella-type jellyfish, and Dunn's original samples are lost. Other reports of Beltanella-type jellyfish in the lower Proterozoic Katherine River Group (Rix, 1965) have not been confirmed. Triact sponge spicules reported from the Vizard Formation near the base of the McArthur Group in the Urapunga sheet area (Dunn, 1963b; 1964) are now believed to be volcanic shards, while "impressions of groups of radiating acicular spines" (Dunn, 1964) on the surface of cherts from the Mount Rigg Group or the McArthur Group are probably crystal casts (cf. Cloud, 1968). The question of trace fossils is open, but all of the structure found so far can be adequately explained as of sedimentary or diagenetic origin. (See Tables 2 & 3, Plates 1E-H, 2A-H, 3A-H and Plate legends).

TABLE 2. LIST OF OUTCROP SAMPLES

Sample Number	Facies	Locality	Place Name	Locality number on map, Figure 4.	Sample stored at.
1	Moroak	14°42½'S,134°22½'E	SW slope, Mt.McMinn	1	BMR
2	Jalboi	14°42'S,134°26'E	Hells Gate Ridge	2	BMR
3	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
4	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
5	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
6	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
7	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
8	Jalboi	14°42'S,134°26'E	Hells Gate Ridge	2	BMR
9	Jalboi	14°42'S,134°26'E	Hells Gate Ridge	2	BMR
10	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
11	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
12	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
13	Jalboi	14°42'S,134°26'E	Hells Gate Ridge	2	BMR
14	Jalboi	14°42'S,134°26'E	Hells Gate Ridge	2	BMR
15	Moroak	14°42½'S,134°22½'E	Mt.McMinn	1	BMR
16	Kyalla	14°44'S,134°16'E	Road cutting	3	IC
17	Kyalla	15°08¼'S,133°58½'E	Hodgson Downs	4	BMR
18	Kyalla	15°07½'S,133°59½'E	Hodgson Downs	5	BMR
19	Kyalla	15°08'S,133°59'E	Hodgson Downs	6	BMR
20	Kyalla	15°08'S,133°59'E	Hodgson Downs	6	BMR

/Continued over

/TABLE 2. LIST OF OUTCROP SAMPLES

Sample Number	Facies	Locality	Place Name	Locality number on map, Figure 4	Sample stored at
21	Kyalla	14°50'S,134°05½'E	Urapunga	7	BMR
22	Kyalla	14°50'S,134°05½'E	Urapunga	7	BMR
23	Kyalla	14°57½'S,133°56'E	Urapunga	8	BMR
24	Kyalla	14°57½'S,133°56'E	Urapunga	8	BMR
25	Kyalla	14°57½'S,133°56'E	Urapunga	8	BMR
26	Kyalla	14°57½'S,133°56'E	Urapunga	8	BMR
27	Kyalla	15°07½'S,133°59½'E	Hodgson Downs	5	BMR
28	Munyi	14°57'S,133°41'E	Road cutting	10	BMR
29	Munyi	14°57'S,133°41'E	Road cutting	10	IC
30	Munyi	14°57'S,133°41'E	Road cutting	10	IC
31	Munyi	14°57'S,133°41'E	Road cutting	10	BMR
32	Munyi	14°57'S,133°41'E	Road cutting	10	BMR
33	Mainoru	14°10'S,133°48'E	Nr Canopy Rock	9	BMR
34	Mainoru	14°10'S,133°48'E	Nr Canopy Rock	9	IC
35	Mainoru	14°10'S,133°48'E	Nr Canopy Rock	9	IC
36	Mainoru	14°10'S,133°48'E	Nr Canopy Rock	9	IC
37	Mainoru	14°10'S,133°48'E	Nr Canopy Rock	9	IC
38	Mainoru	14°10'S,133°48'E	Nr Canopy Rock	9	IC

TABLE 3. DESCRIPTION OF OUTCROP SAMPLES

Sample number	Picture	Description
1	2B	Cast of surface of ripple-marked slab. In the field, ripple marks were parallel on three successive bedding planes. Surface shows small indentations and depressions probably of infilled mud cracks.
2		Push marks, probably made by a large grain or clast during sediment compression.
3		Large sandstone dykes. Shale weathered away, but some fine sediment still preserved in deep pockets.
4		Sandstone dykes.
5	2C	Sandstone dykes. Grade in size from left to right.
6		Sandstone dykes.
7		Sandstone dykes.
8		Clasts and linear drag marks in quartzite.
9		Round clay gall with linear attachment, also of clay.
10		Small circular impression, 1 cm in diameter. Probably a cly gall cast.
11	2D	Contorted sandstone dykes with some shale still in between them. Lower part of picture.
12	2D	Contorted sandstone dykes.
13		Small (2.5 x 0.5 cm) flute casts in white sandstone.
14		Small flute casts in white sandstone.
15		Circular (6 cm diameter) marks in well-sorted massive white sandstone. Conchoidal fracture.
16		Shale. Totally oxidised. No organic matter.
17	3F	Circular marking with tail. The tail continues through the circle, so the trace is probably a composite. The circle is interpreted as a bubble impression while the tail could be a strand line.
18	2G	Braided channel casts. Individual channels are 2 to 5 cm wide.

/TABLE 3. DESCRIPTION OF OUTCROP SAMPLES

Sample number	Picture	Description
19		Rounded impression with a small central mound in fine sandstone. Total diameter 0.5 - 1.0 cm. Probably gas bubble impressions.
20	3D	These markings look like trails, but in the absence of more convincing trace fossils they are here interpreted as strand-line casts. They exactly resemble Recent strand lines as described by Macar (1966-1967).
21	3C	Large clay gall marks in fine sand. Picture is of slab in the field, before collection of part of it.
22		Braided channel traces and clay galls.
23	2F	Fine mud crack casts. Left block in picture.
24	2F	Clay pellet cast with part of filling preserved. Centre block in picture.
25	2F	Empty clay pellet cast showing wrinkled inner surface. Right block in picture.
26	3E	Sub-parallel rill or maybe drag markings on a rippled surface. If considered in isolation, the upper leaf-shaped structure would suggest a cast of some kind of thallus, but the markings below it show its chance sedimentological origin. Note that although apparently bounded, the lower edge of the leaf is made up of two separate linear markings.
27	3A	Interference ripple marks affected by a shoal or boulder, or perhaps partly obliterated by escaping gas or water.
28	3G	)Clay gall casts and brush markings. Similar
29		)pits have been described as crustacean nests
30		) (Conybeare & Crook,1968,pl.92a) while oriented
31	3H	)sets of brush marks imply formation by)swimming crustacea. The marks shown here occur)singly and were probably made by semi-drifting)clasts or clay galls.

/TABLE 3. DESCRIPTION OF OUTCROP SAMPLES

Sample number	Picture	Description
32	1H	Sinuous, lineated mud-crack infilling. This structure crosses several bedding planes, so is not an impression of a bundle of fibrils. Similar laminated cracks are common in flat algal mats, eg those of the Coorong Lagoon in South Australia.
33		) Fine, partly oxidised yellow-cream shales
34		) with fine straight markings 7-10 cm long and
35		) 4 mm wide. In the field these were thought to
36		) be oxidised macroscopic plant remains but
37		) closer examination in the laboratory showed
38		) that they were only superficial stains.

Chapter 3

Core Material

A. General

Coring sites are given more or less accurately in a number of unpublished reports (Cochrane, 1956; Bennett, 1959; Vivian, 1962). These investigators designated each potential ironstone area by a letter and then proceeded to drill a number of test holes, hence the hole numbering DDH B1, B2 etc. up to X31. These letters are shown on Fig.4 (p.15) and the approximate positions of the cores over the ironstone prospects are shown in Figs. 6-8. We were only able to examine core stored in the shed at Sherwin Creek (the original 'Gum Creek' base camp; See Figs.4,6) which holds most of the cores actually recovered.

This material was all examined; some trays were put back in sequence and rough logs made for those holes not drawn by K. A. Plumb. I am grateful to K. A. Plumb and the BMR for permission to include his log chart as Appendix 1. Other holes are charted in Figs. 9-11. A complete catalogue of the contents of the core shed is given in Appendix 2, a list of samples taken (as far as we could judge) is given in Appendix 3, and our logs are listed in Appendix 4.

The core shed is built of corrugated iron on a girder frame with wire netting inside the girders and a concrete floor. Some pieces of corrugated iron had been partly torn off by storms or falling trees but the core itself was in excellent condition, despite providing living accommodation for the nastier elements of the local fauna.

FIGURE 6: SITING OF HOLES A-C

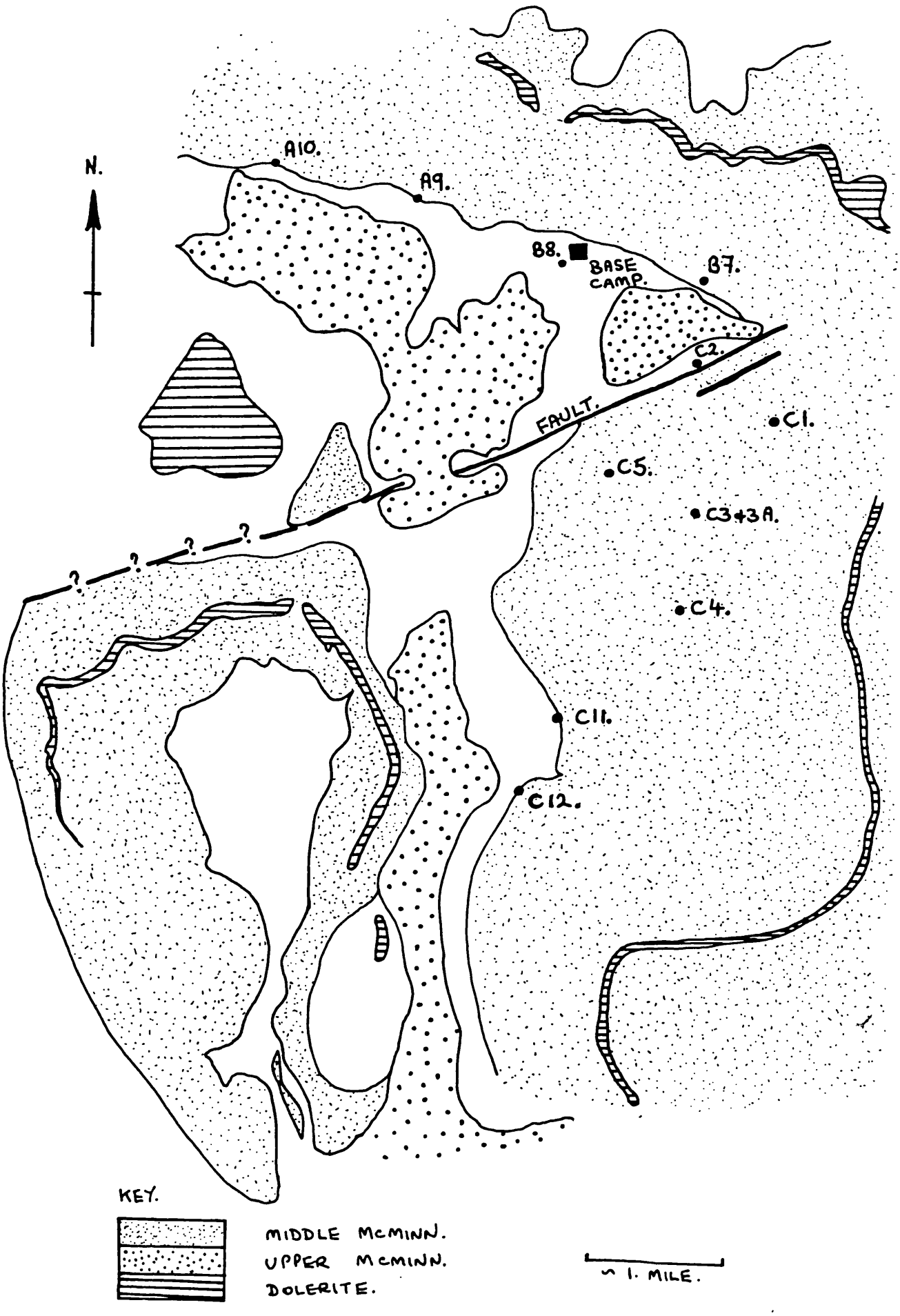
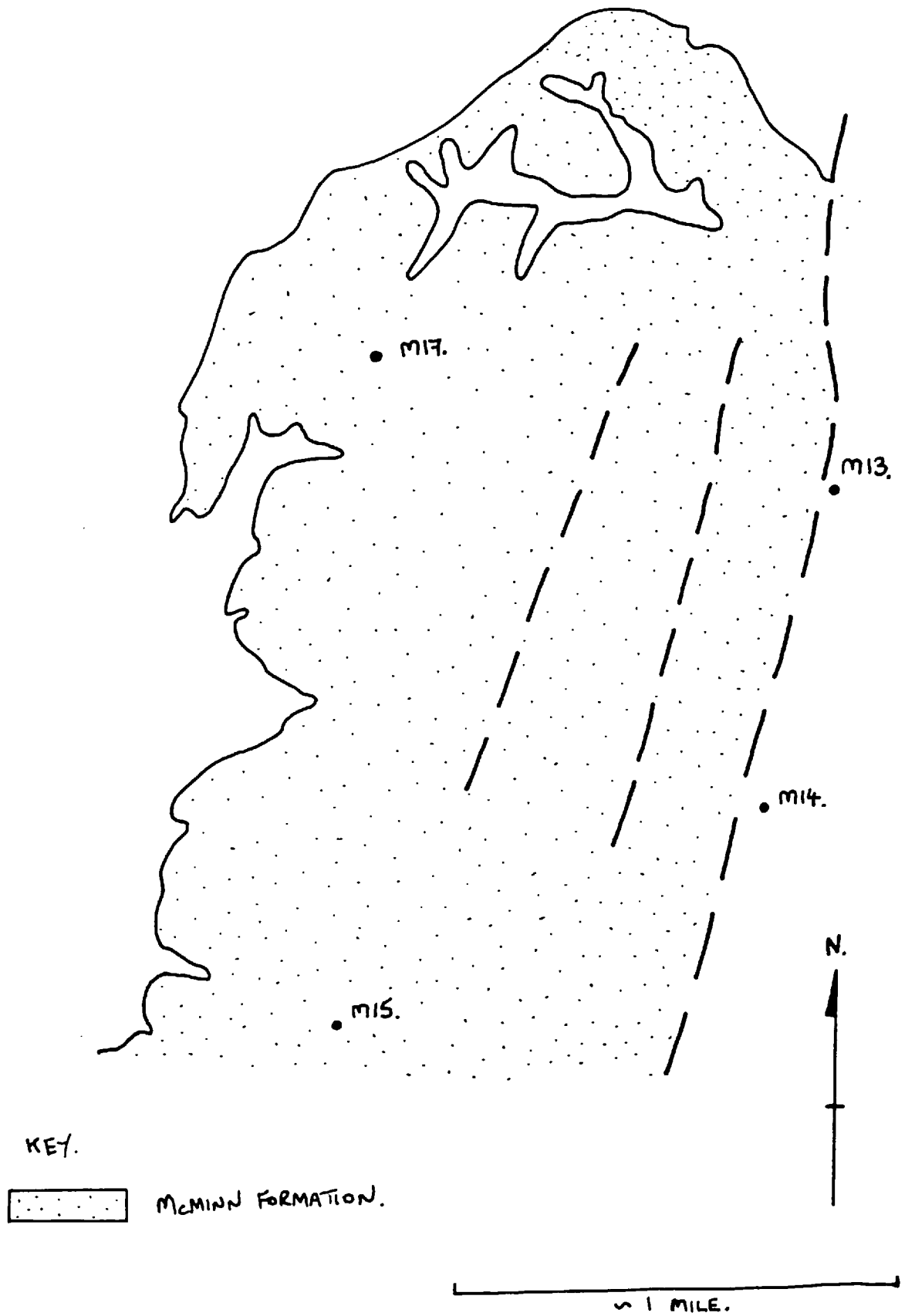


FIGURE 7: SITING OF M-HOLES



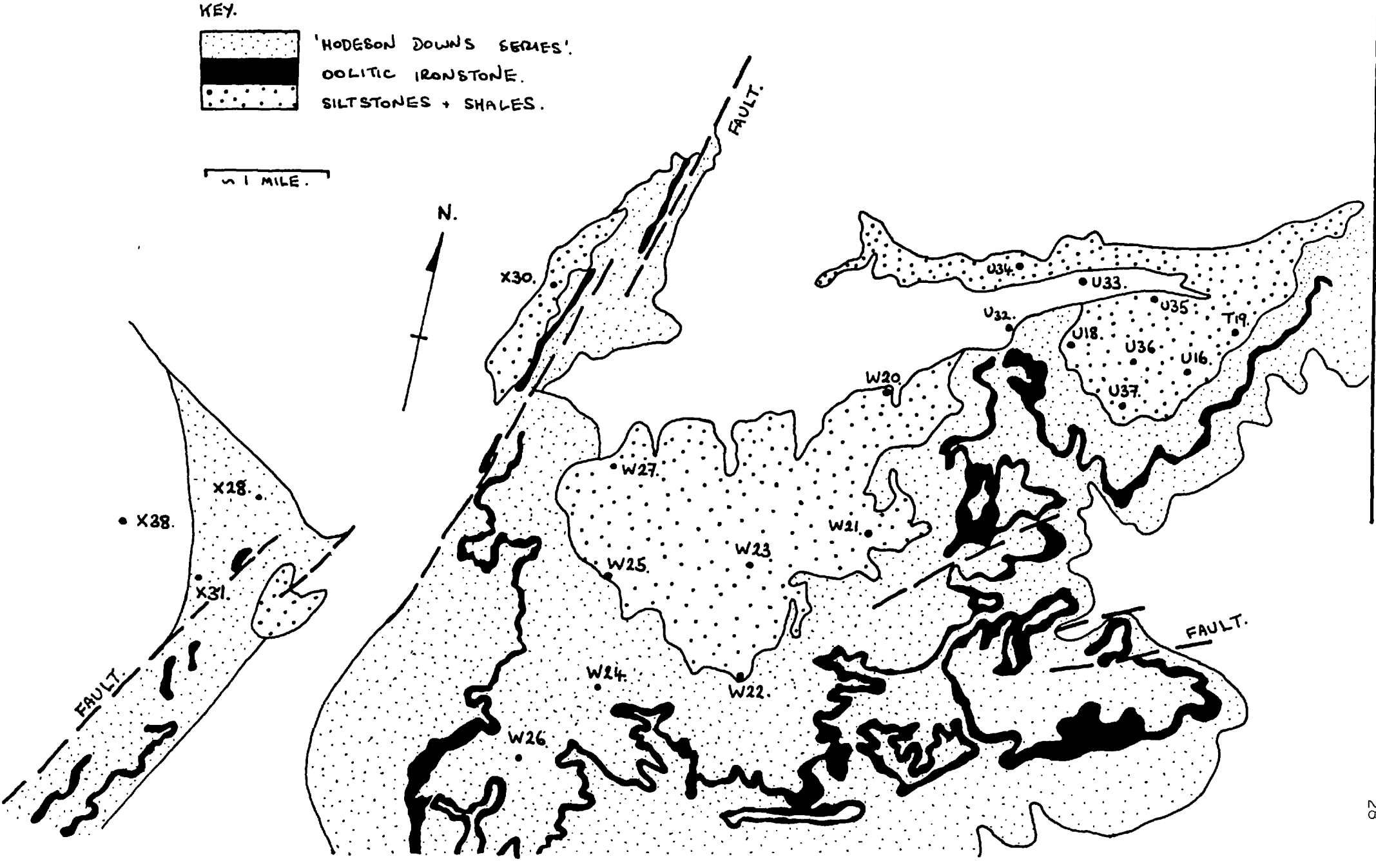


FIGURE 8: SITING OF HOLES T-X

Cores were taken over three main areas - the northerly 'Sherwin Creek' outcrop (Deposits A-C, Fig.6), Deposit M in the middle (Fig.7) and the southern Hodgson Downs area (Deposits T-X, Fig.8). From the core logs (Appendix 1, Figs. 9-11) it is clear that the Sherwin Creek deposit consists of several iron-rich horizons, while the others have only one or two beds.

Another striking difference between the areas is that the ironstones are associated with abundant contorted sandstone dykes in deposit M and the South, but not in the Sherwin Creek area. The dykes are discussed later, but as no dykes are known from the bottom of DDH B7, the correlation of the lowest ore horizon with deposit M (Appendix 1) is questionable. On 1:250,000 maps (Dunn, 1963a, 1963b) the ironstones are variously shown as within or between the Kyalla and Moroak Members.

Both sets of iron-bearing horizons are bracketed by thick shale sequences - the Kyalla Member above and the Velkerri Formation below (Fig.1, p.6). Not only are the ironstones in a sequence of beds that rapidly alternates between sandstone and shale, but one that contains numerous large clasts, oolites and medium to coarse sands. The general succession is one of fairly quiet conditions becoming more agitated, then coarser debris being deposited with clasts, oolite shoals and localised ironstones, followed by a return to fine sediment input. It is not certain whether the ore deposits are laterally continuous or whether they represent diachronous facies. The Moroak facies may be a diachronous unit, possibly reflecting increased sediment input to overlying beds (See below).

Instead of treating the ironstones as a separate mappable unit it seems more appropriate to view the sequence as the Velkerri Formation being superseded by a higher energy Moroak facies including pods of Sherwin Ironstone, this event being followed by the resumption of quiet conditions and the deposition of the Kyalla Shale.

The environment of iron deposition is one of shallow-water shoals, mud flats and stagnant pools, supported by the general geological evidence in Chapter 2, and the occurrence of iron as sandstone cement, in sedimentary granules and encrusting clasts as noted below. The reasons for the shallowing of the Roper Sea are not known. Gradual filling of a slowly subsiding basin in implied by Fig.2 (P.8), while the deposition of laterally continuous, shallow-water sediments over a wide area suggests a broad continental shelf setting. It may be that a sudden influx of coarser sediment filled up the basin and produced extensive flats, initiated the rapid de-watering and compaction of the underlying shales and was followed by a return to quiet conditions.

This shoaling hypothesis would also explain the complete absence of stromatolites in the sequence, though this could equally be due to other factors such as climate. The source of the sediment is not known and the reasons for the observed changes in sedimentation are obscure.

B. Organic Matter

Macerates from the McMinn Formation are generally dark brown to black but when spread out on slides the colour of the dispersed organic matter varies from pale brown to black. Individual fossils from the same horizon also vary in colour from yellow-brown to black, probably due to a combination of recycling before final deposition and slightly different mineralogies and textures in the same bed. Large sphaeromorph acritarchs are commonly associated with clay pockets (see below) and in the same thin section black debris is seen squashed between quartz grains while pale fossils can be found protected in nearby silt pockets. These vagaries of preservation make it difficult to estimate the maturity of the organic matter from individual fossils, but as the palest fossils are a light yellow-brown colour the overall level of metamorphism must be very low.

FIGURE 9: STRATIGRAPHIC COLUMNS. DDH T-U

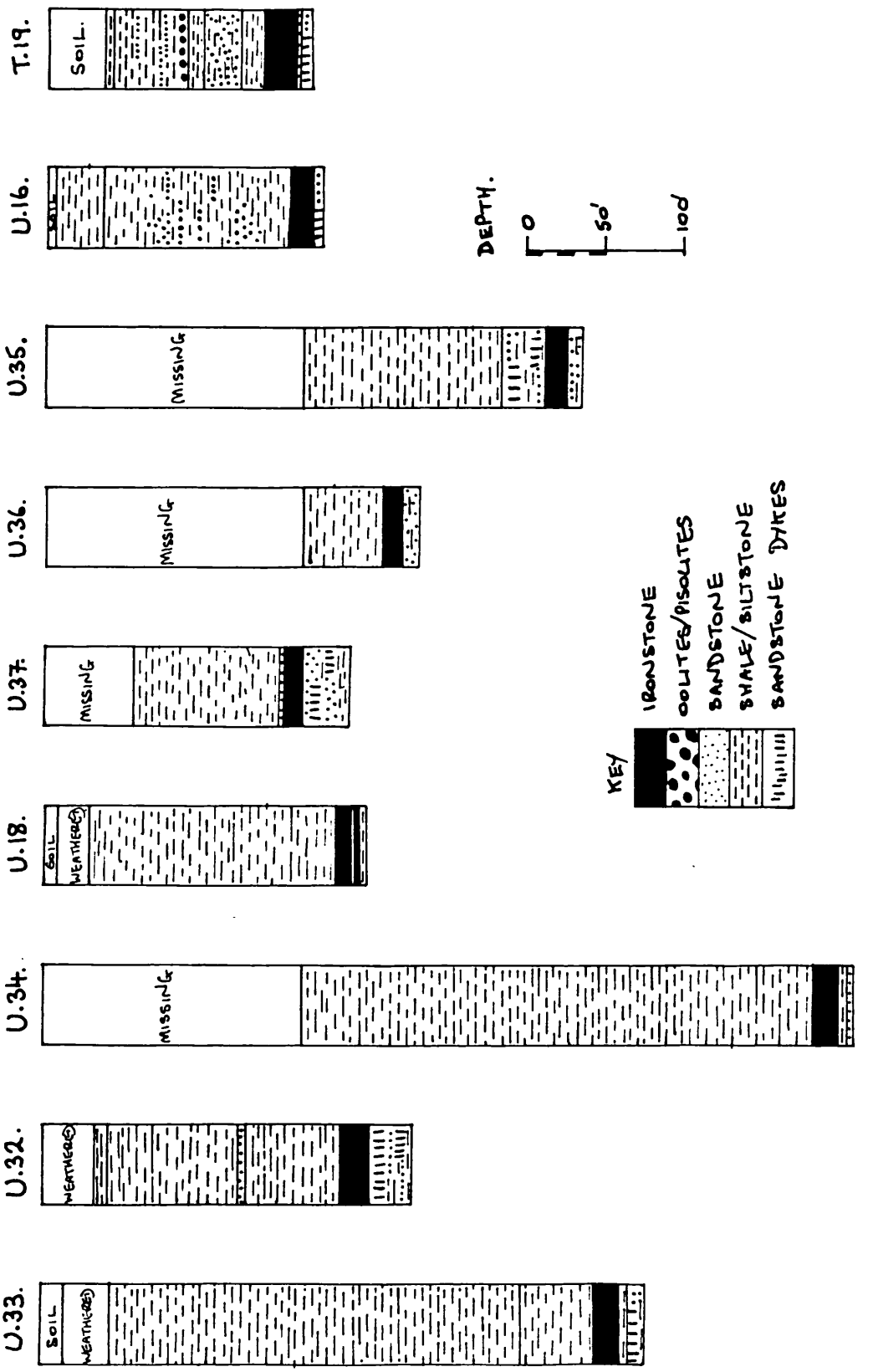


FIGURE 10: STRATIGRAPHIC COLUMNS. DDH W

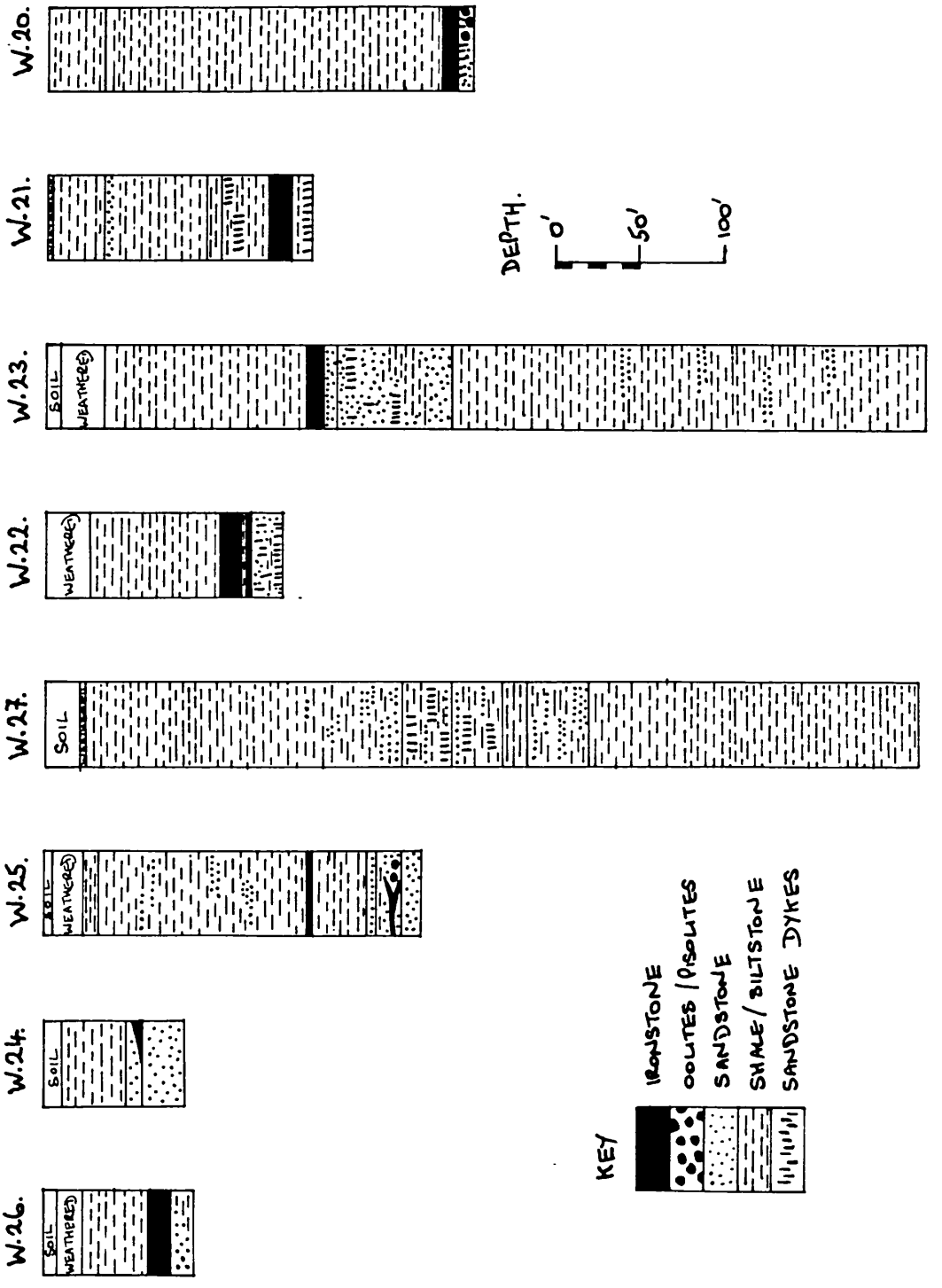
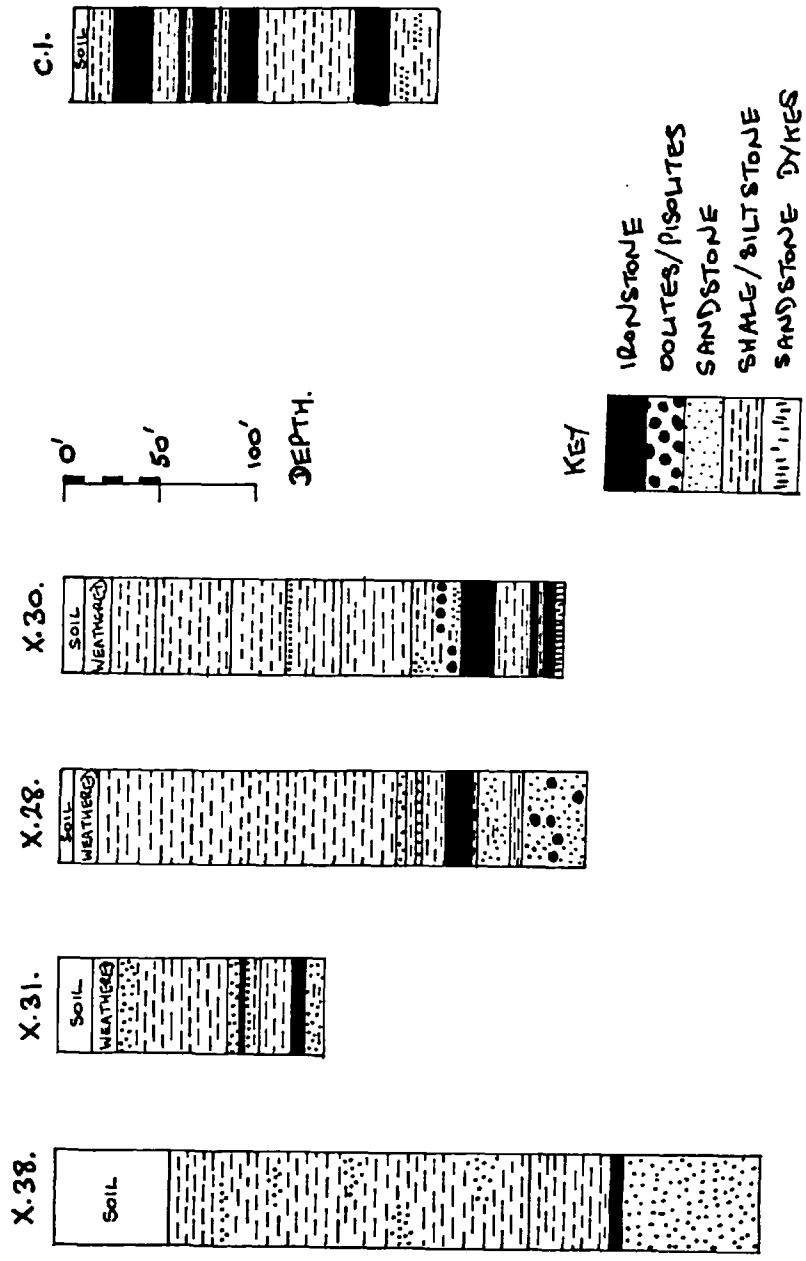


FIGURE 11: STRATIGRAPHIC COLUMNS. DDH X,C



The McMinn Formation is intruded by several dolerite sills, and one of them was completely cored in DDH B7. The sill is 55m thick and exhibits chilled margins 10-15 cm wide. There is a contact zone of 2 cm between the sill and the sediment.

Macerates from near the sill are darker than those taken from further away and several unsuccessful attempts were made to quantify the effect of the sill on the fossil organic matter.

First, different morphotypes from the same sample have different translucencies, so the same morphotype must be used to obtain any set of comparable translucency measurements (Grayson, 1973). Horizons with well-preserved fossils are unfortunately uncommon in DDH B7 and so far there is just not enough material to make a comparative stratigraphic study.

Disseminated organic matter can be isolated from almost any of the shales which regularly contain 1-2% carbon and 500 ppm extractable organic matter (EOM) (data from Hoering, 1967; McKirdy in Peat et al, 1978). Several attempts were made to measure the actual colour of dispersed organic matter using spectrophotometry. Various mounting techniques were tried with different instruments (see Chapter 4) but no useful results were obtained. Freeze-dried and powdered residues may provide more suitable specimens for spectrophotometry, but this has not yet been tried. It should also be possible to use a spot light source in a light microscope to obtain absorption spectra from individual fossils. Apparatus for this technique is still under construction and should have other useful applications, for example the study of pigments in living cells.

D. M. McKirdy (in Peat et al, 1978) noted an increase in kerogen rank as the sill is approached (Table 4). In Table 4 the numbers for 'feet above sill' are estimated from Appendix 1, and the consistency of the H/C ratios supports the correlations suggested there over holes A-C. Further work can be expected to show whether the lowest iron horizon in DDH B7 can be correlated with deposit M.

Table 4

Organic Geochemistry of Selected Samples

Sample Level	Distance Above Sill	Sample Number DDH-	Kerogen Colour	Kerogen H/C Ratio
1	55 m	C4-43' C5-29'	Dark brown	0.86
2	46 m	B8-143' C11-28'	Greyish brown	0.65
3	38 m	A9-72' A10-65' B8-173' C3-101' C5-82' C6-80' C6-85'	Grey brown	0.53-0.59
4	18 m	A10-121' B7-167' C5-155' C6-154'	Brownish grey	0.36-0.40

Using X-ray diffraction on macerates of 8 shale samples, S. N. Karkhanis found no evidence of layer ordering in kerogens from 20'4" above the sill and only slight ordering at 2'7" above. One sample from 73'8" below the sill showed the most marked peak of all. Although it is tempting to suggest that conditions were more severe underneath the intrusion, it is more likely that the odd sample below the sill had a slightly different mineralogy and texture to the others. A full suite of samples would undoubtedly produce some more useful data. (Pers.comm. S. N. Karkhanis, 1976. For details of technique see Karkhanis (1976, 1977, 1978).

In this general approach to the cores it has been found that well-preserved fossils are too scarce to permit palynological correlations between holes. Comparisons of kerogen rank from different cores have provided data to support a purely lithological correlation and imply that the dolerite sill continues under other cores. The beginnings of graphitisation have been observed in samples from close to the sill, but there is too little data to be sure that the observed carbon ordering is entirely due to the intrusion. Other attempts to use the organic matter for correlation or studies of metamorphism have been unsuccessful, though several ideas and possible approaches remain to be tested.

C. Thin Sections

The shales and siltstones are black, brown or greenish in hand specimen, and in thin section are seen to contain abundant dispersed organic particles (Plate 4A-B). Clay minerals are common and often show inter-laminar black streaks of organic matter. Apart from the movement of beds and clasts by sedimentary processes and the disruption of organic matter by small-scale recrystallisation there is no evidence of accumulations or movements of oil or bitumens.

In the core material some beds are well sorted while others are hardly sorted at all. Even the finest siltstones contain occasional clasts of quartz (Plate 4A) and crystals of iron (pyrite, haematite or magnetite) are also common. Pyrite framboids have not been found, though dispersed crystals of iron are often closely associated with fossils and organic matter. Patches of finer grained material are common in all beds and large sphaeromorph acritarchs are often found filled with and embedded in fine silt (Plate 4B). In some beds the regular occurrence of large embedded acritarchs like this suggests that the fossils were flocculated with clays before deposition.

In the Moroak facies, shale beds thicker than 50 cm are uncommon and most laminae are less than 3 cm thick. Bedding, sedimentary and dewatering structures are common at the millimetre scale and disrupted beds (Plate 4D) and shale clasts (Plate 4E) are common. Silt and shale beds may be traversed by narrow dewatering channels (Plate 4C) and often lens out (Plate 5A) or are truncated and deformed (Plate 4D,F). Cross bedding and micro-faults are common (Plate 4G) and it is usual to find abrupt transitions from coarse sand to fine silt and back again (plate 4H, 5B).

Seven siltstone samples were analysed by X-ray diffraction (P. R. Grant, pers.comm, 1976) and the matrix identified as a form of chamosite (See Table 5).

The sandstones are unremarkable quartz sands, generally sorted, with grains varying from well-rounded to sub-angular. In general the coarser sandstones have well-rounded grains while the finer sands have more angular ones.

Sometimes the quartz grains have grown together by solution (Plate 5C) but this has usually been prevented by the matrix of silt (Plate 5D) or iron (Plate 5E). Occasional quartz grains show internal sub-grains (Plate 5B), which implies a metamorphic source for only a small part of the McMinn sediment.

Table 5

X-ray diffraction of McMinn siltstones

A. Samples analysed

1. DDH B8 173'3"
2. DDH B7 33'1"
3. DDH B7 105'2"
4. DDH B7 123'2"
5. DDH B7 199'8"
6. DDH B7 217'5"
7. DDH B7 451'8"

B. Relevant peaks

Aphrosiderite	Chamosite (Ayr)	Observed	Chamosite (Wabana)	Chamosite (Ferrous, Northants)	Plane
7.05	7.05	7.09	7.08	7.12	(001)
3.52	3.52	3.54	3.53	3.55	(002)
14.1					
4.69					
2.51	2.51	2.52	2.52	2.53	(201)
1.56					
2.83					
2.14					
1.78					
1.48					
1.52	1.56	1.56	1.56	1.56	(060)
1.52					
2.02					
	2.14	2.14	2.15	2.15	(202)
	2.68	2.68		2.71	(200)
	2.40				
	1.52	1.52		1.52	
	4.67	4.64	4.68	4.68	
	4.58		2.7		
			1.52		

/ Table 5 continued

Table 5B lists D-spacings in angstrom units, calculated for cobalt k-alpha radiation at 20°C using a Phillips diffractometer with vertical goniometer.

Comparative data is from G. W. Brindley in 'The X-ray identification and crystal structures of clay minerals' Ed. G. Brown. Mineralogical Soc. London. 1972. Table II, p.124.

The peaks tabulated are in decreasing order of intensity and it is concluded that the matrix was a form of orthagonal chamosite.

Oolites seem to have been initiated by the encrustation of sedimentary grains with iron, and iron-crusted grains are found packed together in ore horizons (Plate 5E) or scattered through the sediment (Plate 5F). Isolated oolites are also found (Plate 5A,G).

The oolites and occurrences of iron have been reviewed by Cochrane and Edwards (1960) who divided the ores into four types (Types A-D) based on the proportion of oolites in them. Sometimes the ore is 95% oolites; elsewhere one finds single oolites as prominent clasts in a sand or shaly matrix (Plate 5A,G).

In two samples (DDH A 10 58'6", DDH U33 350'1") the oolites have been leached and replaced by silica. Under crossed polars they appear as ghosts (Plate 5H), sometimes transected by stylolites (Plate 6A-B) or as recrystallised dark clasts with chert rims (Plate 6C). The iron can occur as solid black granules (Plate 6D) or as layers deposited on quartz nuclei (Plate 5E-G) or other oolites (Plate 6E-F). The oolites are not often deformed but sometimes their outer layers are torn open as if abraded before lithification.

Microfossils occur in the fine matrix between oolite grains and are not distorted or obviously sorted. Fossils have not been found inside the oolites, but the iron is so opaque that it is rare to be able to make out any internal structure at all.

The most striking features of core from the Hodgson Downs drill holes are dewatering structures in the form of abundant contorted sandstone dykes (Conybeare & Crook, 1968, Pl.53A). These look like contorted burrows from the side, but are linear features when seen from above (Plate 7). In the field these structures have apparently been mistaken for mud cracks by us and others (See Conybeare & Crook, 1968,Pl.51). Similar but larger structures have also been described from the Jasper Gorge Sandstone of the Auvergne Group (Sweet et al, 1974,p.64, f.18).

The dykes are the result of two contemporaneous processes - the evasion of water producing vertical linear fractures which become filled with washed sand, and differential compaction producing the characteristic contorted sandstone sheets. Sands filling the dykes are always clean, well sorted and cemented by quartz overgrowths (Plate 7E-G).

The dykes range from a few millimetres (Plate 7A) to several centimetres (Plate 7B-C) in length and take many forms from single vugs to highly convoluted aggregations (Plate 7B). When seen in the plane of bedding they are always more or less linear with tapering ends (Plate 7C-D). The associated shale laminae are always contorted (Plate 7E-F) but it is hard to decide how much this distortion was caused by water flow (See Plate 6H) and how much is due to differential compaction.

It is significant that these sandstone dykes are only found at the base of the Moroak facies. Dewatering seems to have been less violent elsewhere (Plate 6G-H), and it is possible that rapid deposition of the coarser Kyalla shoals forced a catastrophic dewatering of the partly compacted shales below. In this connection it would be interesting to see whether similar features tend to occur where thick shale sequences are overlain by coarser sedimentary suites.

Chapter 4

Techniques

A. Thin sections

Thin sections are essential in any study of this kind as they can be used

1. to show whether possible microfossils occur in the rocks;
2. to show whether the presumed microfossils are an original feature or of later (Eg. boring microorganisms, in cracks) or diagenetic (organic matter deformed by crystal growth) origin;
3. to show that presumed microfossils isolated by other techniques are similar to those seen in slices of the rock;
4. to study the structure of fragile or carbonised fossils that would be damaged or destroyed during extraction.

Petrographic thin sections are cut 30 microns thick, either perpendicular to bedding (vertical section) or more or less parallel to bedding (horizontal section). In this study, 30 micron sections were only used for examining grain structures and rock textures.

When searching for microfossils the only requirements for a thin section are that it should be thin enough to see through yet thick enough to determine the relationship of the fossils to the rock matrix. To a certain extent these requirements are in conflict, especially when large (more than 50 microns) microfossils are being studied.

Most of the Roper Group fossils are flattened and are seen only as thin organic streaks in vertical section. Accordingly, most thin sections were cut horizontal and left fairly thick. Wedge-shaped sections are very useful in highly fossiliferous horizons as they show details of the fossils at the thin end and their distribution and relationships at the thick one.

B. Macerations

A macerated sample or maceration (as opposed to a disaggregated one) is a preparation where most of the mineral matrix has been dissolved away, leaving the organic matter as a residue. There are many maceration procedures and reagents (See Funkhouser & Evitt, 1959; Lennie, 1968; Staplin et al, 1960) and the final choice depends on the rocks under investigation, the time available for processing, and which part of the organic fraction is to be studied. For example, crushing the initial rock sample to less than 0.5 mm particle size means faster processing but will destroy large specimens (Timofeev & German, 1974); sieving the macerate results in debris-free preparations and some specimen damage, and will clearly produce artificial size distributions (See Bliss, 1977,p.106), while filtration and centrifugation have similar but less marked effects. Using hot or boiling reagents speeds up the maceration process but can lead to carbonisation, while oxidation of samples may completely destroy thin-walled specimens and will certainly lead to a sample bias towards more resistant or carbonised forms.

The technique used in this study was the gentlest possible and should have conserved most of the available organic matter for examination. There was probably some loss of small (les than 4 microns) particles during processing as residues were left to settle and not centrifuged down. Fortunately the Roper Group shales are not indurated or cleaved and break down readily. The maceration regime used was:-

1. Samples of core were cut and at least 1 mm of the surface ground off on a rotary diamond lap to remove surface contamination. Only samples without obvious fractures were processed. If a sample split during grinding the freshly split surfaces were also ground off.
2. The clean block was washed with distilled water and put into a clean 250 ml polypropylene 'multi-pour' beaker with a 3" polystyrene Petri dish base for a lid.
3. The sample was covered with 10% v/v HCl until the supernatant was colourless (to remove iron) - this usually took about a week.

4. The supernatant was poured off and replaced with a mixture of 10% v/v HCl and 40% HF. This solution was changed every few days, the proportion of HF being gradually increased until only an organic sludge was left - usually 1-3 weeks.
5. The macerate was washed with distilled water by pouring off the supernatant and topping up the beaker until the residue was neutral to litmus paper.

All preparations were carried out in a fume cupboard at room temperature, except that to dissolve the oolitic ironstones 50% v/v HCl was used in a water bath at 50°C, eventually followed by stage 3 to remove residual silicates. The use of HCl and HF together tends to prevent the formation of the insoluble fluorides that can make maceration impossible (Langmyhr & Kringstad, 1966).

Ordinary distilled water was used for washing the original residues because clean and sterile working conditions were not available. The distilled water contains bacteria in the form of blunt rods, fragments of diatoms, occasional coccoliths and rare fungal hyphae. Some of these contaminants occasionally turned up in macerates (along with the all-pervasive cellulose fibres) but were easily recognised, pale in colour and not seen in thin sections. Recent cellulosic material (except when it has passed through the maceration process) is usually birefringent when viewed under crossed polars and is much paler than organic material from the rocks. A detailed account of common contaminants and their avoidance, recognition and control is given by Peat (1973) and a small-scale maceration technique to avoid contamination has been described (Peat, 1974) and applied to one Precambrian sediment (Peat & Lloyd, 1974)

Laboratory contamination is not a serious problem for experienced microscopists and except in special cases or where the relevant equipment and reagents are available there is no need for elaborate precautions to avoid it. In fact any precautions other than ordinary clean working tend to encourage an unwarranted confidence in the purity of macerations.

C. Mounting of residues

The residues described here were mounted in glycerin jelly and the cover slips sealed with cellulose acetate (nail varnish).

The preparations can be regarded as semi-permanent and should last for 20-30 years.

Five test residues were mounted in Araldite Epoxy (Epon 812) embedding resin (See Table 7) and these preparations should be permanent. The procedure here was:-

1. Dehydration of the macerate through an alcohol series and finally into acetone.
2. Thorough mixing of the concentrated residue with resin in the ratio of about 20/80 v/v. Mixing was carried out at 60°C because the resin was more fluid.
3. The residues were mounted on glass slides with cover slips in the usual way and cured at 80°C for 24 hrs.

Other suitable plastics and suppliers are listed by Glauert (1975).

D. Peels

Peels are commonly made of macroscopic plant remains (Joy et al, 1956; Kummel & Raup, 1965) but have not often been used for the extraction of microfossils. When only small samples are available or the fossiliferous beds are very thin it is worth trying to avoid the wastage of material in cutting thin sections. Peels also have the advantage of being cheap and quick to prepare, and it should be possible to take serial peels at much closer intervals than serial sections.

The final technique developed during the course of this work is as follows:-

1. A suitable rock sample is cut to a non-equilateral cross section and ground clean. A quadrant is a good cross section to use with drill core - the curved side makes it easy to orientate the final peels.
2. The face to be peeled (active face) is ground flat and a couple of preliminary peels are taken to clean it.
3. The active face is dipped into an etching solution for a predetermined time. 10% HF for 5 mins was used here.
4. The etchant is removed by immersing the sample in

distilled water (10 mins).

5. The active face is immersed in acetone to dry it (5 mins).
6. The active face is pressed onto a sheet of 0.2 mm thick cellulose acetate sheet and left to dry (10-15 mins).
7. The acetate sheet (peel) is peeled off the active face which is then etched again (Step 3).
8. The peel is trimmed and mounted for observation.

Using this technique I hoped to be able to take small samples apart, a few microns at a time, recovering most of the microfossils in their original orientations. I also hoped to be able to study the peels using SEM and to be able to follow filaments for their whole length in the sediment. These hopes have not materialised for the following reasons, but the technique has some promise and merits further study.

The problems encountered are:-

1. Small fossils and fragments tend to become detached during etching, washing and drying, and are lost.
2. When the active face is pressed onto the acetate sheet there is violent microscopic turbulence as the cellulose acetate is dissolved. This tends to dislodge fossils so that they are not embedded in their original orientation.
3. The active face needs to be pressed firmly onto the acetate sheet or a complete peel is not produced. It is very difficult to press hard and down without some sideways slip or twisting.
4. The cellulose acetate sheet tends to crumple while the peel is drying and curls after peeling. This can be avoided by first sticking the acetate squares to glass (use acetone) or perspex (use chloroform) microscope slides. This brings its own problems after a few peels because the active face etches irregularly and only the humps are peeled. Softening the peel before mounting with acetone vapour or by heating causes stretching.
5. The sides of the sample etch as well as the active face so the sample gets gradually smaller in cross section. After ten or twenty peels, acid will have penetrated along beds and thin opaque slabs of rock will be peeled off. Sideways

attack can be prevented by coating the sides of the sample with paraffin wax, but the edges of the active face have to be kept trimmed or a collar of wax develops and obscures the edges of the peels.

6. It is difficult to mount the peels for LM. The best method found so far is to embed the peels in a solution of cellulose acetate in acetone and leave them to dry under weighted coverslips. Peels sometimes stretch and fossils may be displaced as the peels dry.
7. Peels cannot be used for SEM as the fossils disappear into the acetate sheet when the peel is made.

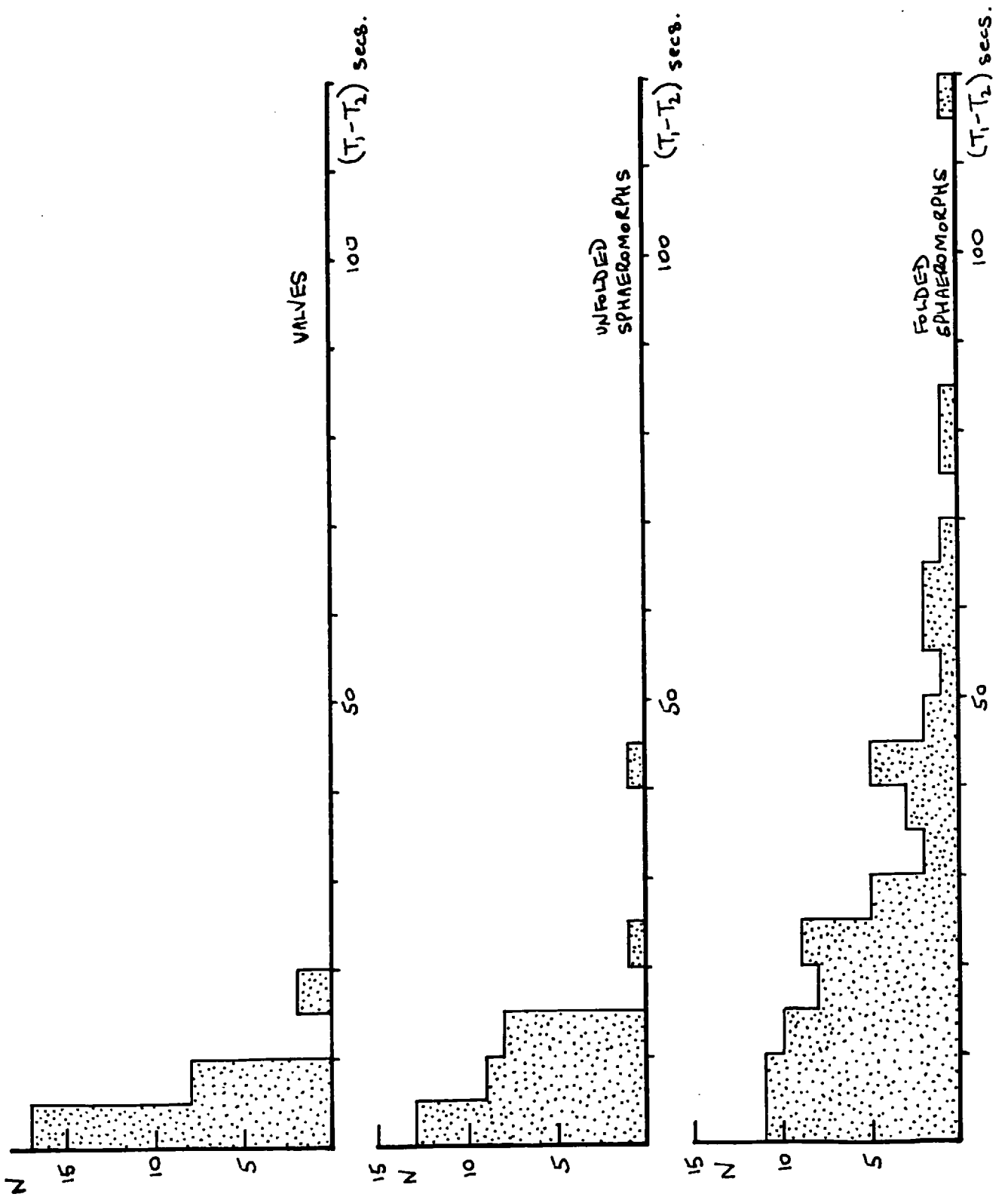
F. Translucency and spectrophotometry

The relative translucency of different microfossils was measured using the photomicrograph exposure meter on a Zeiss photomicroscope III. Exposure timing and film transport are both automatic on this microscope and exposure time can be estimated from either the whole frame area or over a small central spot (similar to the TTL meter in a 35 mm camera). The relative translucency of individual microfossils was measured by pretending to take pictures of the fossils and timing the exposure with a stopwatch. Two exposures were made for each fossil - one with the spot over the fossil (T_1), the other immediately adjacent to the fossil (T_2) to compensate for the mount so that (T_1-T_2) could be used as a measure of translucency.

To get reasonable exposure times (10-60 secs) the film speed dial was set to 10 DIN and a daylight filter used. All observations were made with Koehler illumination through a 40x objective at a total magnification of 2048x. The results of one set of measurements from several separate traverses of the same slide (MAC-DDH-M14-250'8-18) are plotted in Fig.12. This merely confirms that the translucency of single 'valves' is generally higher and falls within a narrower range than the translucency of folded 'spheres'.

Unfortunately, comparably fossiliferous horizons have not yet been found in DDH B7 so there is no way of using this technique to estimate the effect of the dolerite intrusion. In any case the kerogen H/C ratios (See Table 4,p.35) probably measure this with less effort and greater precision. In the long term it might

FIGURE 12 : MICROFOSSIL TRANSLUCENCY



be better to concentrate on carbon layer ordering using electron diffraction as a direct estimate of kerogen rank (See Saxby & Stephens, 1973).

Because of the absence of microfossils in the critical horizons near to the dolerite sill in DDH B7, an attempt was made to measure the colour of the unstructured organic matter by spectrophotometry (For instrumentation see Table 6). The sample was a maceration of DDH-C6-54' and was mounted

1. as a suspension in a 1 mm path length cell (the spectrum was recorded within 6 minutes, ie before settling occurred).
2. as a residue, spread onto a glass slide and vacuum dried at room temperature.

Preparation (1) showed uniform transmittance, while
(2) showed a uniform decrease in transmittance from 33% at 800 nm to 17% at 400 nm.

This approach was abandoned, but it should be possible to measure the colour of organic material. One possibility would be to arrange for a narrow beam of illumination in a light microscope to pass through the sample (which could be a single fossil), and then to use a slit, diffraction grating and photomultiplier to generate a spectrum. Such a system may be available commercially, but if so I have not come across it (Leitz Wetzlar manufacture compatible components that could be used in this way, but the total cost of the instrumentation would be in the £25,000-£30,000 range. Leitz, pers.comm.).

Since most of the vital components were available, work was begun on the construction of a prototype. This has continued sporadically, but engineering and mechanical problems such as the design of stepper motors and stable housings have delayed progress and no measurements have yet been made. It would probably be worth developing an integrated system which would have many applications in other fields - for example the measurement of polarisation colours or the direct measurement of the absorption spectra of pigments in living cells.

Table 6

Materials and instrumentation

1.	X-ray diffraction	Phillips diffractometer with vertical goniometer using cobalt k-alpha radiation at 20°C.
2.	Spectrophotometry	Perkin-Elmer 124 double-beam spectrometer with W lamp light source and 1 micron slit running at a scan speed of 60 nm min^{-1} over the range 370-800 nm.
3.	Light microscopy	Zeiss photomicroscope I or III.
4.	Scanning electron microscopy	Cambridge Stereoscan S600 or JEOL JSM 35 scanning microscope.
5.	Transmission electron microscopy	Siemens Elmiskop I.
6.	Ultramicrotome	LKB 8800 Ultramicrotome III with thermal feed.
7.	Knives	Glass knives were used for trimming, diamond knives for final sections.
8.	Film	Efke KB 14 fine grain, or Ilford Pan F, FP4, medium grain.

G. Scanning electron microscopy

In my experience with shales it is a waste of time, effort and facilities to search routinely for OWMs with the SEM alone. The three basic methods of specimen preparation for direct searching are fresh fracture surfaces, etched surfaces and strew mounts of macerates.

Fractures tend to follow lines of weakness in the sample, usually thin clay partings, which can make it difficult to get a fracture surface of a pre-selected lamina. Even when a suitable surface is prepared, there is often so much topographic detail that it is unusual to find anything resembling a fossil, and even then it is impossible to be sure that a certain textured patch is actually of organic origin. OWMs are too intimately connected with the rock matrix to split out of it as mineralised skeletons do, so one is usually looking at tantalising fragments.

The same drawbacks are found with etched surfaces and here it is also difficult to clean the etched surface before observation. The etching process and reagents used also produce artifacts and may be a source of contamination (Peat, 1973; 1974).

In strew mounts it is usual to find that abundant organic debris obscures the fossils to some extent. The smaller the fossils the more difficult they will be to find among the rubbish. With large pollen grains with distinctive ornament, direct searching of macerates by SEM can be more useful and time effective than light microscopy, picking and SEM observation of selected grains (N F Hughes, pers.comm.). The commonest artifact in preparations of macerates is a surface dusting of small crystals precipitated as the preparation dried out.

Most pollen grains and decorated OWMs are easily recognised in the SEM, but smooth OWMs, small cells and poorly preserved material present problems. The only way to be sure of recognising these microfossils by scanning electron microscopy is to find them in thin sections and macerations, pick them out, and study their structure in the SEM so that they can be recognised with confidence. In the literature there are many examples of an uncritical acceptance of any smooth or rounded

structure as a fossil, even where there is no other evidence for microfossils in the sample studied, nor any evidence that the supposed fossils are organic or come from the sample (See MacGregor et al, 1974; Nagy, 1971, 1978; Nagy & Zumberge, 1976; Pacltova, 1977).

The SEM becomes a much more effective tool when used in conjunction with other techniques. Fracture surfaces are difficult to work with, but thin rock chips can be scanned in the LM and suitable pieces photographed or marked for SEM. It is sometimes useful to etch these fragments to expose the fossils, monitoring the process by LM. This technique can also be applied to thin sections where the slide is carefully polished away until the fossil is exposed and either lightly etched or viewed immediately. In situ microprobe analysis of the fossils can provide useful additional information (Muir et al, 1974a, 1974b).

H. SEM in conjunction with other techniques

In general the SEM provides most useful information when used for the detailed observation of pre-selected specimens rather than as a primary scanning tool. Although the selection of individual specimens may introduce a sampling bias it does allow each specimen to be carefully cleaned and prepared and mounted exactly as required. The value of any set of observations by one technique is enhanced if they can be directly related to observations made by another technique. For example, the illustrations of Multiplicisphaeridium piriferum piriferum (Eisenack, Cramer & Rodriguez, 1973, pl.3a-d) provide an excellent overall picture of the microfossil as well as details of the process structure that are not obvious in light micrographs. They would be even more useful if SEM and LM pictures were provided for each specimen, if only because the processes in pl.3d apparently have spines while those of pl.3a-c have tubercles.

Various techniques have been described for the study of the same specimen by various combinations of LM, SEM and TEM (See eg Kempf, 1973; Leffingwell & Hodgkin, 1971; D Z Oehler, 1976; Thierstein et al, 1971) but only one for all three together (Doyle et al,1975). Impressive results have also been obtained by cutting ultrathin sections for LM and TEM and then etching the residual specimen block for SEM (Erlandsen et al, 1973;

Kempf, 1973) or cutting thick sections from the same block for LM, etching and SEM (Lange & Kegel, 1972; Thurley & Mouel, 1974).

Two techniques are described below. The first is a very simple way of examining the same specimen by LM and SEM (mentioned by Muir in 1970 but not described in detail elsewhere) while the other was developed in the course of this study and permits the study of a single pre-selected microfossil by LM, SEM and TEM. The latter technique has not yet been extensively applied but holds great potential for studies of all aspects of biological ultrastructure.

Technique 1: LM and SEM of the same microfossil

1. Clean cellulose acetate sheet is cut into 5 mm squares. The squares are kept as clean as possible and are only handled with forceps by their corners.
2. The acetate squares are stuck onto 3x1" glass or perspex microscope slides, either with a little bit of adhesive tape at one corner or by dropping each square onto a drop of chloroform or acetone. Several squares are stuck onto each slide.
3. A macerated residue is studied using either a high powered stereomicroscope or a binocular microscope with a cavity slide. Individual microfossils are picked out of the macerate with a fine pipette and transferred to an embryo dish or cavity slide of deionised water. Fine pipettes are made by repeatedly drawing out Pasteur pipettes or soda-glass tubing in a low bunsen flame (the tube is softened in the flame but moved out of it for pulling). Picked microfossils must be thoroughly washed in an excess of pure water (ordinary distilled water will NOT do - see Peat, 1973).
4. Each microfossil is pipetted from the wash and dropped into the centre of an acetate square in the smallest possible volume of water. The fossil is orientated with a fine mounted needle and should be pushed to the very edge of the water droplet. The excess water is now drawn off with fine pieces of paper tissue and the preparation left to dry out. The evaporation of the very small volume of

water under the fossil precipitates crystals which stick it to the acetate sheet.

5. Each microfossil is labelled and identified by scratching a square round it and a number or letter next to the square. To do this I use a steel rod ground to a fine point (See Fig.14).
6. The microfossils are photographed in the LM in air. (Oil immersion objectives can be used if the fossils are stuck down in some way and covered with deionised water and a coverslip. In general adhesives are unsatisfactory for small fossils; if oil immersion work is essential the wax mounting technique of Finch (1974) can be used with a thin film of wax on the acetate sheet. The wax is not so opaque as to preclude reasonably good micrographs. For larger fossils a tiny droplet of acetone on a single hair can be sucked under the specimen by capillary attraction and will dissolve the acetone just enough to secure the fossil.).
7. The acetate squares are carefully removed from the microscope and mounted on SEM specimen stubs with double sided adhesive tape.
8. The stubs are coated with gold and studied in the SEM. The scratched squares and numbers make it easy to identify and orientate specimens while additional lines and arrows can be used as pointers to structures of special interest.
9. If required, the acetate sheets can be removed from the SEM stubs and re-mounted on glass slides for further LM study or permanent storage. The gold coating results in a pale blue colour but does not obscure visible detail.

This technique has been used to prepare single specimen mounts of microfossils as small as 8 microns in diameter but this is very tedious and about 60% of specimens are lost in transit. With a micromanipulator there is no reason why single bacteria could not be handled. With practice, specimens down to about 20 microns in diameter can be handled with a success rate of about 95%; anything bigger than 50 microns can be handled very easily and with confidence.

The technique has the advantages of being fast and simple, providing several clean, orientated and labelled specimens on the same stub. The acetate sheet provides a clean and smooth background for the photographs and does not lead to charging of the specimen. The use of a suspension of microfossils makes mounting much easier, results in cleaner prepaprations, and obviates the need for glues or special mounting compounds (See eg Leffingwell & Hodgkin, 1971).

Technique 2: LM, SEM and TEM of the same fossil

The previous technique was a precursor of this one. The idea was to embed the acetate sheets in resin and cut ultrathin sections of them. This will not work because of the different hardness of the two plastics - any thin sections immediately fall apart into three slices (two resin and one acetate) with the fossil thin section somewhere between them. To prevent splitting it is necessary to use plastic of uniform composition throughout, so this technique is based on the previous one with resin replacing acetate. I am grateful to S Golubic (pers.comm, 1977) who told me of his trick of using one batch of resin and keeping it in the refrigerator in his work on casts of boring microorganisms.

The procedure is described below and illustrated in Figure 13. Steps 1-4 are best performed on the evening of Day 1 and steps 5-10 on day 2. Once the specimens have been embedded and cured steps 11 and 12 can be done at any time.

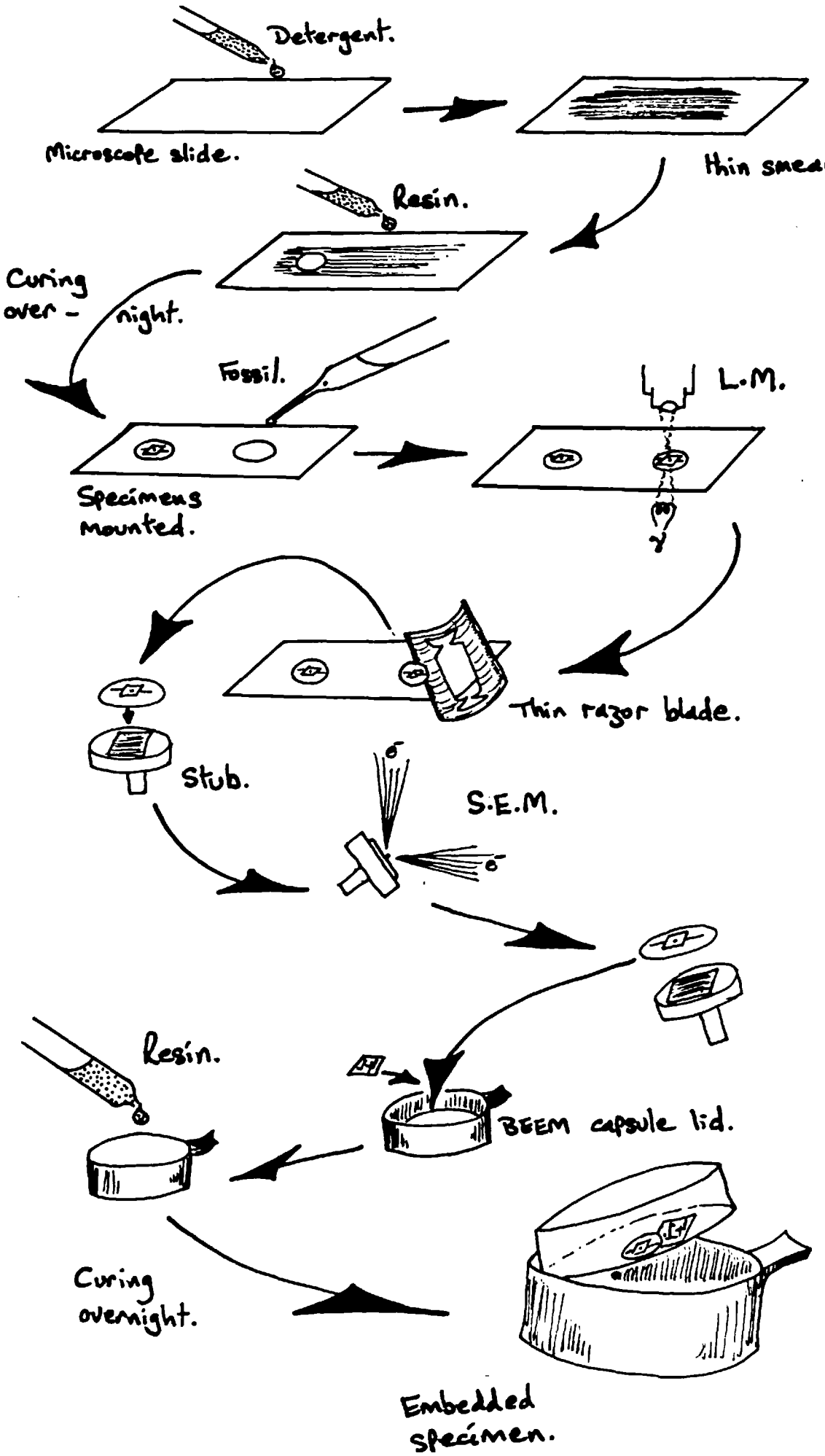
1. A batch of TEM embedding resin is made up as shown in Table 7.
2. Clean 3x1" glass microscope slides are smeared with a thin film of detergent. Any commercial washing up liquid will do.
3. Two spots of resin are dropped onto each slide (See Fig.13).
4. The slides are left in an oven at 80°C for 18-24 hrs or overnight. The remainder of the resin is stored at 4°C.
5. Individual microfossils are picked out of macerates as described in Technique 1 (Steps 3-6), and mounted one fossil to each resin pedestal. The fossils are marked and numbered by scratching the resin pedestal (Figure 14).

Table 7

Embedding resin for TEM

Stock A	25 ml Epon 812 15 ml Araldite 4 ml Dibutyl phthalate
Stock B	DDSA (Dodecenyl succinic anhydride)
Embedding resin	1.8 ml Stock A 2.2 ml Stock B 7-9 drops DMP 30 (Dimethyl aminomethyl phenol)
	Shake very hard for 5 mins
	Mixture should turn orange
	Cure 18-24 hrs at 80°C
	Fresh resin can be stored for 24-48 hrs at 4°C

FIGURE 13. TECHNIQUE 2: LM, SEM AND TEM OF THE SAME MICROFOSSIL



6. The fossils are photographed in the LM and the film developed immediately and checked for mistakes.
7. Using a thin razor blade the resin pedestals are peeled off the glass slides and stuck onto SEM stubs with double sided adhesive tape.
8. The stubs are dried and gold coated, and the specimens examined and photographed in the SEM.
9. The resin pedestals are peeled off the SEM stubs and placed to one side of the lids of embedding capsules. It is useful to write the number of the specimen in pencil on a scrap of paper which is placed face down in the lid, underneath the resin pedestal.
10. The lids are filled up with stored resin and cured in the oven (80°C for 18-24 hrs).
11. The embedded specimens are trimmed and ultra-thin sectioned as required. The orientation of the specimen for trimming is the most difficult part of the whole technique and is best controlled by scratching reference lines on the resin block as shown in Figure 15.

    These can be referred to in trimming (Figure 16) so that a properly trimmed block is obtained with the specimen ready for sectioning (Figure 17).

FIGURE 14. MICROFOSSIL ON RESIN PEDESTAL

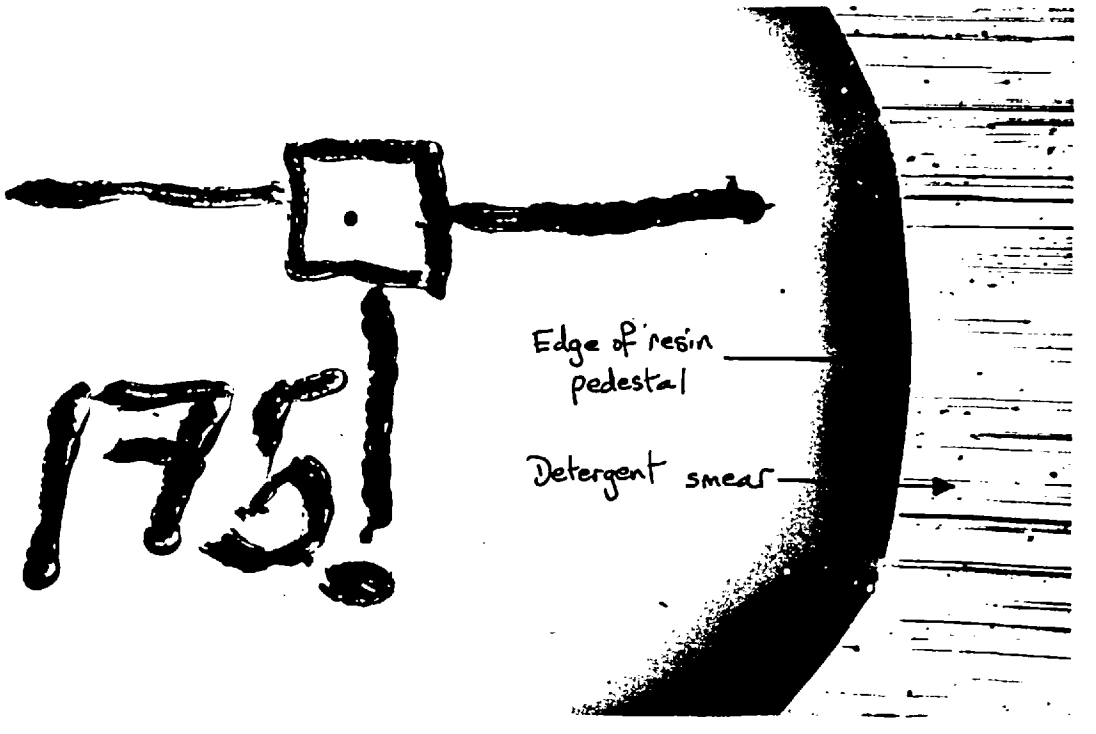


FIGURE 15. MARKING THE EMBEDDED BLOCK

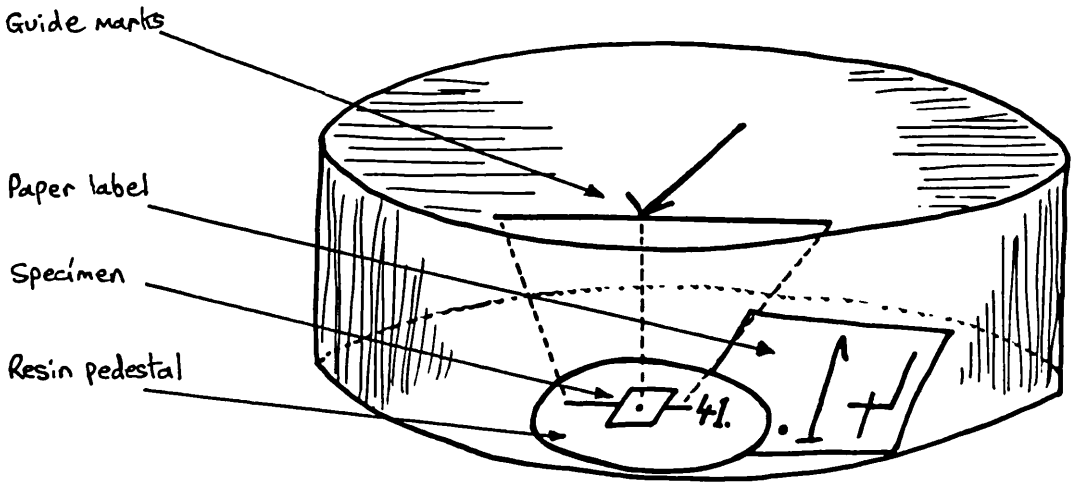


FIGURE 16. BLOCK TRIMMING

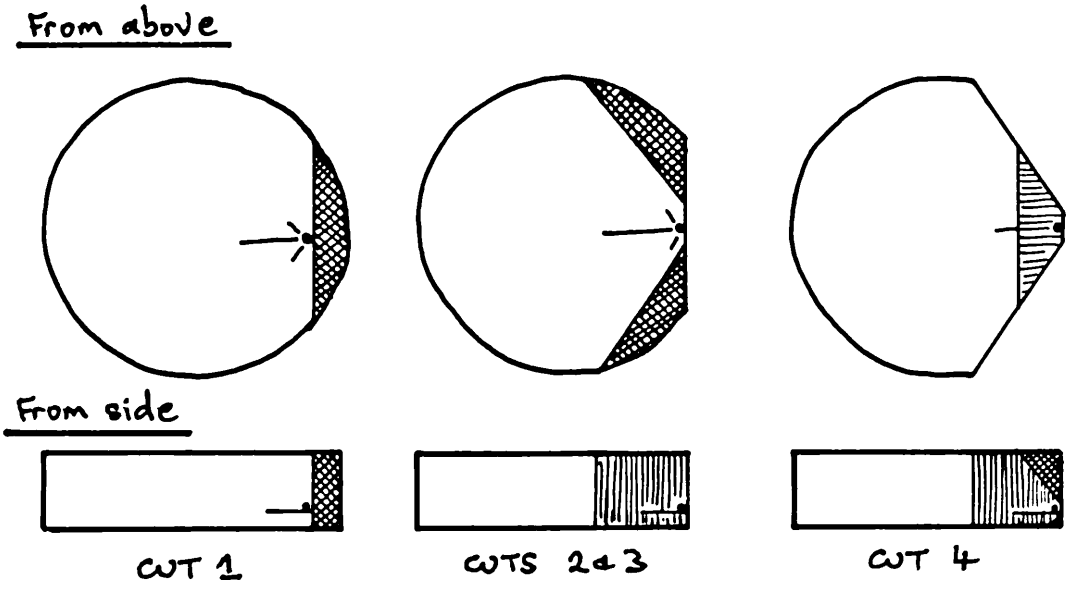
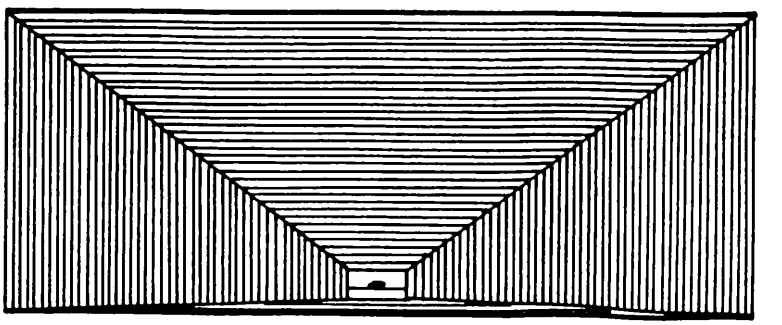


FIGURE 17. TRIMMED BLOCK WITH SPECIMEN READY FOR SECTIONING



12. The sections are examined and photographed in the TEM, preferably with the specimen block still on the ultramicrotome so that more sections or cuts from further into the microfossil can be made. The thin black line of the gold coating is a valuable reference line in the TEM.

Very little TEM work has been done because ultramicrotomy supervision and facilities were not available. I am grateful to Peter Munro of the Biopolymer Group at Imperial College who gave up his time to help me with these parts of this technique.

Ultrathin sections were not stained because this was not helpful in other Precambrian material (D Z Oehler, 1975, pers.comm.). In fact the Roper Group microfossils seem to be much better preserved than the Bitter Springs material (See D Z Oehler, 1976) probably because the McMinn Formation shale matrix has not been recrystallised like the Bitter Springs chert. Section staining would probably provide better specimen contrast and more structural information (See Larson, 1964).

The technique described above is the simplest possible way of studying a selected specimen by LM, SEM and TEM, with the possibility of using and correlating information from all the peripheral techniques now available with these instruments (Eg. cathodoluminescence, X-ray microanalysis and electron diffraction).

As well as the advantage of correlation between different images, which should make the tedious job of 3-dimensional reconstruction from TEM sections much easier, it should now be possible to make quantitative studies of the uptake of labelled compounds by living cells using fast freezing, critical point drying and microanalytical techniques in the SEM and TEM.

Chapter 5

Classification of organic-walled microfossils incertae sedis

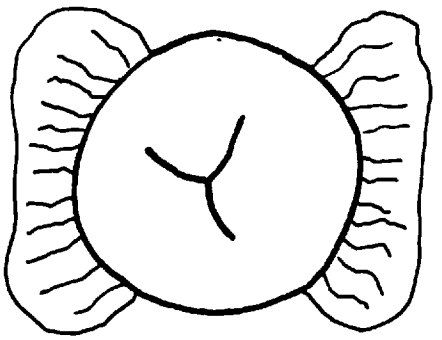
This chapter is based on a manuscript submitted for publication by W. L. Diver and C. J. Peat (1979). Five years ago we held diametrically opposed views on microfossil classification, but after mutual criticism, argument and further study, we were amazed to find ourselves in fundamental agreement. I would like to thank Mr. Diver for the free exchange of ideas in many discussions, and point out that half of this chapter should be attributed to him.

A. Present approaches to classification

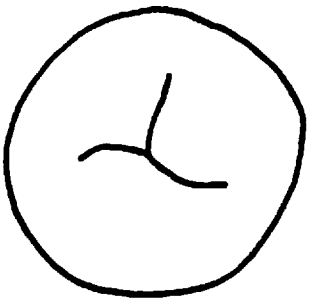
Organic-walled microfossils (OWMs) are presently divided into various categories (Figure 18) of which only acritarchs and incertae sedis are known from the Precambrian. This discussion refers specifically to Precambrian OWMs, but the conclusions reached are of general significance. Although OWM incertae sedis are abundant in Palaeozoic and younger sediments, they have not been well studied there because more obvious fossils have been used as stratigraphic markers. In the Precambrian, OWM incertae sedis are often the only fossils available and are being intensively studied. The relationship of Precambrian to younger OWMs incertae sedis is often neglected and so far there have been no studies comparing the facies control of Precambrian and younger OWM assemblages.

The comparison of new Precambrian microbiotas with published material is a difficult and frustrating exercise. Some problems are to be expected when new material of uncertain affinity is being described, but many of the present difficulties are the result of poor taxonomic practice and ignorance of the rules of nomenclature. More general problems stem from the use of different taxonomic schemes by different workers in essentially the same field and from currently popular approaches to the biological interpretation of OWMs with simple morphologies. Even a cursory analysis of the Precambrian and

FIGURE 18. CATEGORIES OF ORGANIC-WALLED MICROFOSSILS

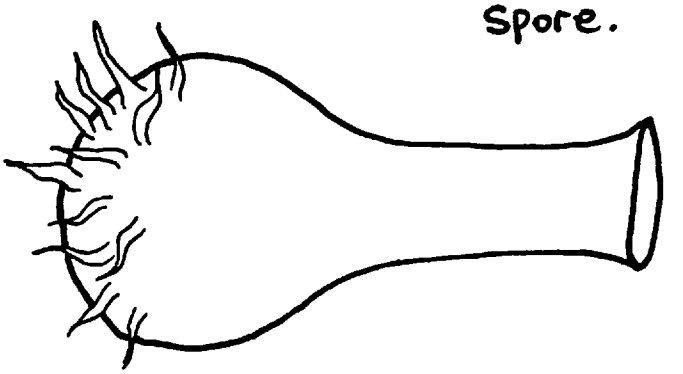


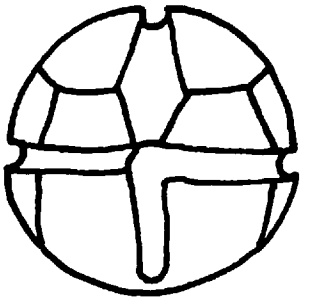
Pollen.



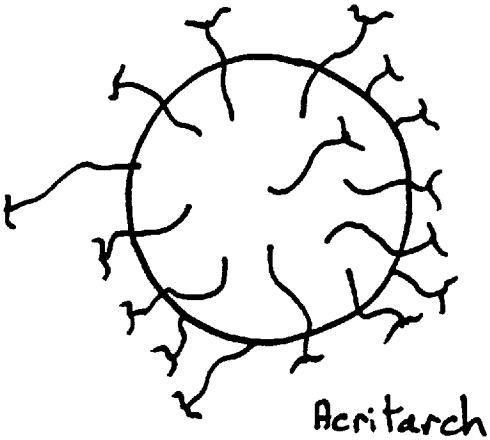
Spore.

Chitinozoan.

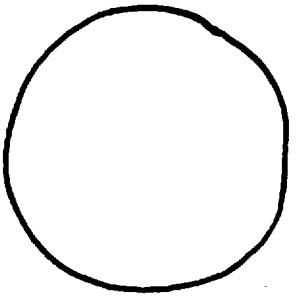




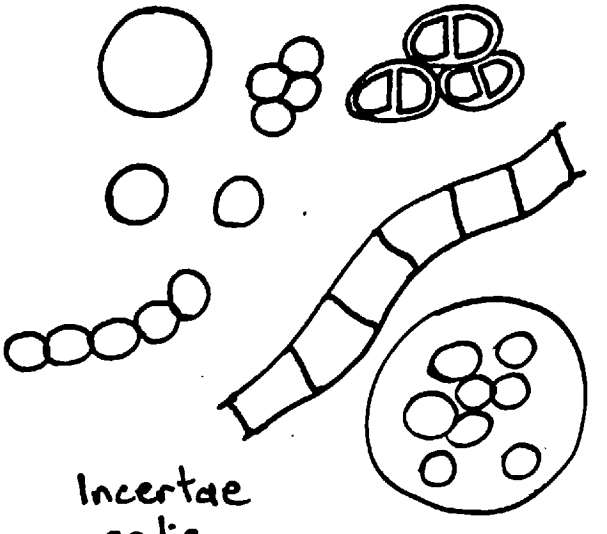
Dinoflagellate.



Acritarch.



Acritarch.



Incertae sedis.

lower Palaeozoic literature shows that morphologically indistinguishable OWMs are being assigned to different taxa which have been defined according to conceptually different taxonomic schemes. This state of affairs cannot be allowed to continue, since

a. the effective communication of palaeontological data is being prevented,
b. potential biostratigraphical and palaeoecological applications are being obscured,
c. confused and misleading phylogenetic inferences are becoming enshrined in the literature.

Some of these difficulties in the study of simple OWMs are the result of isolated groups of workers with different backgrounds who have employed a variety of techniques in the course of studies with widely different aims. The workers themselves fall into two broad groups - the biostratigraphical school and the palaeobotanical school - which are discussed below.

The biostratigraphical school is essentially European and originated in the Soviet Union over 30 years ago. The works of Naumova, Timofeev and Volkova exemplify this school, which applies palynological techniques to lower Palaeozoic and Precambrian rocks - usually dark shales (Naumova, 1962; Timofeev, 1966; Volkova, 1974). The biostratigraphers have a purely morphological approach to classification and although some of their OWMs are acritarchs, many are not and are classified in a variety of ways. The affinities of the OWMs and the effects of facies on their preservation and distribution are rarely discussed in detail. This work is unfortunately marred because many genera and species were not originally described in accordance with any of the codes of nomenclature. Some genera have subsequently been validated, while others have been re-described, sometimes under new names, to produce a plethora of ill-defined and partly superfluous taxa.

The palaeobotanical school began in North America with the work of Walcott (1899), but the description of the Gunflint Chert microbiota some 15 years ago (Barghoorn & Tyler, 1965) was followed by a rapid expansion of research. This approach is principally concerned with the biological affinities and

evolutionary significance of Precambrian microfossils, and attention has centred on the examination of early diagenetic cherts developed in stromatolitic carbonates.

In modern stromatolites, cyanobacteria (blue-green algae) are the dominant organisms and by analogy it has been argued that the microfossils found in ancient stromatolites have cyanobacterial affinities (Schopf, 1975). On this basis the bulk of stromatolitic microbiotas have been included in various taxonomic categories within the Cyanophyceae (sensu. lato.), while the remainder have been assigned to positions within several eukaryotic, usually algal, classes (Schopf, 1968; Schopf & Blacic, 1971). The validity of the criteria used for the recognition of Precambrian eukaryotes has been challenged (See Knoll & Barghoorn, 1975; Schopf & Oehler, 1976). Irrespective of the course or outcome of this controversy, it is now quite clear that unequivocal evidence for the biological affinities of stromatolitic microfossils is wanting.

The lack of communication between the palaeobotanical and the biostratigraphical schools is unfortunate because their techniques and aspirations are complementary. One consequence of this polarity has been that discussions of Precambrian evolution have tended to consider evidence from only one school. This is especially obvious where stromatolitic chert microbiotas have been used to reconstruct Precambrian evolution without considering other, ecologically less restricted, facies (Schopf, 1974). A coherent account of Precambrian evolution will only be feasible if shale and carbonate microbiotas are examined by the maceration techniques of the biostratigraphers as well as the petrographic methods of the palaeobotanists.

B. Fossil evidence

In the clastic Roper Group and Torridonian microbiotas, microfossils previously considered to be typically stromatolitic are common, and occur as integral parts of the assemblages (Peat et al, 1978; W. L. Diver, pers.comm.). When seeking to apply names to these fossils one finds that the same OWM

would be classified in one form-genus as a Cyanophyte, Dinophyte, Prasinophyte or Chlorophyte by a palaeobotanist and in another genus as an acritarch by a biostratigrapher. Before trying to resolve this conflict, it is essential to consider the nature of the fossil evidence and the classification of living organisms.

Palaeontological evidence is notoriously incomplete. It represents an extremely biased and fragmentary sample of life in the geological past and requires careful evaluation. Familiarity with fossils obscures the fact that the recognition of a structure as the remains of an organism involves an interpretative decision. This fundamental judgement may be based solely on the morphology, structure and composition of the entity under consideration, or may rely on other adduced evidence. When stripped of interpretative trappings the microfossils discussed here are simply thin films of organic material of unknown composition with a broadly cellular (Sensu Hooke, 1665) appearance. It follows that all statements concerning the origin, affinities and significance of a microfossil are a priori interpretative and speculative, even when supported by other valid evidence.

Even when working with well preserved material, the interpretation of OWMs with simple morphologies is rarely straightforward. It is often extremely difficult to decide whether a particular organic film is the remains of a cell wall, a membrane or a mucilaginous envelope, and similar problems may be experienced when attempting to recognise and distinguish between vegetative, reproductive or other types of cells. The cysts and spores of many living organisms are robust and resistant to decay but the presence of chemically resistant biopolymers in the walls of the vegetative cells of algae (Atkinson et al, 1972; Loeblich, 1970) and the observed preservation of mucilaginous sheaths (Schopf & Blacic, 1971) do not encourage generalisations about the significance and homology of fossil organic films. These problems are further complicated by the inconsistency of preservation and post mortem transport of remains that are typical of most sedimentary environments.

C. Classification of living microorganisms

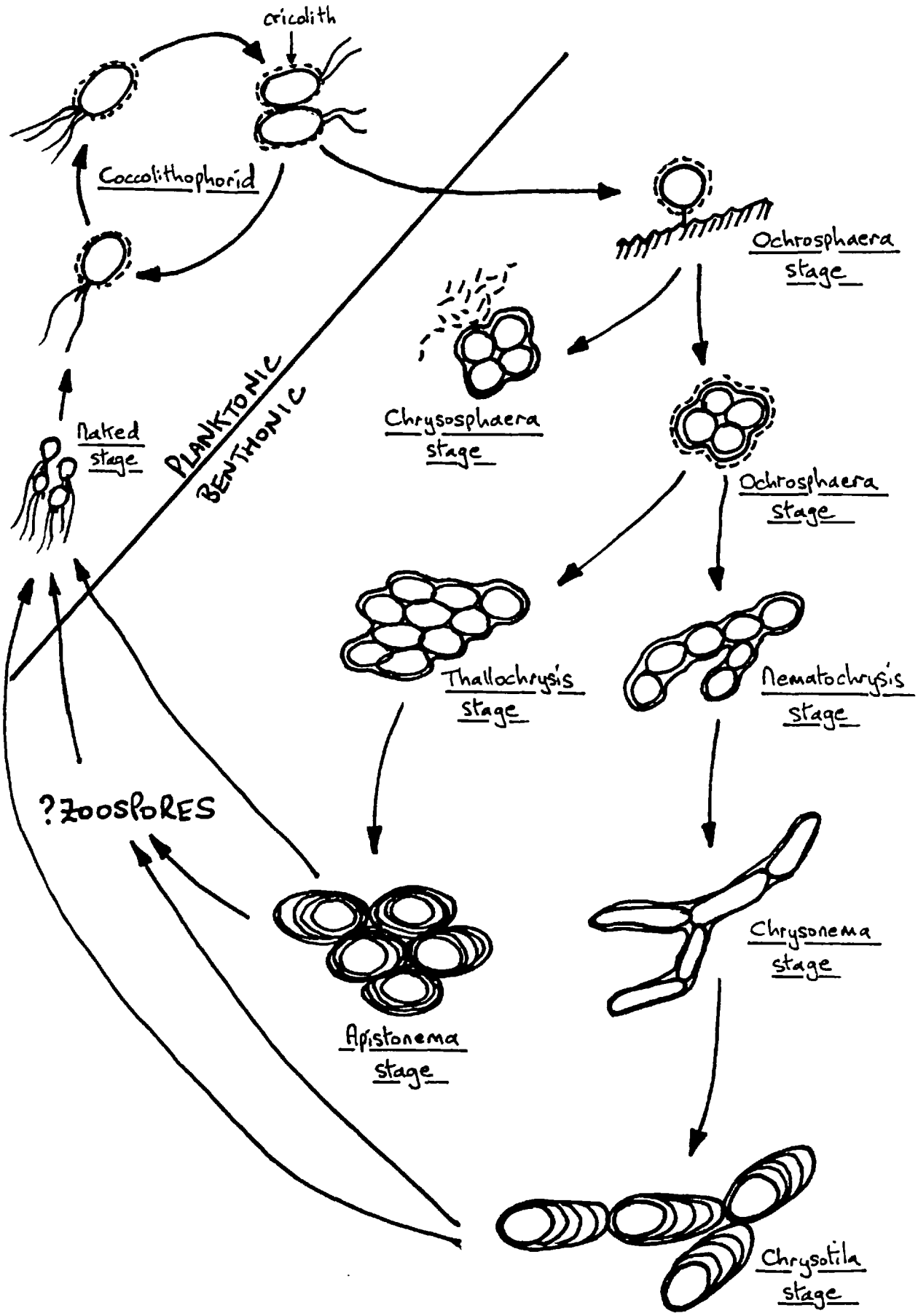
The higher taxonomic categories of living organisms are based on fundamental traits such as levels of inter- and intra-cellular organisation, the normal energy source, and the general nature of the life cycle. The classification of microorganisms relies increasingly on an array of ultrastructural, nutritional and biochemical data because gross morphology has been shown to be of limited systematic value (Lund, 1962). Most wild microorganisms collected from natural habitats cannot be identified without the study of cultured material and it is only by recourse to cultures that the full life cycle of an organism can be observed and the effects of phenotypic variation assessed. Sophisticated study of cultured material has permitted a rationalisation of the taxonomy of difficult groups such as the soil algae (Bold, 1970), and has been responsible for major advances in our knowledge of microorganisms.

The Haptophyceae provide a pertinent example here. This class was only defined after ultrastructural studies and the recognition of the significance of the characteristic flagellum-like haptonema (Parke et al, 1962). In culture these organisms have been shown to have complex life cycles in which, for instance, a benthonic filamentous phase may give rise to two phases of motile cells (Leadbeater, 1970; Parke, 1961). Previously, individual phases had been found in different habitats and described as entirely separate taxa.

It is very unlikely that a convincing fossil haptonema will ever be discovered (for a very dubious example see Wetzel, 1961,p.348) and equally unlikely that different phases of a microorganism would ever be recognised as such in the fossil record.

Most microorganisms have life cycles involving several phases of diverse morphology. Complex life cycles are the rule in the eukaryotic unicellular algae, and not many cycles have been studied in detail. Some phases of the life cycle of Pleurochrysis scherffelii Pringsheim are shown in Figure 19. If phases like this were fossilised there is no way in which a palaeontologist could find out whether his fossils represented

FIGURE 19. LIFE CYCLE OF PLEUROCHRYSIS SCHERFFELII



This diagram is an interpretation of data presented by Parke (1961) for P. scherffelii Pringsheim 1955.

one organism or many.

At a less specific level, the classification of well established higher taxa of microorganisms is becoming increasingly dependent on microscopic characters, often only exhibited for part of the life cycle. The fungi, for example, are classified on the nature of the thallus and the method of sexual reproduction (Fig.20). In this example, I doubt whether a fungal plasmodium could be reliably distinguished from an algal one by morphology alone.

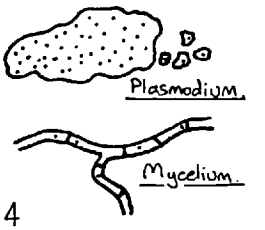
Fragments of vegetative mycelium are common OWMs in Palaeozoic rocks but cannot always be distinguished from algal filaments. Evidence of sexuality is rarely preserved (but see Tiffney & Barghoorn, 1974) and I doubt whether zoospores or gametes could ever be reliably identified in fossil material. Flagella could possibly be preserved (See D. Z. Oehler, 1977 for an account of possible intracellular organelles), but they will certainly never be commonly found and it is unlikely that their type and polarity could ever be known, even if the fungal affinities of the fossil cell were certain.

In addition to increasing our understanding of described organisms and their relationships, modern techniques are also beginning to influence systematics and nomenclature. The designation of type cultures of living organisms is becoming more common and can be expected gradually to supersede the classical concept of the morphological description of a preserved type specimen (See Stanier et al, 1978).

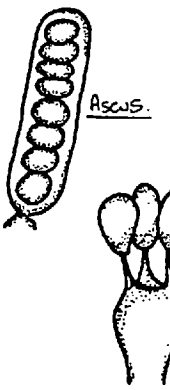
D. Practical classification of OWMs

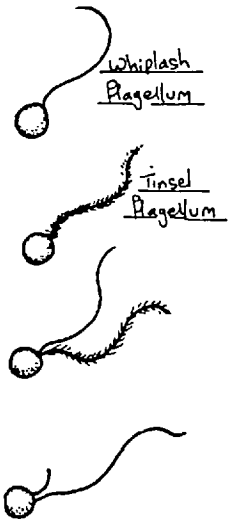
From the foregoing examples it is clear that the morphology of a single cell is totally inadequate for the identification of a living microorganism. Without the information provided by pigmentation, intracellular structures and motility it would be impossible to place most living organisms in the appropriate phylum, let alone division. It follows that for most OWMs, especially simple Precambrian ones, the available palaeontological evidence is not sufficient to justify the close comparison of fossil with living taxa, or the inclusion of microfossils in the present taxonomic hierarchy

FIGURE 20. CLASSIFICATION OF EUMYCOTA (FUNGI)



1a	Thallus a plasmodium	Myxomycota
b	Thallus not a plasmodium	Eumycota : 2
2a	Zoospores produced	Mastigomycotina : 4
b	Zoospores not produced	3
3a	Asexual reproduction by aplanospores. Sexual reproduction by gametangial copulation	Zygomycotina
b	Sexually produced spores in an ascus	Ascomycotina
c	Sexually produced spores on a basidium	Basidiomycotina
d	Sexual reproduction unknown	Deuteromycotina
4a	Zoospores uniflagellate	5
b	Zoospores biflagellate	6
5a	Zoospores with posterior flagellum of the whiplash type	Chytridiomycetes
b	Zoospores with anterior flagellum of the tinsel type	Hyphochytridiomycetes
6a	One flagellum of tinsel type, other of whiplash type	Oomycetes
b	Both flagella of whiplash type, one much shorter than the other	Plasmodiophoromycetes





After Webster, 1970.

of living organisms. Indeed, when one considers that the Precambrian era encompasses biological evolution from the origin of life to the development of the metazoa, it is likely that many Precambrian OWMs will represent extinct lines that do not fit into our current concepts of protistan phylogeny.

In view of the uncertain affinities of most OWMs it is regrettable that so many genera are being given the same names as their supposed living analogues with the prefixes Eo- or Palaeo-. Although many published speculations of the probable affinities of Precambrian OWMs are reasonable enough, they are based on limited evidence and will always be liable to re-evaluation. It is misleading and irresponsible to give names that imply a close relationship to particular living taxa.

In future the codes of nomenclature relevant to OWMs can be expected to require the deposition of living type strains rather than herbarium specimens. One move in this direction is the recent change in status of the blue-green algae from Cyanophyceae to Cyanobacteria (Stanier et al, 1978). The Bacteriological Code of nomenclature is currently being revised (See Buchanan & Gibbons, 1974; Stanier et al, 1978) but can be expected to make scant provision for fossil material, and will also have a later starting date of Jan. 1 st. 1980. Although most OWMs have been described under the Botanical Code (ICBN, 1972) there have been problems in Acritarch nomenclature caused by the use of the Zoological code. Such unnecessary complications could be avoided by the provision of a unified code of Biological Nomenclature ... or exacerbated by the development of a code of Organic-walled Microfossil Nomenclature. (A code of trace fossil nomenclature is currently in preparation, and may be applied to stromatolites. M. R. Walter, pers.comm. 1977).

E. Advantages of an informal scheme of classification

The problems of classification and nomenclature discussed above are not new (J. M. Schopf, 1969; Traverse, 1957). The combination of a rapid accumulation of data and ambivalent attitudes towards classification and nomenclature were, in part, responsible for the formulation of the Acritarcha

(Downie, Evitt & Sarjeant, 1963; Downie, Williams & Sarjeant, 1961; Evitt, 1963). This informal scheme of suprageneric subgroups was developed to include a distinctive but enigmatic group of OWMs having strong morphological similarities and a synpatric abundance. Irrespective of its limitations, the concept of the Acritarcha and the use of subgroups has brought a degree of order to what was taxanomic chaos, and has been the means to an appreciation of the stratigraphic and palaeoecological potential of these fossils (Downie, 1973). The informal subgroup system of classification also has several advantages -

1. The decision to assign an OWM to a subgroup is objective and based on preserved morphology.
2. Subgroups combine a generally accepted type-based system of nomenclature under the ICBN with a straightforward morphological approach.
3. Suprageneric categories do not carry implicit phylogenetic inferences as they do in biological classification.
4. The system is readily comprehensible to the non-specialist and is straightforward and practical to use.

It was originally intended that the acritarchs would be a temporary grouping for OWM form genera incertae sedis. Once the relationships of the microfossils could be determined they were to be attributed elsewhere. I have argued above that the biological relationships of most acritarchs and OWMs incertae sedis can never be known. Although the expression of biological relationships in taxonomy is a laudable aim, attempts to classify OWMs on the lines of living microorganisms are more likely to obscure phylogeny than illuminate it. For these reasons I see the subgroup system as a permanent arrangement, parallel to that adopted for fossil pollen and spores (Potonie, 1956; Schopf, Wilson & Bentall, 1944).

The adoption of a group and subgroup system of classification will bring order to those OWMs originally excluded from the Acritarcha as well as providing a rational framework for the incorporation of new data. It will also ensure that morphologically similar fossils are classified together, and that taxonomic discussions are based only on the available morphological information rather than on extraneous hypothetical biological considerations. A subgroup system will also facilitate the exchange of palaeontological data between groups of workers with

different interests and backgrounds, and will permit an objective reassessment of Precambrian evolution and the influence of facies on Precambrian microbiotas.

F. Introduction to new proposals

Since the acritarchs are now a generally accepted and well circumscribed group, it would be inadvisable to interfere drastically with their definition. The most practical way of extending the sub-group system to OWMs incertae sedis is the erection of a parallel group of equal status for colonies and filaments.

Many colonial and filamentous OWM incertae sedis are already known to break down into or release solitary cells which are indistinguishable from sphaeromorph acritarchs. Such assemblages are abundant in the Precambrian but apparently become less common thereafter, except for occasional dominance in certain facies or horizons. Because of their regular occurrence together and morphological intergradation, I propose to group the sphaeromorphs with colonies and filaments.

The significance of intracellular bodies in colonial and solitary cells also needs to be reconsidered. Where adequate material has been examined (eg. Hofmann, 1976) it is common to find a continuous gradation of inner bodies from hollow sacs to condensed solid spots within otherwise identical cells in the same cluster. Inner bodies are often only present in some cells of a colony and in this case their range of variation is usually ascribed to partial plasmolysis before fossilisation (Knoll, Barghoorn & Golubic, 1975). In solitary cells, however, inner bodies can be the result of plasmolysis, the development of endospores, or both. Cells containing several inner bodies have also been reported but rarely discussed in detail (See Leiosphaera cf media Eisenack,1955,pl.1,f.14).

It has been argued above that it is impossible to distinguish between outer mucilage envelopes and plasmolysed or degraded cellular contents and cell walls. Because of this, and because of the common occurrence of one or more cells within an outer membrane or layer of mucilage, I propose to

abandon the disphaeromorph acritarchs and to consider them as sphaeromorphs with preserved cellular contents or endospores.

A clear division of OWMs incertae sedis now emerges (Fig.21). The Group Acritarcha comprises fairly large cells (usually more than 20 microns across), usually solitary, common in Cambrian and younger sediments, with a distinctive shape and/or processes. The new Group Cryptarcha comprises filaments, colonies of intimately connected cells, solitary and clumped round cells without processes, and cells with inclusions. Formal definitions of these two groups are suggested below. Cryptarch classification and the differences between cryptarchs and acritarchs are discussed in Chapter 6.

G. Systematic proposals

Organic walled microfossils incertae sedis.

Group Acritarcha (Downie, Evitt & Sarjeant, 1963). Emend.

Microfossils of uncertain affinity consisting of a vesicle composed of organic substances enclosing a central cavity. Vesicles sometimes associate in chains but are usually solitary and never intimately connected. Vesicles are characterised by their overall shape or by the possession or distribution of processes. These may be in the form of simple or branched tubes or spines, raised ridges, crests, flanges or wings, distributed regularly or irregularly. The surface of the vesicle may be smooth, decorated or have a characteristic texture. Vesicles may open by rupture, splitting or the formation of a pylome.

Group Cryptarcha Diver & Peat 1979.

Microfossils of uncertain or ambiguous affinity consisting of hollow vesicles or cellular bodies with walls composed of organic substances. These bodies are intimately associated in pairs, clusters, colonies or filaments or are aseptate filaments, or are solitary spheroids or ellipsoids. They never have any processes, but may have distinctive surface textures or ornament, or pores. Vesicles may open by rupture, splitting or the formation of a pylome. They may contain one or more

solid or hollow inner bodies, spots or granules, and may occur within one or more membranes or in sheets of amorphous organic material.

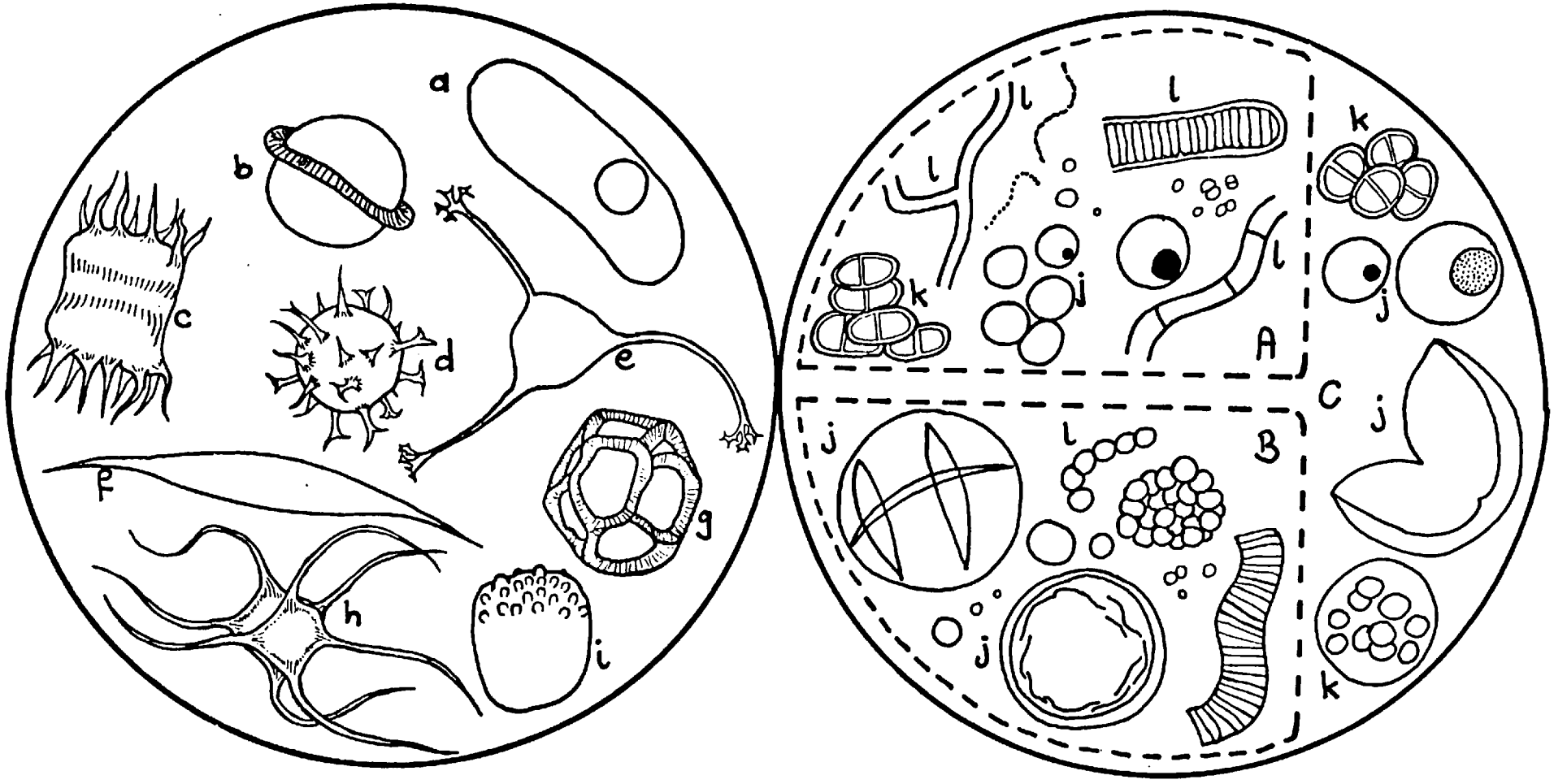


FIGURE 21. PROPOSED CLASSIFICATION OF ORGANIC-WALLED MICROFOSSILS INCERTAE SEDIS

A - previous stromatolitic chert microbiotas; B - previous shale microbiotas; C - new shale microbiotas. a-platymorph; b-pteromorph; c-diacromorph; d-acanthomorph; e-polygonomorph; f-netromorph; g-herkomorph; h-prismatomorph; i-oomorph; j-sphaeromorphs; k-synaplomorphs; l-nematomorphs. Not strictly to scale.

Chapter 6

Cryptarch classification

A. Scope and intent of the Cryptarcha

The general scope and intent of the Cryptarcha were discussed in Chapter 5, and because of the morphological definition of the Group, the assignment of most OWM genera is straightforward. One small problem is that cryptarch and acritarch subgroups are not defined on the basis of one characteristic morphological feature but a combination of characters. This tends to turn any attempt at formal Group definitions into catalogues of subgroup characteristics. Cryptarchs and acritarchs can be distinguished by using a simple morphological key (Table 8).

Some descriptive terms used in the key are discussed below. In all cases the emphasis is on regular occurrence in large samples rather than on occasional variants.

Intimately connected means that the vesicles concerned occur embedded in common mucilage, free within a binding membrane or closely pressed together. In general smaller vesicles are more often found in colonies. This character is inevitably rather subjective, especially since some colonies probably reproduced by splitting up while some large solitary vesicles probably developed from the cells of small membrane-bound clusters (See Chapter 9).

Filaments are defined as three or more vesicles regularly linked end to end or a strikingly elongate colony. Some small cryptarchs may occasionally form short filaments when growing close together in mats (Eg. Glenobotrydion aenigmatis Schopf 1968, type specimen) while others seem to produce short filaments by dividing preferentially in one direction (Eg. Eosynechococcus moorei Hofmann 1976, type specimen). Larger vesicles are sometimes found in chains, and these are classified as filaments if adjacent cells are in close contact or if separate vesicles occur in a common sheath (See Maithy, 1975; Timofeev & German, 1974).

Processes of various kinds have been defined and discussed in the acritarch literature (See Eisenack & Cramer, 1973) and most of them are more than 2 microns long and hollow. Very short solid protuberances, tubercles, thickenings and reticulations are called decoration or surface texture here, and are important in the definition of some cryptarch taxa. This distinction follows the example of Downie (1963) with Lophosphaeridium citrinum, and Vidal (1976) with Trachysphaeridium laufeldi.

Surface texture and decoration do grade into small processes and it is difficult to frame a hard and fast distinction. The boundary will no doubt be defined by usage; for example I would not wish to transfer Baltisphaeridium nanninum Eisenack 1965 to the Cryptarcha, but it could be placed there if the genus Baltisphaeridium was re-defined so as to exclude it.

B. Cryptarch subgroups

As defined in Chapter 5 and discussed above, the microfossils assigned to the Cryptarcha fall naturally into three subgroups: filaments, colonies and solitary vesicles. These subgroups are defined as follows:-

Subgroup Nematomorphitae Diver & Peat 1979

Filamentous cryptarchs consisting of aseptate filaments or chains of vesicles. Filaments may be branched or unbranched, uniseriate or multiseriate.

Etymology - Nema, a thread, Greek.

Subgroup Synaplomorphitae Diver & Peat 1979

Colonial cryptarchs consisting of intimately connected vesicles. Within colonies, vesicles may be arranged in regular and distinctive ways.

Etymology - Syn, together, Greek; haplo, simple, Greek.

Subgroup Sphaeromorphitae Downie et al 1963 emend Diver & Peat 1979

Spherical or ellipsoidal cryptarchs which occur singly or in loose association.

With the definition of the new Group Cryptarcha, this subgroup now includes all taxa previously assigned to the Disphaeromorphitae Downie et al 1963.

C. Features of cryptarchs and their potential usefulness in classification

The scheme of classification discussed here is based on preserved gross morphology for reasons of practicality. Ultrastructural studies may eventually provide more information on the affinity of some cryptarchs, and may have to be used to subdivide some groups (Eg. the thin-walled smooth sphaeromorphs). In general, however, I believe that any broad and practical scheme of classification should be based on preserved morphology as seen in the transmitted light microscope.

Ideally, the features selected as a basis for classification should also meet the following criteria:-

1. They should reflect original features of the living organism rather than the way in which it has been preserved.
2. They should be likely to survive diagenesis and some metamorphism.
3. They should be permanent features of vegetative cells rather than only developed during part of the life cycle.

Using an acanthomorph acritarch as an example, there can be no reasonable doubt that the spines of Baltisphaeridium pauciverrucosum Kjellstrom 1971 are an original feature of the vesicle, though their warty appearance could be due to diagenesis. I would give much more weight to the relative size and distribution of the processes than to the texture of the vesicle surface.

When dealing with cryptarchs which have very few really distinctive features, one is forced to rely on relatively doubtful or poorly expressed characters. Even though it has such a distinctive appearance, B. pauciverrucosum may not represent a vegetative cell, but could be the cysts, egg or spore of some totally different organisms, or even the zygote or endospore of a smooth sphaeromorph cryptarch. Even if the affinities of a microfossil like this are ever determined, I would still advocate the retention of the form taxon for the description and determination of dispersed material (See Chap.5).

The relative reliability and potential usefulness of the characters available for cryptarch classification are discussed below.

1. Cell differentiation.

This can take the form of single differentiated vesicles in a colony or filament, or aggregations of different types of vesicles to form simple tissues. The development of tissues must rank as an important evolutionary event that we should be able to recognise in the fossil record. Care must be taken to ensure that large colonies of the type common in some mat communities are not mistaken for multicellular organisms.

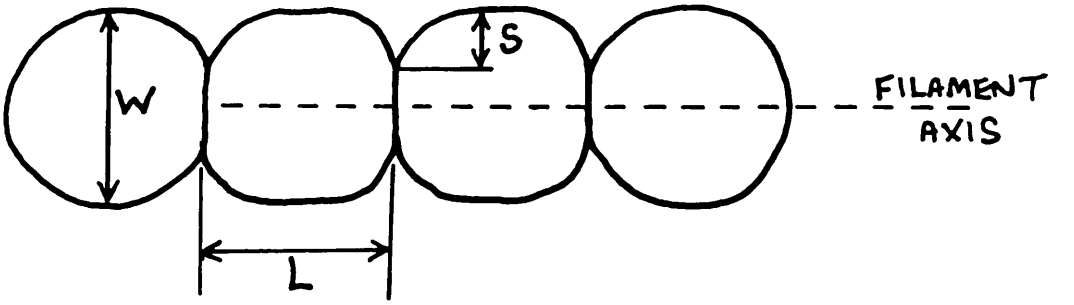
The only single differentiated cells that have been described from the Precambrian are supposed heterocysts and akinetes in possible fossil cyanobacteria. The only convincing heterocyst I have seen is illustrated by Shenfil (1978,pl.i,f.p); considering the good preservation of much of the described Precambrian material,it is very surprising that better examples of heterocysts have not been discovered.

Filaments of living cyanobacteria tend to break at heterocysts or fragment into akinetes. Such cells are not likely to be found in the commonest fossil material (vegetative filaments), and solitary akinetes would inevitably be classified as colonies. For the classification of Precambrian material I would therefore consider the presence of tissues to be very important, but single odd cells very much less so.

In the Phanerozoic, spore-producing filaments and tissues become more and more common. Many of these fossils are complex enough to be referrable to extant families (See Tiffney & Barghoorn, 1974) though I would suggest that fungal sporae dispersae are best treated as cryptarchs. There is no easy answer to the problem of hyphae, spores, and hyphae bearing spores being referred to different taxa. In practice a lot of precise taxa are better than a few very general ones. Ultimately, it is much simpler and acceptable to synonymise several taxa than to split one.

FIGURE 22.

MEASUREMENT OF CRYPTARCH VESICLE SHAPE AND CONTACTS

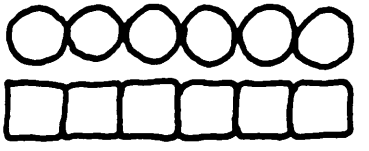


W - CELL WIDTH.
L - CELL LENGTH.
S - SEPTUM DEPTH.

A FILAMENT IS CONSTRICTED AT SEPTA IF

$S \geqslant 0.25L$ OR $S \geqslant 0.25W$

EXAMPLES OF NEMATOMORPH VESICLE SHAPE AND SEPTATION



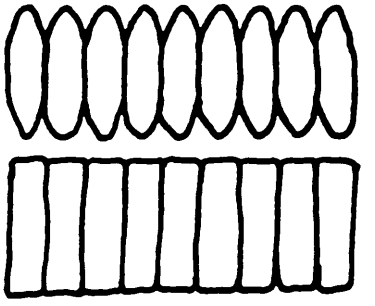
a.
b.

$0.5 < L/W < 2.0$



a.
b.

$L/W \geqslant 2.0$



a.
b.

$0.5 < L/W$

a - Constricted at septa.
b - Not constricted at septa.

2. Colony form.

In some cryptarchs such as Eovolvox Kazmierczak 1975 the form of the colony is very distinctive and clearly an original feature. In Pila (fossil Botryococcus) it is the arrangement of the cells within the laminated mucilage which is diagnostic (Traverse, 1955). With nondescript clumps of small smooth cryptarchs it is largely a matter of personal judgment whether the cells are described as colonial or not. Some colonies tend to break up when macerated, so it is wise to base definitions on material examined in thin sections. The marked division of an assemblage into solitary and paired cells and colonies of twenty or more is good presumptive evidence for the preservation of two original forms. How the preserved forms relate to one another and to biological species is a matter for conjecture. For classification, the arrangement of cells in a distinctive way (Eg Pila, Eovolvox, Eucapsis (?) of Licari et al, 1969) is an important and original feature. The mere aggregation of vesicles is less useful, though the shape of the colony and the packing of individual vesicles are important features.

3. Vesicle shape.

This is only relevant to the nematomorphs and synaplomorphs since sphaeromorphs are more or less round. For the nematomorphs, general cell shape is an easily measured feature where cells can be distinctly seen. It is unfortunate that some described cells are a product of graphitisation and recrystallisation. In this treatment I have split cellular filaments into three groups on the basis of the length/width ratio of vegetative cells (L/W greater than 2, between 2 and 0.5, less than 0.5; See Figure 22). Although the arrangement of cells in some filaments is probably a result of shrinkage (Eg. Archaeothrix Kidston & Lang 1921; Halythrix Schopf 1968), the original cell size and shape cannot be inferred and these degradational forms will have to be attributed to separate taxa. In all taxa considered here the length/width ratio (L/W) of N vegetative cells is the average

$$\left(\Sigma (L/W) \right) N^{-1} .$$

Table 8

Key to distinguish cryptarchs from acritarchs

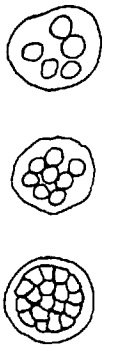
1	A	Vesicles intimately connected* in a filament* or colony, or vesicle/a hollow tube.	Cryptarcha.	
	B	Vesicles not intimately connected.	2.	
2	A	Vesicles with processes*, crests*, wings* or flanges.	Acritarcha.	
	B	Vesicles without processes etc.	3.	
3	A	Vesicles smooth.	4.	
	B	Vesicles with distinctive surface texture*.	5.	
4	A	Vesicles rounded, originally more or less spherical, often flattened and folded.	Cryptarcha.	
	B	Vesicles not originally spherical.	Acritarcha.	
5	A	Decoration restricted to one or both poles, or to specific parts of the vesicle.	Acritarcha.	
	B	Surface texture covers most of the vesicle.	Cryptarcha.	

* the interpretation of these terms is discussed in the text.

Most Proterozoic synaplomorph vesicles are more or less round. Even in the Palaeozoic, the only common colonial synaplomorph with distinctively shaped cells is Pediastrum, and here the vesicle shape is an obvious distinguishing characteristic. For synaplomorphs with rounded vesicles the way in which the cells are packed and their closeness have been used in classification in the absence of more reliable characters.

Three categories of vesicle closeness are recognised in synaplomorphs:-

1. Vesicles separate - spaced apart or only touching.
2. Vesicles connected, but constricted at septa. S is greater than 0.25L or W as for nematomorphs (See Fig.22).
3. Vesicles closely connected. S is less than 0.25L or W (Fig.22).



4. Processes.

Since fossil vesicles with processes are acritarchs by definition, processes are very important in the classification of OWMs but irrelevant here. The only hypothetical microfossil with processes that could be thought of as a synaplomorph would be a Pediastrum-like colony of Domasia and even this would be most conveniently classified as, or at least with, Domasia.

This said, one is led to wonder why solitary vesicles develop processes whereas colonial vesicles apparently do not. Are all organic processes merely vestigial structures remaining after cyst formation, or could some of them be functional structures? If processes are functional, is their role superseded in the colonial mode of life, or is it just that colonial organisms live in a different habitat?

5. Vesicle decoration.

It is generally easier to evaluate big surface features than little ones. Obvious features that occur regularly are most useful for classification and will be best preserved. For example, the low relief decoration of Dictyotidium and Stictosphaeridium is well shown in fossil material and is no

doubt an original feature of the vesicles. The faint large-celled surface reticulation of Retisphaeridium has much less relief, is rarely well -preserved and can be hard to distinguish from fine criss-cross folds. The even smaller fine reticulation of some species of Huroniospora is a disruption of the vesicle wall rather than a surface feature of it, and is probably due to the recrystallisation of the rock matrix.

Pits and pores can also be difficult to interpret. The pores of Tasmanites rifejicus Yankauskas 1978 are no doubt an original feature, whereas the angular pits of Megasacculina atava Naumova 1960 are most probably damage caused by compaction and diagenetic crystal growth (See Volkova, 1974).

It is difficult to interpret some described surface features because of poor illustrations and inadequate diagnoses and descriptions. The pores of the type species of Trematosphaeridium (T.decoratum Timofeev 1959) could be bordered pits caused by crystal growth, while other species (especially T.sinuatum Timofeev 1966) seem to show genuine pits.

The structural integrity and preservation of a population of vesicles should be critically studied before surface features are given any taxonomic status. In this treatment, very fine surface features such as shagreenate and granulate are not considered because they could so easily result from compaction, diagenesis or biological degradation before fossilisation (See Moore, 1963).

6. Excystment structures.

Many cryptarch vesicles have been found to open in some way, presumably to release their contents in the course of a life cycle. The presence of presumed excystment apertures is the principal reason for interpreting larger sphaeromorphs as cysts of some kind.

When pylomes, epityches and sutures are found, their position and morphology are clearly of considerable interest. Where the incipient suture line of the vesicle can be seen on all specimens (Eg. Hoegisphaera, Palambages) this feature

is clearly original and important for classification. Of course a living organism may only develop an incipient suture line at one stage in its life cycle.

Unfortunately, most sphaeromorphs excyst via a cryptosuture, which means that the site and nature of the excystment opening cannot be determined in entire specimens (Lister, 1970, p.37). In these cases (Eg. Tasmanites, Leiosphaeridia), although it is intrinsically interesting to know that vesicles of a certain morphology may open in a special way, the opening mechanism should not be used as a diagnostic feature. For this reason cryptosutures are not considered useful for classification, and groups defined by cryptosutures (Eg. Partitomorphitae Pocock & Sarjeant; Schismatomorphitae Segroves) are here rejected.

There is also a tendency to interpret any opening as an excystment structure. Although a brittle vesicle might excyst via a jagged broken aperture, such openings could be simple damage. Even apparently controlled splits could be caused by sediment compaction squashing the vesicle. Peas, especially the processed variety, split in the same way as some sphaeromorphs and have led me into dinnertime reveries. One speculation is that some sphaeromorph vesicles may have an inherent but invisible line of weakness like the dehiscence line of the pea. Another is that the wall of some sphaeromorphs might be a multiple structure that falls apart after excystment rather than a system of originally separate membranes and walls.

The medial splitting of smooth sphaeromorphs to produce pairs of valves is well demonstrated by the Roper Group assemblage (Chapter 9), and here it is often impossible to determine whether a particular specimen is a valve or complete. I am quite sure that many previously described sphaeromorphs actually represent valves of one kind or another (See Madler, 1963, 1969; Timofeev & German, 1974; Timofeev, German & Mikhailova, 1976).

The classification of these smooth valves is a problem, because even in abundant and well preserved material it is not possible to assign complete vesicles and valves to their multiwalled parents. In most assemblages it is difficult to distinguish valves and spheres, while suitable parents for

them are either extremely rare or not found at all. Any thermal maturation makes the problem more difficult.

The most practical solution is to continue the present practice of treating valves in the same system as complete vesicles, but to be more careful when interpreting a flat disc as a former sphere. The fold patterns of valves of various densities will differ from each other and from those of complete vesicles, so further work can be expected to show separate ranges of valves and vesicle taxa within the same overall system of classification. This system of passive discrimination is adopted here, and the results so far justify this approach (See Chapter 9).

7. Cell walls, mucilage and membranes.

At present there is little consistency between different authors in the identification of the various layers of synaplomorphs as cell walls, mucilage or membranes. The layers of small vesicles are generally interpreted as mucilage or cellular contents; those of larger vesicles as membranes or cysts. Because of the nature of the fossil evidence (Chapter 5), such interpretations are bound to remain largely speculative and may cause confusion when discussing the comparative morphology of vesicles. To take as an extreme example the hypothetical microfossil shown in Figure 23, any of the layers A-D could be interpreted as a cell wall, making the fossil

A. a sphaeromorph with inclusions
B. a synaplomorph with cells showing two levels of inclusion

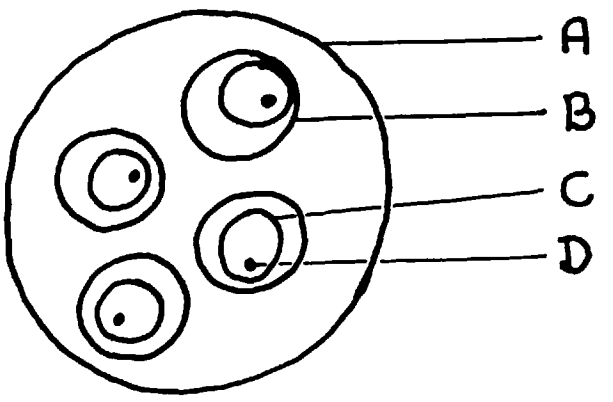


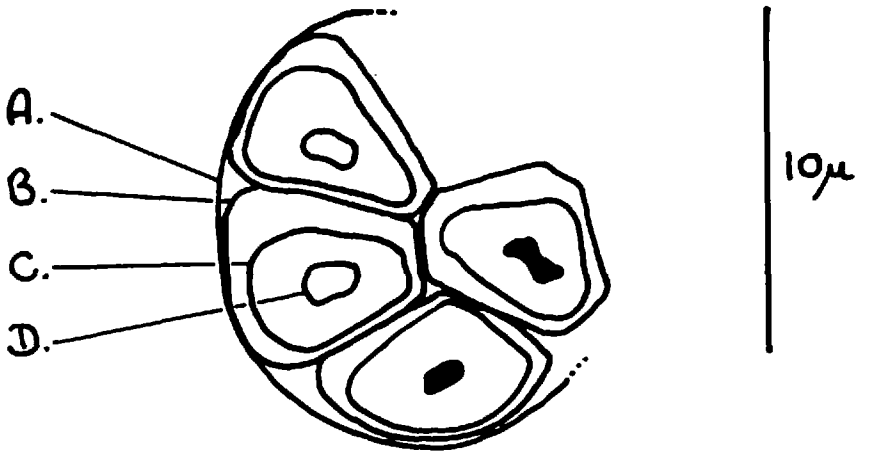
FIGURE 23. HYPOTHETICAL MANY-LAYERED MICROFOSSIL

C. a synaplomorph with 'spot' cells embedded in their own and common mucilage

D. a synaplomorph with shrunken cells embedded in several layers of mucilage.

For the purpose of objective description, the outermost discrete layer of the subunits in complex multilayered structures (ie layer B of Fig.23) is here interpreted as the cell wall. This usage differes from that of some descriptions. For example, in Bisacculoides tabeoviscus Oehler 1977 the second membrane counting inwards is here interpreted as the cell wall, not the third layer as in Oehler 1977,p.341-342,fig.11F-H. (See Fig. 24, below).

FIGURE 24. INTERPRETATION OF BISACCULOIDES



Bisacculoides tabeoviscus

Sketch of part of type specimen after Oehler 1977, Fig.11,F-H.

Layer	Interpretation	
	Oehler 1977	Here
A	Mucilage	Mucilage
B	Mucilage	Cell wall
C	Cell wall	Cell contents
D	Cell contents	Cell contents

Where one of the outer membranes has a distinctive structure or decoration (Eg. Tasmanites medius Eisenack 1968,pl.2,fig.7) it is possible to recognise sphaeromorph endocytes as such. In the absence of such good evidence the only reasonable course is to classify internal vesicles as if they were colonial forms. Where a vesicle consists of several concentric layers it can be classified as a sphaeromorph, so while Gloeodiniopsis lamellosa is a sphaeromorph, Bigeminococcus lamellosus is a synaplomorph. Among sphaeromorphs, no attempt is made to distinguish between layers of mucilage, vesicles and endospores.

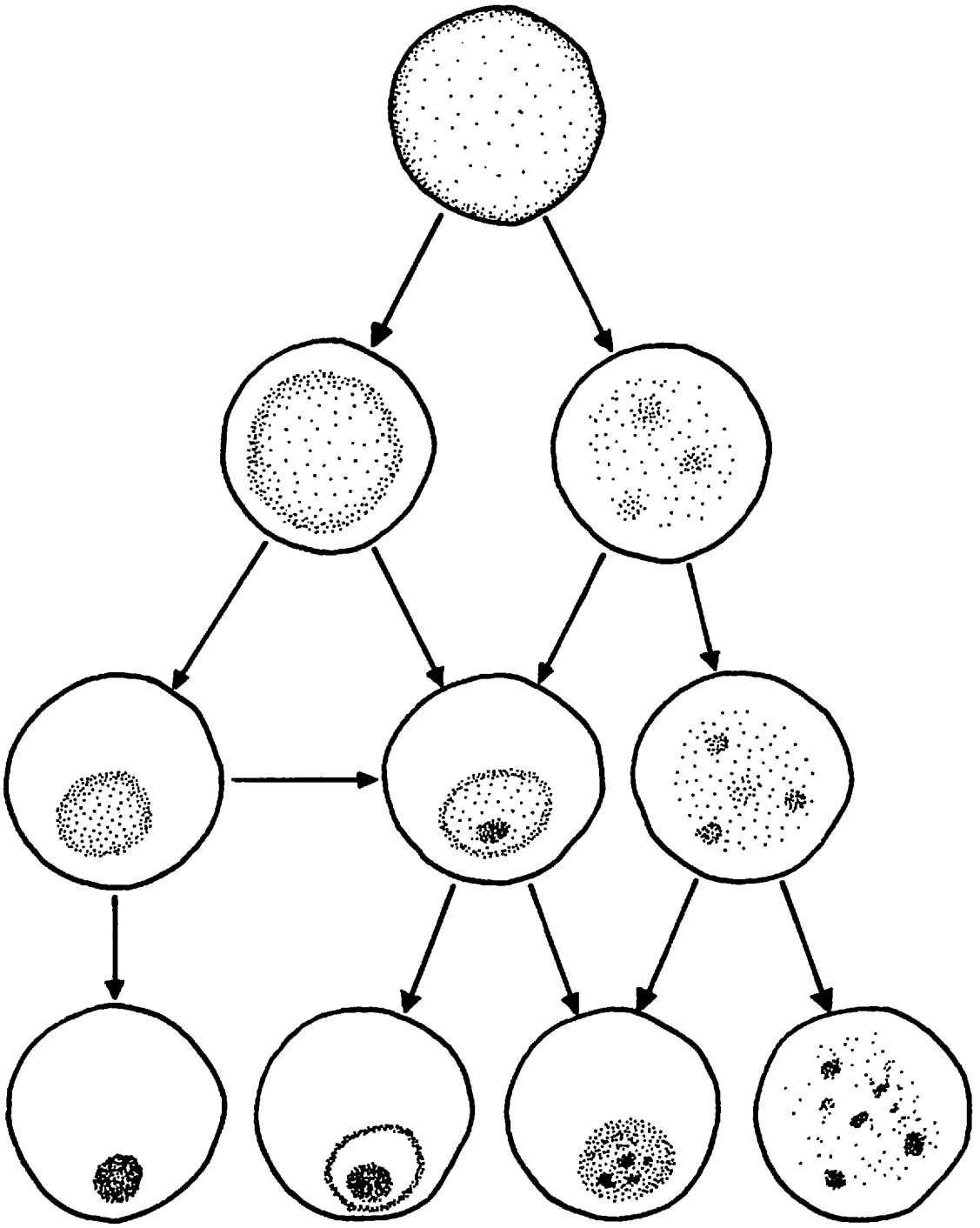
8. Inclusions.

In the Roper Group material, inclusions grade imperceptibly into inner membranes and hollow endocyst-like bodies (See Chapter 9). A variety of inclusions and endocysts has also been described in Tasmanites by Eisenack (1968). In general, if a particular layer of a vesicle has been interpreted as the wall of a cell, relatively small internal membrane systems and solid bodies have been called intracellular inclusions. In larger specimens where a membrane has been interpreted as an acritarch vesicle, inclusions have been referred to as inner bodies, cysts or inner cells.

Cryptarchs consisting of concentric membranes, with or without spots and granules are here classified as sphaeromorphs, and those with a hierarchical arrangement of membranes are classified as synaplomorphs.

Many taxa have been erected on the basis of the relative size and structure of presumed cellular bodies. In sphaeromorphs these take the form of spots, granules and membranes in various combinations (See figure 25). It has been shown that a variety of inclusions very similar to the fossil ones are produced by the plasmolysis and decay of cyanobacterial cells in dying unialgal cultures (Knoll & Barghoorn, 1975. See also Schopf & Oehler, 1976). The presence of inclusions cannot be used to infer a eukaryotic origin for such cells, and it is doubtful whether the various intracellular inclusions have much biological significance (though different living species may degrade in different ways in different conditions). However, in well preserved material various inclusions do occur consistently in certain populations and it is possible to recognise several

FIGURE 25. POSSIBLE DEGRADATION AND PLASMOLYSIS PATHWAYS OF A SINGLE CELL TYPE



fossil taxa as possible degradational forms of what may have been a single biological species (Hofmann, 1976, text figs. 5 & 6).

Even if not biologically meaningful, different inclusions could provide detailed information on early diagenesis and the conditions of deposition and sedimentation. At the present time there is nothing to be gained by the synonymy of presumed degradational variants into 'biological' species, though inclusions are clearly not as important for classification as cell arrangement or surface decoration.

In the sphaeromorphs, inclusions are only used in classification when more definitive characters are lacking - ie for the smooth, thin-walled sphaeromorphs. The reasoning implicit in this practice is that inclusions are less useful than vesicle structure and decoration, but better than nothing.

9. Wall structure.

For routine palynological purposes it is best to rely on gross characters that can be seen by transmitted light microscopy. Cryptarch wall ultrastructure is just beginning to be studied (Jux, 1971; Chapter 4) and although it may eventually help in working out the possible biological affinities of some taxa, the techniques involved are too specialised and time consuming for routine use.

Cryptarch wall structure as seen in the light microscope will most likely be an original feature of biological significance and of practical use in classification. It is so easy to mistake diffraction phenomena for vesicle walls that for practical purposes it is best to define a thick wall as one where the material of the wall can be clearly seen in optical transverse section in the light microscope - ie thicker than about 2 microns.

Using this definition, existing genera fall into three groups:-

1. thin walled - Protoleiosphaeridium type.
2. thick walled
   - A. with pores - Tasmanites type.
   - B. solid - Zonosphaeridium type.

10. Folds.

Most microorganisms are inflated by turgor pressure while alive, and only become wrinkled and flaccid in very severe conditions or when dying. The fold pattern of vesicles and valves can therefore be regarded as a secondary feature and will depend on:-

A. The original structure, thickness and flexibility of the vesicle wall.
B. Any modifications to (A) before or during sedimentation.
C. The size of the vesicle relative to the grain size of the enclosing sediment.
D. The structure of the matrix in which the vesicle is deposited and the degree of compaction.

Although folds and their arrangement may reflect important and original characteristics of a vesicle, they can clearly be influenced by many external processes and are necessarily unreliable characters for classification. If used in classification, folds will widen the taxonomic gap between shale and chert microbiotas.

Fold structures have not been studied and could provide important information on the mechanical strength of vesicle walls and the fossilisation and diagenesis of organic-walled microfossils. Palynologists in general have noted folds as imperfections in preservation rather than potentially useful features; two notable exceptions are Potonie (1962) and Harris (1974). No experimental work has yet been carried out on appropriate natural vesicles, though preliminary observations on squashed apples and stems (Walton, pers.comm. in Harris, 1974), spherical balls (Harris, 1974 ; and peas, above) suggest a potentially rewarding field of enquiry.

Further studies may show that folds can be a useful character in other taxa, but in this treatment I have only used them diagnostically in the classification of the smooth, thin-walled sphaeromorphs. These vesicles lack other distinctive features and there are currently two approaches to their classification.

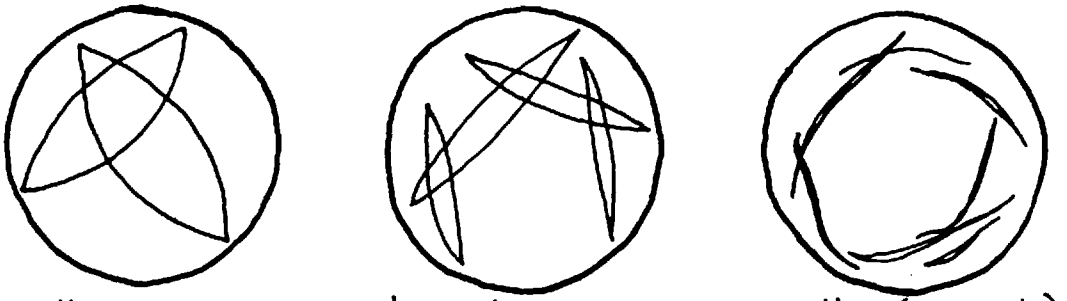
FIGURE 26. THE DESCRIPTION OF CRYPTARCH FOLDS

1. LINEAR SURFACE FEATURES



a. ridge and furrow. b. wrinkle. c. fold.

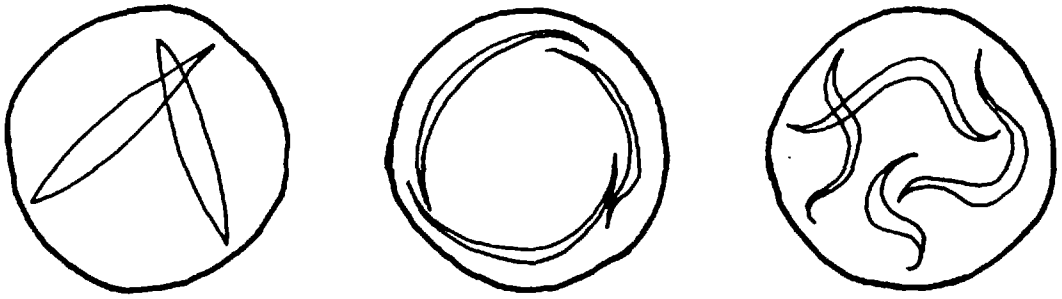
2. RELATIVE SIZE OF FOLDS



a. thick. b. medium. c. thin (= wrinkle).

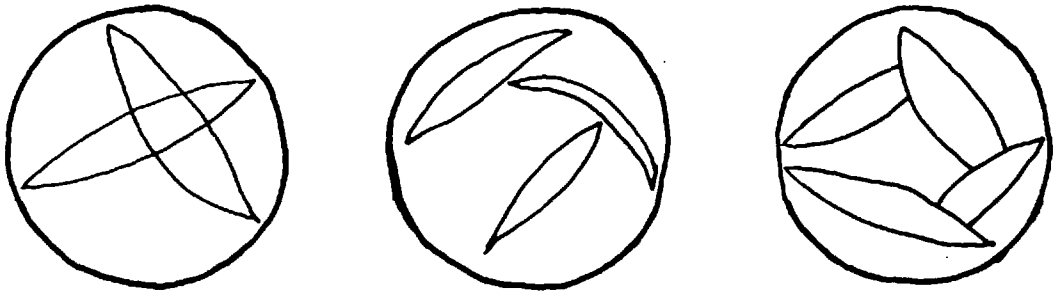
(relative to diameter of vesicle)

3. FOLD SINUOSITY



a. straight. b. curved. c. sinuous.

4. FOLD INTERACTION



a. folds cross. b. folds do not cross. c. folds truncate each other.

Downie & Sarjeant (1963) did not consider folds, and suggested that most existing leiosphere genera could be considered as subgenera of Leiosphaeridia Eisenack distinguished by vesicle ornament. Other workers have continued to erect new taxa on the basis of fold patterns, associations and vesicle surface microstructure (See Timofeev et al, 1976).

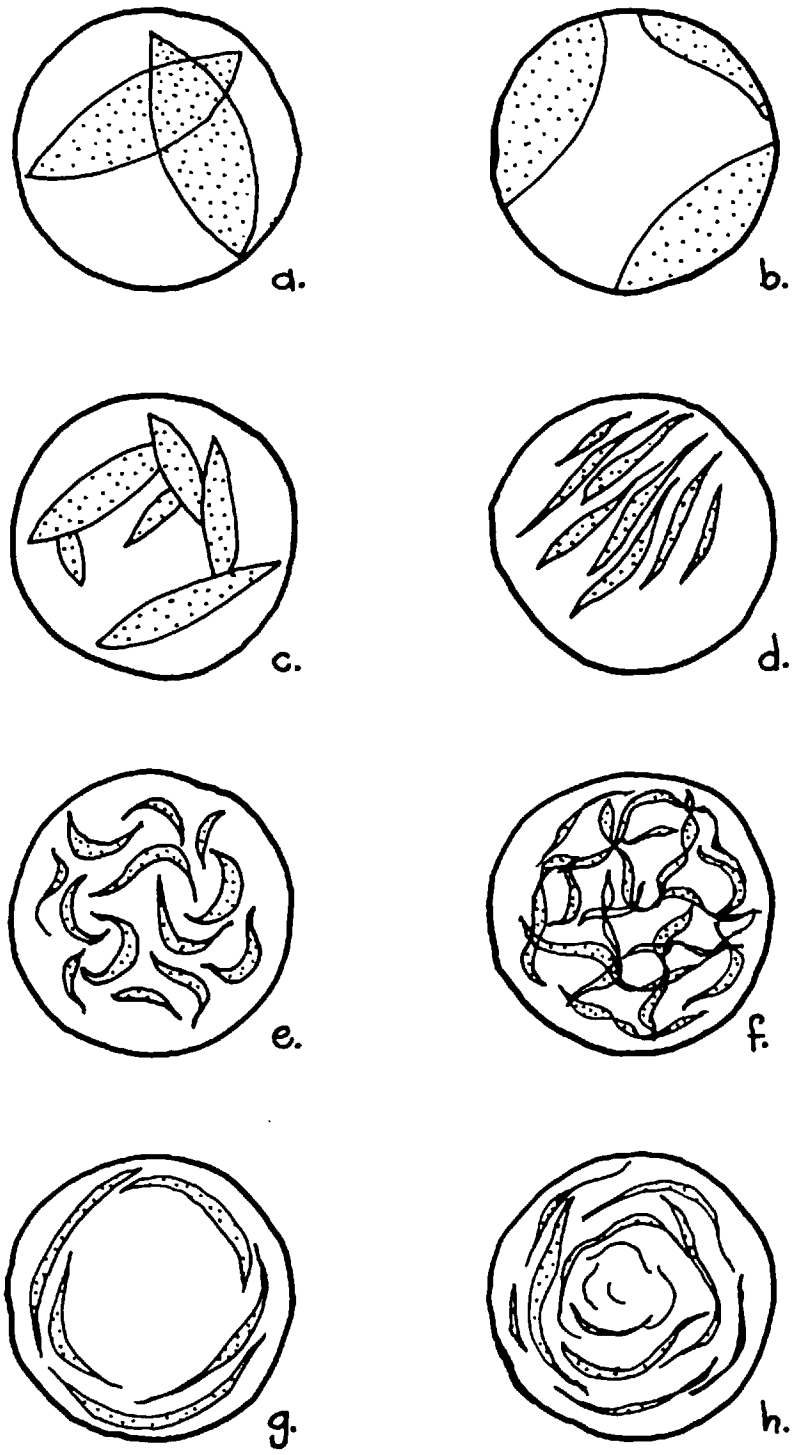
Wholesale synonymy would be premature at present, and anyway such sweeping reform should not be proposed without re-studying type material. At the same time, most 'leiosphere' genera have ambiguous and overlapping definitions. In this study I have attempted an objective reassessment of sphaeromorph cryptarch genera using described type material. On the basis that fold patterns may reflect the original structure of a vesicle wall, and that folds have already been used to distinguish many taxa, I have used folds diagnostically in the absence of more useful characters. Some of the descriptive terms used here are illustrated in a general way in Figures 26-27. Precise definitions are not warranted at this stage.

In the usage propose below, different stages in the life cycle of a single biological species will no doubt be assigned to several different form genera. It is also inevitable that biologically conspecific individuals that were decaying, dead, dying or alive at the time of final burial may also be assigned to different form taxa. When fold genesis and control are better understood it may become possible to recognise the influence of sedimentation and compaction in some groups of taxa, and to suggest meaningful synonymies. It is unfortunate that an objective approach to classification can only be achieved through an expansion of nomenclature, but I believe this to be the only practical approach at present.

11. Size.

Size is the most obvious and easily measured feature of any microfossil, and although it can be modified by fossilisation and sample preparation it is largely an original feature of the organism. Living species have characteristic size ranges and modal size classes, but in any environment it is rare for the size ranges of individual taxa not to overlap.

FIGURE 27. EXAMPLES OF CRYPTARCH FOLD PATTERNS



a. thick, random, crossing.
b. thick, marginal, extend to edge of vesicle.
c. medium, random, truncated.
d. thin to medium, linear.
e. short, curved, medium, non-crossing.
f. thin, sinuous, crossing in a reticulate pattern.
g. thin to medium, curved, marginal.
h. thin, curved, concentric.

In clastic environments there is usually considerable sorting of material before deposition, so the size ranges of preserved specimens may reflect nothing more than local hydrodynamic conditions near the time of burial. Even in permineralised benthonic communities only a part of the living ecosystem will be preserved. Thus, although statistical studies of the size of individuals within a taxon may indicate that the taxon contains several modal size classes or that it is unlikely to be the product of binary division of a single species (See Schopf, 1976), size alone cannot be used as a diagnostic criterion.

12. Colour.

The brown colour of subfossil vesicles in Recent sediments is caused by processes ranging from the purely inorganic (iron staining, oxidation) through the biochemical (impregnation by humic acids) to the biological (attack by extracellular enzymes). These processes continue in the sediment, but with progressively deeper burial, chemical reactions with interstitial pore waters become more important. Eventually, the more volatile components of the vesicle wall are lost and it becomes 'carbonised' (See Grayson, 1973; Karkhanis, 1976, 1977, 1978).

From experimental work (Sengupta, 1973, 1974, 1975; Sengupta & Rowley, 1974) it is clear that spores of different species react differently to diagenesis and various histological techniques, so the colour of fossil vesicles could reflect original differences of composition. Unfortunately these processes depend on time and the environment, and the final colour of a vesicle will depend on extraneous sedimentological and geological factors such as sediment recycling, rates of burial and deposition, depth of burial, local mineralogy and pore water chemistry.

This means that it is impossible to work out whether colour differences in an assemblage of fossil vesicles are due to original differences in composition, reworking of material, or microscopic differences in mineralogy. In some samples it may be possible to recognise reworked material, or to suggest that colour differences are an original feature (See Hofmann, 1976). Extrapolation of such observations to other samples in the same

sequence is a subjective exercise; the use of colour in defining taxa to be used in inter-regional correlation is clearly to be avoided.

D. Hierarchy of characters for classification

From the foregoing discussion it is possible to judge the relative usefulness and reliability of the characters available for diagnostic use in classification. The most useful characters will be those which are:-

1. Original.
2. Most easily seen.
3. Likely to survive diagenesis and some metamorphism.

Considering characters according to these criteria allows them to be ranked as shown below. Although the relative position of some characters is subjective, these hierarchies conform well with the rankings implicit in many previously described cryptarch taxa. These tables have been used to construct the keys which are the basis of the scheme of classification proposed in Chapter 7.

E. Sphaeromorphitae - ranked characters

1. Presence of localised structures such as incipient suture lines, bordered pylomes, polar appendages.
2. Wall thickness.
3. Structures within the wall.
4. Surface decoration.
5. Presence of inclusions, membranes or sheaths.
6. Fold pattern.
7. Size.
8. Colour.

F. Synaplomorphitae - ranked characters

1. Differentiation into vesicle types - ie tissues.
2. Presence of occasional differentiated vesicles - ie spores, cysts.
3. Outer wall of colony with localised structures - ie incipient suture lines, opercula, stalk.

4. Vesicle walls with localised structures - ie pylomes, incipient suture lines etc.
5. Vesicle shape.
6. Processes.
7. Special spatial arrangement of vesicles within colony.
8. Nature of contact between individual vesicles.
9. Surface decoration of vesicles.
10. Vesicle inclusions.
11. Size.
12. Colour.

G. Nematomorphitae - ranked characters

1. Habit - ie heterotrichous, homotrichous.
2. Presence of vesicles - ie cellular filaments, coenocytic or hollow sheath.
3. Vesicle arrangement - ie uniseriate, multiseriate.
4. Mode of growth - ie branched, unbranched.
5. Shape of vegetative vesicles.
6. Nature of contact between vesicles.
7. Presence of sheaths.
8. Vesicle surface decoration.
9. Presence of differentiated cells.
10. Size.
11. Tapering.
12. Nature of terminal cell.
13. Colour.

Chapter 7

Classification of existing OWM taxa

The hierarchy of characters developed in Chapter 6 can be used to devise keys to known OWM taxa (Tables 9-11). One advantage of a purely morphological scheme of classification is that such characters, selected objectively, will have taxonomic importance. Different levels of the keys represent more or less significant differences between taxa, and can be used to reconcile the views of different authorities. For example Timofeev (1966) discriminated generically between smooth thin-walled sphaeromorphs at the sub-subset level, whereas Downie & Sarjeant (1965) synonymised genera from sets VI, VIII and IX under Leiosphaeridia Eisenack 1958. The 14 genera and 26 species listed as Nematomorphitae Set IX-A are distinguished on very doubtful characters, and while I would not synonymise them, they could be considered en bloc as the 'Cephalophytarion group' for most practical purposes.

When different species of the same form genus are found to be spread over a wide range of key endings, it is clear that either the genus was originally defined on a character not considered to be a priori most useful for classification, or that a new character needs to be considered at a higher level of the key.

Leiosphaera Eisenack 1938 is one example of the way in which the interpretation of a genus has gradually been refined. Leiosphaera was originally defined and interpreted as including all smooth, originally spherical, hollow vesicles. If classified here, species of Leiosphaera would be found spread over a wide range of key endings, and the genus could be interpreted as a senior subjective synonym of most current smooth sphaeromorph cryptarchs. The significance of the porate wall structure of some species was recognised by Eisenack (1958), who assigned some species to Tasmanites Newton and others to Leiosphaeridia Eisenack. In this re-assessment I suggest that the definition of Leiosphaeridia is too broad to be useful and restrict the genus to smooth sphaeromorph cryptarchs with thick aporate walls. It is also

suggested that Tasmanites Newton should be restricted to smooth sphaeromorph cryptarchs with thick porate walls. These suggestions are based on published descriptions and illustrations of type material.

Many commonly encountered cryptarch genera and species are classified here for the first time, and many emendations and interpretations are suggested (Tables 12-15). Because of limited time and space, the emphasis here is on Precambrian taxa, most of which are listed. Some relevant Phanerozoic taxa are included but Tasmanites and its allies are only mentioned incidentally (See Muir & Sarjeant, 1971) and most fossil fungal spores, asci and mycelia have been neglected (See Meschinelli, 1898; Tiffney & Barghoorn, 1974).

The results achieved here with Precambrian taxa have justified the adopted procedure and show that it would be useful to include Phanerozoic cryptarchs in this system. Work in this direction has begun, but as it will require a re-assessment of all OWM taxa described since the time of Sternberg (1820) it will be a long time before even a preliminary synthesis can be attempted.

My policy here has been to conserve all valid names and to interpret genera and species on the basis of the designated type material. Type specimens were not traced or re-examined because time and money were limited and effort was best directed to a general survey. The results so far are tabulated below. First are three keys in which the Sphaermorphitae (Table 9), Synaplomorphitae (Table 10) and Nematomorphitae (Table 11) are divided into sets of genera. These are followed by tables in which the taxa attributed to each set are listed (Sphaermorphitae, Table 12; Synaplomorphitae, Table 13; Nematomorphitae, Table 14). Some sets have been subdivided. Type species are marked with an asterisk. The chapter ends with an alphabetical list of genera and species considered here with comments on their interpretation and circumscription (Table 15). If classified in Tables 12-14, the attribution of the species is given in an abbreviated form here (Eg. SPH-VII means that the species is classified as a sphaeromorph, Set VII).

to face p.101

Figure 28

Fold patterns of smooth, thin-walled sphaeromorph cryptarchs

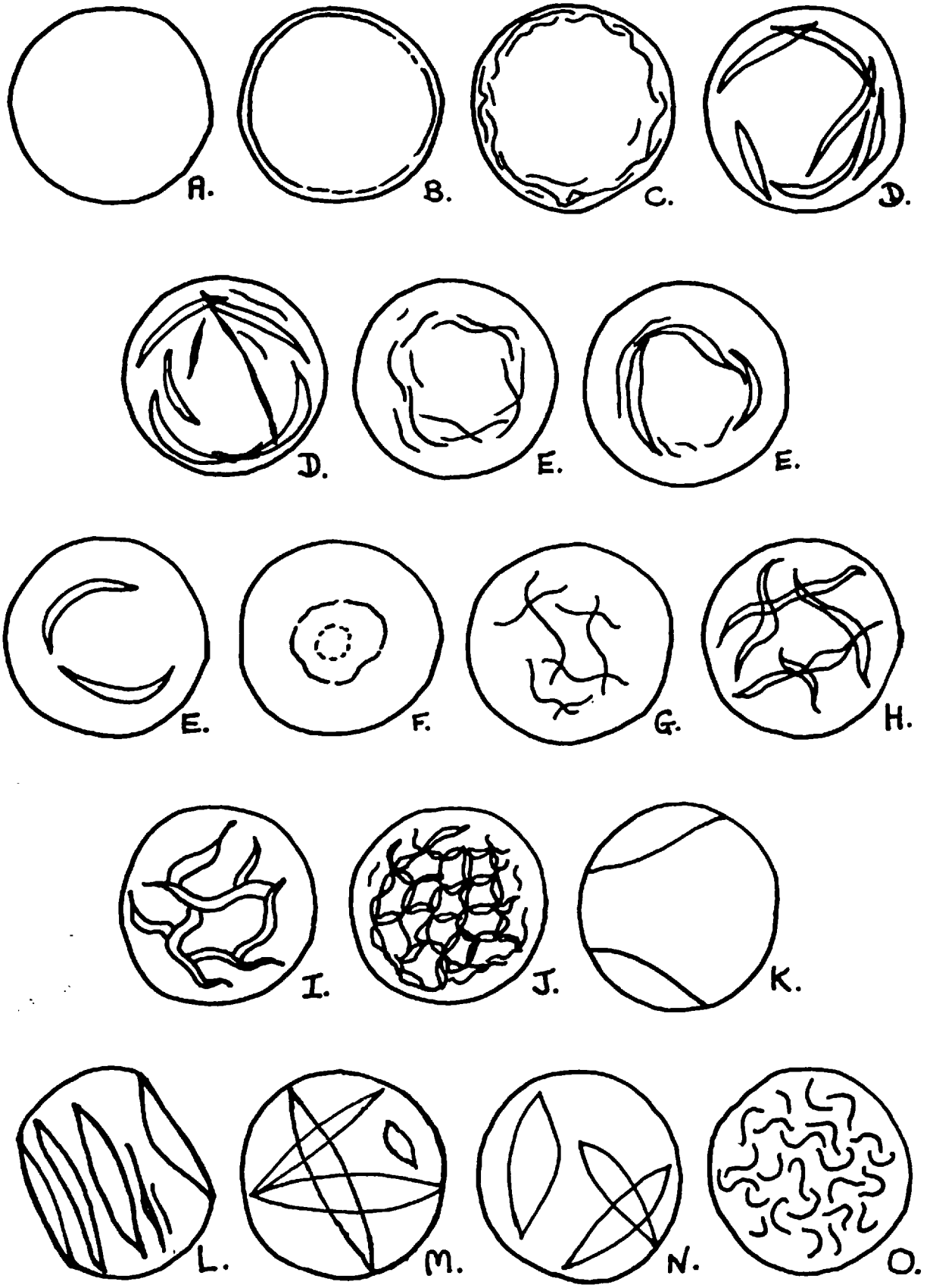
Legend

Simple thin-walled vesicles ...

A. without folds.
B. with a single marginal fold at the edge of the vesicle.
C. with many very thin curved folds in a circular pattern around the margin of the vesicle.
D. with few folds, thick to medium in width, straight or gently curved, crossing, arranged at random but rare in the marginal zone of the vesicle.
E. with thin to medium folds, restricted to near the edge of the vesicle, but not occurring in the marginal zone.
F. vesicle flattened into a round layered structure with more layers in the middle than near the edges.
G. with few thin folds which may cross.
H. with few to many sinuous folds of medium width, arranged at random.
I. with folds of medium width which truncate each other.
J. with numerous folds, thin to medium in width, criss-crossing to form a reticulate pattern.
K. with thick to medium folds, restricted to the very margin of the vesicle.
L. with few to many folds or wrinkles, arranged in a linear pattern.
M. with few to many medium to wide straight folds which cross the vesicle and each other at random.
N. with few wide, straight to slightly curved folds arranged at random but rarely crossing.
O. with many curved interlocking wrinkles.

FIGURE 28.

FOLD PATTERNS OF SMOOTH, THIN-WALLED SPHAEROMORPH CRYPTARCHS



Probably the most important contribution of this reassessment is the proposed classification of the smooth, thin-walled sphaeromorph cryptarchs on the basis of their fold pattern. It remains to be seen how much fold pattern is controlled by original features of the living organism and how much it is influenced by external processes (See Chap. 6). At least the approach adopted here is a reasonably objective and consistent way of interpreting and distinguishing between existing genera. The fold patterns used here are shown schematically in Figure 28. The letters on the figure refer to the appropriate sub-sets of Sphaeromorphitae Set IX.

It is interesting that most of the morphological features here considered significant are of most recent origin and vice versa. The maxim that 'simplest came first' apparently holds, though the evolution of homoeomorphs and the production of simple cysts by advanced organisms may be difficult to recognise. The implications of this idea are that although the percentage of the living biota capable of preservation as cryptarchs has probably fallen with time, the absolute number of possible sources for a given cryptarch have increased (Figure 29). This means that cryptarch studies will be most meaningful in the biological sense in older sediments.

The way in which these keys emphasise the basic similarity of groups of taxa should improve the standard of nomenclature and classification. Many of our present problems result from the description of partially synonymous new genera and species without adequate comparison with existing taxa (Eg. Nucellosphaeridium and Glenobotrydion; Bavlinella, Pyritosphaera and Sphaerocongregus; Leiosphaeridia (sensu novo) and Zonosphaeridium). At least these keys will facilitate identification and suggest similar taxa with which putative new genera and species should be compared.

In the longer term, this approach should also lead to a closer scrutiny of the characters by which taxa are distinguished, hopefully resulting in a more precise discrimination of taxa and a better understanding of cryptarch preservation and diversity.

FIGURE 29. CRYPTARCHS AS PART OF THE LIVING BIOTA

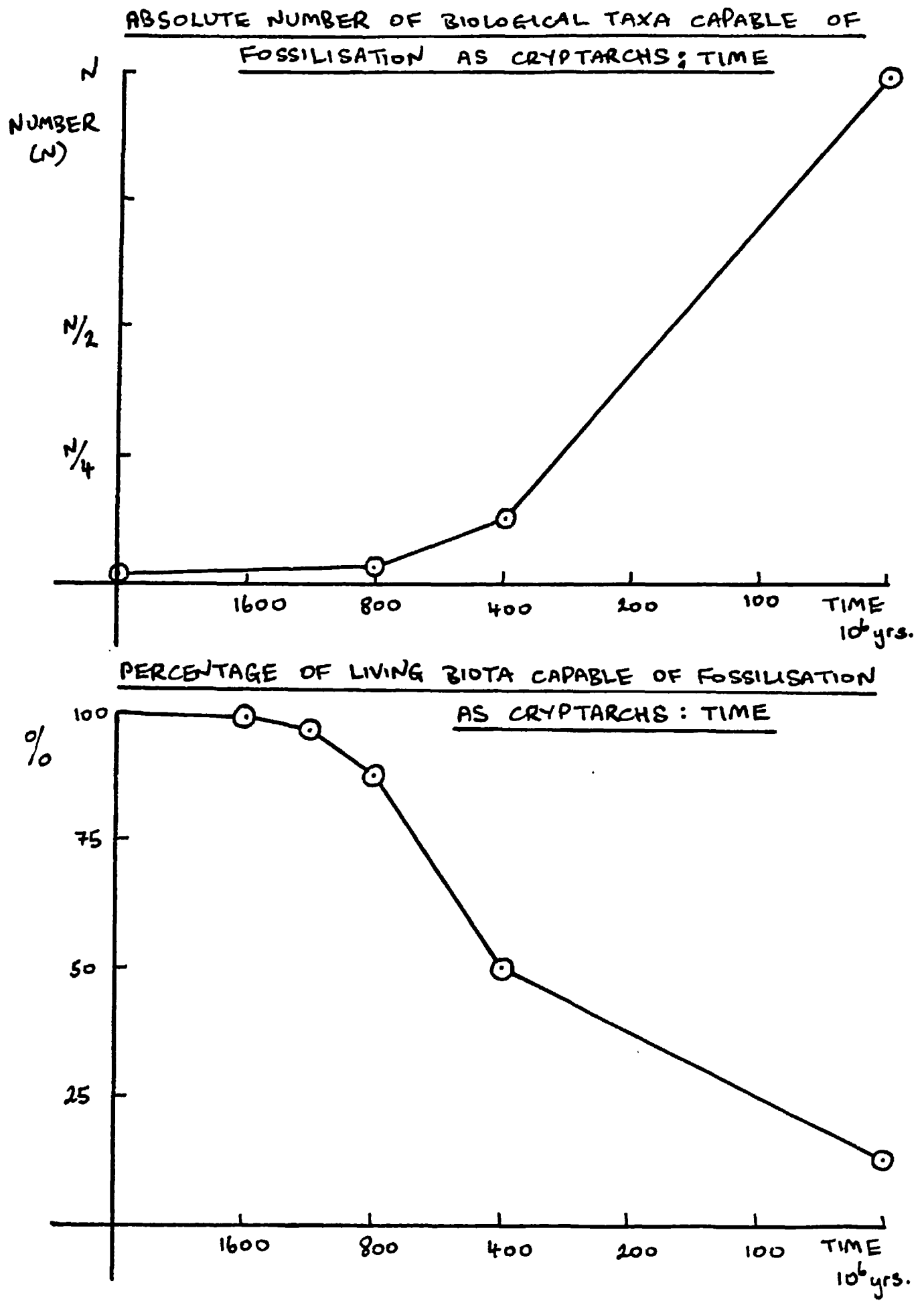


Table 9

Subgroup Sphaeromorphitae. Key to sub sets

SPHAEROMORPHITAE

PRESERVATION GOOD ENOUGH AND VESICLE LARGE ENOUGH TO DISTINGUISH VESICLE WALL.

Y — VESICLE VERY SMALL (IE LESS THAN 2 OR 3 MICRONS IN LONGEST DIMENSION).

Y — SET I

N — VESICLE POORLY PRESERVED — SET X

N — VESICLE SHOWS INCIPIENT SUTURE LINES, RECOGNISABLE CLOSED PYLOMES OR OTHER LOCALISED STRUCTURES.

Y — SET II

N — VESICLE WALL THICK. THICKNESS CAN BE CLEARLY SEEN IN THE TRANSMITTED LIGHT MICROSCOPE (IE THICKER THAN ABOUT 2 MICRONS).

Y — STRUCTURES SEEN WITHIN WALL IE PORES ETC.

Y — VESICLE SURFACE DECORATED.

Y — SET III

N — SET IV

N — VESICLE SURFACE DECORATED.

Y — SET V

N — SET VI

N — VESICLE SURFACE DECORATED OR WITH PORES.

Y — SET VII

N — VESICLE WITH INCLUSIONS, MEMBRANES OR SHEATHS.

Y — SET VIII

N — SET IX

Table 10

Subgroup Synaplomorphitae - key to sub sets

SYNAPLOMORPHITAE

PRESERVATION GOOD ENOUGH TO DISTINGUISH MUCILAGE, MEMBRANES, INCLUSIONS AND CELLS.
Y N ..... SET XII

COLONY MADE UP OF VESICLES OF MORE THAN ONE MORPHOLOGY (NOT SIMPLE MECHANICAL DIFFERENCES BETWEEN INNER AND OUTER CELLS).
N Y

1. TISSUES FORMED ..... SET I

2. SPORES PRODUCED ..... SET II

VESICLES WITHIN A MEMBRANE WITH AN OPERCULUM OR STALK.
N Y ..... SET III

VESICLES HAVE INCIPIENT SUTURE LINES, RECOGNISABLE CLOSED PYLOMES OR OTHER SUCH LOCALISED STRUCTURES.
N Y ..... SET IV

INDIVIDUAL CELLS MORE OR LESS ROUND OR SUB-POLYGONAL.
Y N ..... SET V

CELLS HAVE PROCESSES.
N Y ..... SET VI

CELLS HAVE SURFACE DECORATION.
N Y ..... SET VII

SPECIAL SPATIAL ARRANGEMENT OF CELLS IN COLONY.
N Y ..... SET VIII

SEPTA 1. ABSENT (IE CELLS SEPARATED) ..... SET IX

2. CONSTRICTED ..... SET X

3. NOT CONSTRICTED ..... SET XI

Table 11

Subgroup Nematomorphitae - key to sub sets

NEMATOMORPHITAE

PRESERVATION GOOD ENOUGH TO DISTINGUISH WALLS, CELLS ETC.
Y N ..... SET XI

CELLS SEEN.
Y N

FILAMENT BRANCHED.
Y ..... SET I

N ..... SET II

MORE THAN ONE TYPE OF CELL PRESENT.
N Y

1. FILAMENTS ARISE FROM PARENCHYMATOUS TISSUE ..... SET III

2. FILAMENTS GIVE RISE TO SPORES ..... SET IV

3. FILAMENTS ARISE FROM CENTRAL BODY ..... SET XII

FILAMENT UNISERIATE.
Y N

FILAMENT BRANCHED.
Y ..... SET V

N ..... SET VI

FILAMENT BRANCHED.
N Y ..... SET VII

CELL LENGTH/WIDTH RATIO

1. LESS THAN 0.5 ..... SET VIII

2. BETWEEN 0.5 AND 2.0 ..... SET IX

3. GREATER THAN 2.0 ..... SET X

Table 12. Subgroup Sphaeromorphitae - attributed taxa

SPHAEROMORPHITAE SET I

SMALL BACTERIUM-LIKE VESICLES.

*EOBACTERIUM ISOLATUM BARGHOORN AND SCHOPF 1966.

SPHAEROMORPHITAE SET II

VESICLES WITH INCIPIENT SUTURE LINES OR OTHER LOCALISED STRUCTURES.

*BULLASPHAERA VARIEGATA LICARI 1978.

HEMISPHAERIUM GERMANUM HEMER AND NYGREEN 1967.
*H.INOMINATUM HEMER AND NYGREEN 1967.
H.SIGNUM HEMER AND NYGREEN 1967.
SURFACE WITH GROOVE.

*HOEGISPHAERA GLABRA STAPLIN 1961.

*KAKABEKIA UMBELLATA BARGHOORN 1965.

*LACUNALITES SPHAERICUS HEMER AND NYGREEN 1967.

LEIOSPHAERIDIA LEPTOTHECA EISENACK 1968.
L.OELANDICA EISENACK 1962.
L.TUBULOSA EISENACK 1963.
L.VOIGTI EISENACK 1958.

*PORTALITES CONFERTUS HEMER AND NYGREEN 1967.
THICKENED WALL WITH SINGLE CIRCULAR PORE.

*SCHISMATOSPHAERIDIUM PERFORATUM STAPLIN ET AL 1965.

SPHAEROMORPHITAE SET III

THICK WALLED DECORATED VESICLES WITH STRUCTURES WITHIN THE WALL.

*ARABISPHAERA BELLULA HEMER AND NYGREEN 1967.
A.FOSSILIS HEMER AND NYGREEN 1967.

*CRASSOSPHAERA CONCINNA COOKSON AND MANUM 1960.
C.COOKSONI KRIVAN-HUTTER 1963.
C.DIGITATA COOKSON AND MANUM 1960.
C.MANUMI KRIVAN-HUTTER 1963.
C.MINOR KRIVAN-HUTTER 1963.
C.STELLULATA COOKSON AND MANUM 1960.
C.STELLULATA VAR MINOR KEDVES 1962.

*HUNGARODISCUS FRAGILIS KRIVAN-HUTTER 1963.

*NOREMIA MAJOR KEDVES 1962.

*PLEUROZONARIA GLOBULUS WETZEL 1933.

SPHAEROMORPHITAE SET IV

THICK WALLED SMOOTH VESICLES WITH STRUCTURES WITHIN THE WALL.

TASMANITES BALTEUS FELIX 1965.
T.CORRUGATUS FELIX 1965.
T.FISSURA FELIX 1965.
T.FULGIDUS FELIX 1965.
T.HURONENSIS (DAWSON 1871) SCHOPF ET AL 1944 EMEND WINSLOW 1962.
T.MARTINSSONI EISENACK 1958.
T.MINUTUS EISENACK 1965.
T.NOREMI EISENACK 1962.
T.POROSUS FELIX 1965.
*T.PUNCTATUS NEWTON 1875.
T.SINUOSUS WINSLOW 1962.
T.SOMMERI WINSLOW 1962.
T.TARDUS EISENACK 1958.
T.TREMATUS EISENACK 1962.
T.USITATUS FELIX 1965.
T.VALIDUS FELIX 1965.
T.VERRUCOSUS EISENACK 1962.

*TYTTHODISCUS CALIFORNIENSIS NOREM 1955.
T.CHONDROTUS NOREM 1955.

/Table 12 continued

SPHAEROMORPHITAE SET V

THICK WALLED DECORATED VESICLES WITH NO STRUCTURES WITHIN THE WALL.

*ANTROSPHAERA CALLOVIENSIS SARJEANT 1961.
WALL WITH DEPRESSIONS.

SPHAEROMORPHITAE SET VI

THICK WALLED SMOOTH VESICLES WITH NO STRUCTURES WITHIN THE WALL.

*GRANOMARGINATA PRIMA NAUMOVA 1960.
G.PRIMITIVA SALUJHA ET AL 1971.

*LEIOSPHAERIDIA BALTICA EISENACK 1958.
L.PLICATA FELIX 1965.
L.RALLA FELIX 1965.
L.RUGOSA BONEHAM + TAILLEUR 1972.

ZONOSPHAERIDIUM CRASSUM TIMOFEEV 1969.
Z.KALJOI (TIMOFEEV 1966). FORMERLY TASMANITES.
*Z.LIMPATUM TIMOFEEV 1969.
Z.MANGASEUS (TIMOFEEV 1966). FORMERLY TASMANITES.

SPHAEROMORPHITAE SET VII

THIN WALLED DECORATED AND PORATE VESICLES.

A. ORNAMENT OF SHORT SPINES.

*ACANTHOSPHAERIDIUM CITRINUM (DOWNIE 1963). FORMERLY LOPHOSPHAERIDIUM.
A.GRANULATUM (MAITHY 1975). FORMERLY LOPHOSPHAERIDIUM.
A.JAINII (SALUJHA ET AL 1971). FORMERLY LOPHOSPHAERIDIUM.
A.JANSONIUSII (SALUJHA ET AL 1971). FORMERLY LOPHOSPHAERIDIUM.
A.LAUFELDI (VIDAL 1976). FORMERLY TRACHYSPHAERIDIUM.
A.MICROSAETOSUM (STAPLIN 1961). FORMERLY PROTOLEIOSPHAERIDIUM.
A.PAPILLATUM (STAPLIN 1961). FORMERLY PROTOLEIOSPHAERIDIUM.
A.PILOSUM (DOWNIE 1963). FORMERLY LOPHOSPHAERIDIUM.
A.TRIANGULATUM (DOWNIE 1963). FORMERLY LOPHOSPHAERIDIUM.

*NUCELLOHYSTRICHOSPHAERA MEGALEA TIMOFEEV IN TIMOFEEV ET AL 1976.

*SYNSPHAERIDIUM GOTLANDICUM EISENACK 1965.

*TRACHYHYSTRICHOSPHAERA AIMICA HERMANN IN TIMOFEEV ET AL 1976.

B. ORNAMENT OF TUBERCLES.

*LOPHOMINUSCULA PRIMA NAUMOVA 1960.
L.VERRUCOSA (NAUMOVA 1960). FORMERLY MARGOMINUSCULA.
TUBERCULATE SURFACE, MARGINAL FOLD.

LOPHOSPHAERIDIUM GIBBEROSUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
L.MICROGRANULOSUM THUSU 1973.
L.PARVERARUM STOCKMANS + WILLIERE 1963.
L.PARVIGRANULOSUM (STAPLIN 1961). FORMERLY PROTOLEIOSPHAERIDIUM.
L.PARVUM STOCKMANS + WILLIERE 1963.
L.PODOLICUM (TIMOFEEV 1966). FORMERLY NUCELLOSPHAERIDIUM.
*L.RARUM TIMOFEEV 1959 EX DOWNIE 1963.
L.RUGOSUM THUSU 1973.
L.SCABRIDUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
L.TALLINICUM (TIMOFEEV 1966). FORMERLY TYLOSPHAERIDIUM.
L.TORTULOSUM (TIMOFEEV 1966). FORMERLY STICTOSPHAERIDIUM.
L.TORULOSUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
L.TUBERCULATUM (EISENACK 1965). FORMERLY SYNSPHAERIDIUM.
L.TUBERCULIFERUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
L.VETULUM SALUJHA ET AL 1971.

*MEMBRANOSPHAERA MAASTRICHTICA SAMOILOVICH IN MALYAVKINA ET AL 1961 EX NORRIS + SARJEANT 1965. INTERPRETATION UNCERTAIN.

C. WALL PERFORATED BY PORES.

PUNCTOSPHAERIDIUM DEFLANDREI (STOCKMANS + WILLIERE 1963). FORMERLY LEIOSPHAERIDIA.
*P.RIFEJICUS (JANKAUSKAS 1978). FORMERLY TASMANITES.
NUMEROUS PORES.

SPHAEROPORALITES MULTIFLEX HEMER AND NYGREEN 1967.
*S.SOLUS HEMER AND NYGREEN 1967.
FEW PORES.

D. WALL PITTED-POROUS.

ORYGMATOSPHAERIDIUM DISTRIBUTUM TIMOFEEV 1973.
*O.RUMINATUM TIMOFEEV 1959.
O.TRIZONATUM MAITHY 1975.
INTERPRETATION UNCERTAIN.
O.VULGARUM MAITHY 1975.
INTERPRETATION UNCERTAIN.

E. WALL PITTED OR ALVEOLAR.

PROTOLEIOSPHAERIDIUM FLEXUOSUM TIMOFEEV 1966.

TRACHYSPHAERIDIUM LAMINARITUM VIDAL 1976 NON TIMOFEEV 1966.

*TREMATOSPHAERIDIUM DECORATUM TIMOFEEV 1959.
T.HOLTEDAHLII TIMOFEEV 1966.
T.INSPISSATUM SALUJHA ET AL 1971.
INTERPRETATION UNCERTAIN.
T.SINUATUM TIMOFEEV 1966.
T.ZAIRIENSIS MAITHY 1975.
ATTRIBUTION DOUBTFUL.

F. WALL WITH RIDGES OR RETICULATION.

1. RIDGES DO NOT ANASTOMOSE, SOMETIMES BRANCH.

STICTOSPHAERIDIUM BRAYENSE GARDINER AND VANGUESTAINE 1971.
S.IMPLEXUM TIMOFEEV 1966.
S.PECTINALE TIMOFEEV 1966.
S.SIBIRICUM TIMOFEEV 1969.
*S.SINAPTICULIFERUM TIMOFEEV 1966.
S.VERRUCATUM VIDAL 1976.

2. RIDGES ANASTOMOSE TO FORM A RETICULATE NETWORK.

HURONIOSPORA MACRORETICULATA BARGHOORN IN BARGHOORN AND TYLER 1965.
*H.MICRORETICULATA BARGHOORN IN BARGHOORN AND TYLER 1965.
RETICULATION VERY FINE.

*DICTYOTIDIUM DICTYOTUM (EISENACK 1938) EISENACK 1955. FORMERLY LEIOSPHAERA. MESH REGULAR, USUALLY POLYGONAL.
D.POLOSYMMETRIUM STAPLIN 1961.
D.POLYGONIUM STAPLIN 1961.
D.TENUIORNATUM EISENACK 1955.

FAVOSOSPHAERIDIUM BOTHNICUM TIMOFEEV 1966.
F.FAVOSUM TIMOFEEV 1966.
F.KOZLOWSKII TIMOFEEV 1966.
*F.SCANDICUM TIMOFEEV 1966.
MESH IRREGULAR, PRONOUNCED.

*RETISPHAERIDIUM DICHAMERUM STAPLIN ET AL 1965.
MESH IRREGULAR, FAINT.
R.VINDHYANENSIS MAITHY 1968.

SPHAEROPHYCUS RETICULATUM MUIR 1976.
RETICULATION VERY FINE.

VAVOSOSPHAERIDIUM BHARADWAJII SALUJHA ET AL 1971.
V.DENSUM MAITHY 1975.
*V.MICHAILOVSKYI TIMOFEEV 1959.

3. RIDGES CIRCULAR, IN A CONCENTRIC PATTERN.

*CIRCULISPORITES PARVUS JERSEY 1962.

*CONCENTRICYSTES RUBINUS ROSSIGNOL 1962. INVALID.

G. WALL WITH ANGULAR PROTRUSIONS.

HURONIOSPORA ORNATA MUIR 1976.

/Table 12 continued

SPHAEROMORPHITAE SET VIII

THIN WALLED VESICLES WITH INCLUSIONS, MEMBRANES OR SHEATHS.

A. FOSSIL CONSISTS OF TWO CONCENTRIC MEMBRANES.
(IE AN ENDOSPORE OR CELL IN MUCILAGE).

*ARCHAEOPERISACCUS BALTICUS NAUMOVA 1960.
NATURE OF INNER BODY UNCERTAIN.

*CHLAMYDOSPHAERIDIA BALTICA EISENACK 1971.
OUTER WALL WITH MANY FOLDS.

CLONOPHYCUS REFRINGENS OEHLER 1978.

*DISPHAERIA MACROPYLA COOKSON AND EISENACK 1960.
DIAMETER OF INNER BODY ABOUT HALF THAT OF THE VESICLE.

*GALAXIOPSIS MELANOCENTRA AWRAMIK AND BARGHOORN 1977.
ROUND INNER BODY, IRREGULAR OUTER WALL.

GLOBOPHYCUS MINOR OEHLER 1977.
*G.RUGOSUM SCHOPF 1968.

*MEGALYTRUM DIACENUM BARGHOORN AND AWRAMIK 1978.

*PROTOARCHAEOSACCULINA ATAVA NAUMOVA 1960.

PTEROSPERMOPSIMORPHA ANNULARE TIMOFEEV 1969.
P.BINATA TIMOFEEV 1966.
P.INSOLITA TIMOFEEV 1969.
*P.PILEIFORMIS TIMOFEEV 1966.
DIAMETER OF INNER BODY MORE THAN 2/3 THAT OF THE VESICLE.
P.ZONATA (MAITHY 1975). FORMERLY NUCELLOSPHAERIDIUM ZONATUM.

B. VESICLE CONTAINS A SMALL, SOLITARY, DENSE INNER BODY OR SPOT.
DIAMETER OF THE SPOT IS LESS THAN 1/3 THAT OF THE VESICLE.

EOSYNECHOCOCCUS GRANDIS HOFMANN 1976.
E.MEDIUS HOFMANN 1976.
*E.MOOREI HOFMANN 1976.

*LATISPHAERA WRIGHTII LICARI 1978.
POORLY PRESERVED.

*MACULOSPHAERA KINGSTONENSIS LICARI 1978.
POORLY PRESERVED.

NUCELLOSPHAERIDIUM BELLUM TIMOFEEV 1969.
N.DEMINATUM TIMOFEEV 1969.
*N.DEUNFFI TIMOFEEV 1966.
N.GLENOS (SCHOPF 1968). FORMERLY GLENOBOTRYDION AENIGMATIS (PART).
N.MAGNUM MAITHY 1975.
N.MAJORINUM (SCHOPF AND BLACIC 1971). FORMERLY GLENOBOTRYDION.
N.MEDIANUM TIMOFEEV 1966.
N.MINUTUM TIMOFEEV 1966.
N.TRIANGULATUM MAITHY 1975.
N.ZONALE SIN AND LIU 1973.

*PILAVIA MACULATA OEHLER 1978.

C. VESICLE CONTAINS SEVERAL TO MANY SEPARATE SMALL OPAQUE INNER BODIES, SPOTS OR GRANULES.

*MELASMATOSPHAERA MAGNA HOFMANN 1976.
M.MEDIA HOFMANN 1976.
M.PARVA HOFMANN 1976.

D. VESICLE CONTAINS A SMALL TRANSLUCENT GRANULAR AREA OR DISCRETE BODY. THE DIAMETER OF THE INNER BODY IS LESS THAN 1/3 THAT OF THE VESICLE.

*ARCHAEODISCINA GRANULATA NAUMOVA 1960.

KILDINELLA MIROEDICHIA TIMOFEEV 1969.

E. VESICLE CONTAINS A MEMBRANE. WITHIN THE MEMBRANE IS A SMALL OPAQUE SPOT.

*CARYOSPHAEROIDES PRISTINA SCHOPF 1968.
C.TETRAS SCHOPF 1968.

/Table 12 continued

F. FOSSIL CONSISTS OF THREE OR MORE CONCENTRIC MEMBRANES.
(IE LAMELLATED MUCILAGE OR MULTIPLE INCLUSIONS).

*GLOEODINIOPSIS LAMELLOSA SCHOPF 1968.

SPHAEROMORPHITAE SET IX

SIMPLE THIN WALLED VESICLES.

A. WITHOUT FOLDS.

HURONIOSPORA PSILATA BARGHOORN IN BARGHOORN AND TYLER 1965.

*PHANEROSPHAEROPS CAPITANEUS SCHOPF AND BLACIC 1971.

PROTOLEIOSPHAERIDIUM ACIS TIMOFEEV 1966.
P.PUSILLUM TIMOFEEV 1966.
P.RIGIDULUM TIMOFEEV 1966.
P.SOLIDUM SIN AND LIU 1973.

SINAIICOCCUS AVNIMELECHI SHIMRON AND HOROWITZ 1972.
*S.DELICATUS SHIMRON AND HOROWITZ 1972.
S.MINUTUS SHIMRON AND HOROWITZ 1972.

SPHAEROPHYCUS DENSUS MAITHY 1975.
S.GIGAS EDHORN 1973.
*S.PARVUM SCHOPF 1968.
S.TETRAGONALIS MUIR 1976.

TRACHYSPHAERIDIUM TIMOFEEVI VIDAL 1976.

TURUCHANICA TERNATA TIMOFEEV 1966.
TRIPLE SPLIT GIVES LOBED APPEARANCE.

B. SINGLE MARGINAL FOLD AT EDGE OF VESICLE.

*LEIOMARGINATA SIMPLEX NAUMOVA 1960.

MARGOMINUSCULA ANTIQUA NAUMOVA 1960.
*M.RUGOSA NAUMOVA 1960.

PROTOLEIOSPHAERIDIUM CRYPTOGRANULOSUM STAPLIN 1961.
P.DENSUM MAITHY 1975.
P.PATELLIFORME TIMOFEEV 1966.

C. MANY VERY THIN CURVED FOLDS IN A CIRCULAR PATTERN AROUND THE MARGIN OF THE VESICLE.

*CHUARIA CIRCULARIS WALCOTT 1899.

LEIOSPHAERIDIA WENLOCKIA DOWNIE 1958.

*PSEUDOZONOSPHAERA VERRUCOSA SIN AND LIU 1973.
P.KANSHIENSIS (MAITHY 1975). FORMERLY LEIOSPHAERIDIA.
P.SINICA SIN AND LIU 1973.

D. FOLDS FEW, THICK TO MEDIUM, STRAIGHT OR GENTLY CURVED, CROSSING, ARRANGED AT RANDOM BUT RARE IN THE MARGINAL ZONE OF THE VESICLE.

KILDINELLA EXSCULPTA TIMOFEEV 1969.
K.FASTIGATIRUGOSA (STAPLIN 1961). FORMERLY LEIOSPHAERIDIUM.
*K.HYPERBOREICA TIMOFEEV IN TIMOFEEV + SHEPELEVA 1963 EX TIMOFEEV 1966.
K.JACUTICA TIMOFEEV 1966.
K.MAGNA TIMOFEEV 1969.
K.NORDIA TIMOFEEV 1969.
K.PELLUCIDA (SALUJHA ET AL 1971). FORMERLY LEIOSPHAERIDIA.
K.RIFEICA TIMOFEEV 1969.
K.SINICA TIMOFEEV 1966.
K.TIMANICA TIMOFEEV 1969.
K.TIMOFEEVII MAITHY 1975.
K.TSCHAPOMICA TIMOFEEV 1966.
K.UNDULATA (TIMOFEEV 1973). FORMERLY LEIOSPHAERIDIA.
K.VOLYNICA (TIMOFEEV 1973). FORMERLY LEIOSPHAERIDIA.

LEIOSPHAERIDIA BOREALIS BONEHAM + TAILLEUR 1972.
L.LINEBACKI BONEHAM 1970.

/Table 12 continued

E. THIN TO MEDIUM FOLDS, RESTRICTED TO NEAR THE EDGE OF THE VESICLE, BUT NOT OCCURRING IN THE MARGINAL ZONE.

*ARCHAEOPERTUSINA ATAVA NAUMOVA 1960.

PROTOLEIOSPHAERIDIUM BITUMINOSUM (TIMOFEEV 1966).
FORMERLY LEIOSPHAERIDIA BITUMINOSA.
*P.CONGLUTINATUM TIMOFEEV 1959 EX TIMOFEEV 1960.
P.DENSUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
P.DIAPHANIUM STAPLIN 1961.
P.DIATRETUS SALUJHA ET AL 1971.
P.GRANULOSUM STAPLIN 1961.
P.LACCATUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
P.LAEVIGATUM MAITHY 1975.
P.MAJOR STAPLIN 1961.
P.MICROGRANIFER STAPLIN 1961.
P.MINUTUM STAPLIN 1961.
P.ORBICULATUM STAPLIN 1961.
P.PAPYRACEUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
P.PARVULUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM.
P.PRISTINUM SALUJHA ET AL 1971.

*TRACHYSPHAERIDIUM ATTENUATUM TIMOFEEV 1959 EX TIMOFEEV 1966.
T.CONCENTRICUM (TIMOFEEV 1973). FORMERLY STICTOSPHAERIDIUM.
T.EISENACKI (TIMOFEEV 1959). FORMERLY LEIOSPHAERIDIUM.
T.LAMINARITUM TIMOFEEV 1966 NON VIDAL 1976.
T.MAICUM TIMOFEEV 1969.

F. VESICLE FLATTENED INTO A ROUND LAYERED STRUCTURE WITH MORE LAYERS IN THE MIDDLE THAN NEAR THE EDGES.

*MEGASACCULINA ATAVA NAUMOVA 1960.

G. FEW THIN FOLDS, MAY CROSS.

LEIOMINUSCULA INCRASSATA SIN AND LIU 1973.
*L.MINUTA NAUMOVA 1960.
L.PELLUCENTIS SIN AND LIU 1973.
L.RUGOSA NAUMOVA 1960.

PROTOLEIOSPHAERIDIUM ASAPHUM TIMOFEEV 1966.
P.PALEACEUM TIMOFEEV 1966.

H. FEW TO MANY MEDIUM SINUOUS FOLDS, ARRANGED AT RANDOM.

*LEIOPSOPHOSPHAERA MICRORUGOSA NAUMOVA 1960.
L.SIMPLICISSIMA NAUMOVA 1960.

LEIOSPHAERIDIA TENUISSIMA EISENACK 1958.

I. FOLDS OF MEDIUM WIDTH WHICH TRUNCATE EACH OTHER.

DICTYOSPHAERIDIUM ENISEICUM TIMOFEEV 1969.
*D.TUNGUSUM TIMOFEEV 1969.

J. FOLDS MEDIUM TO THIN, NUMEROUS, CRISS-CROSSING TO FORM A RETICULATE PATTERN.

ARCHAEOFAVOSINA NAUMOVAE MAITHY 1975.
*A.SIMPLEX NAUMOVA 1960.

K. THICK TO MEDIUM FOLDS RESTRICTED TO THE VERY MARGIN OF THE VESICLE.

L. FEW TO MANY FOLDS ARRANGED IN A LINEAR PATTERN.

MACROPTYCHA BIPLICATA TIMOFEEV IN TIMOFEEV ET AL 1976.
M.MULTIPLICATA TIMOFEEV IN TIMOFEEV ET AL 1976.
M.TRIPLICATA TIMOFEEV IN TIMOFEEV ET AL 1976.
*M.UNIPLICATA TIMOFEEV 1973 EX TIMOFEEV IN TIMOFEEV IN TIMOFEEV ET AL 1976.

PODOLINA ANGULATA HERMANN IN TIMOFEEV ET AL 1976.
P.ECHINATA HERMANN IN TIMOFEEV ET AL 1976.
*P.MINUTA HERMANN IN TIMOFEEV ET AL 1976.

*SCAPHITA ENISEICA TIMOFEEV 1973 EX TIMOFEEV IN TIMOFEEV ET AL 1976.

/Table 12 continued

M. FEW TO MANY MEDIUM TO WIDE STRAIGHT FOLDS CROSS VESICLE AND EACH OTHER AT RANDOM.

LEIOSPHAERIDIA LAEVIGATA STOCKMANS + WILLIERE 1963.
L.OCHROLEUCA TIMOFEEV 1966.

N. FEW WIDE STRAIGHT TO SLIGHTLY CURVED FOLDS ARRANGED AT RANDOM BUT RARELY CROSSING.

LEIOSPHAERIDIA CERINA TIMOFEEV 1966.

O. MANY CURVED INTERLOCKING WRINKLES

*PODOLIELLA IRREGULARE TIMOFEEV 1973.
P.MULTANGULARE (TIMOFEEV 1959). FORMERLY TRACHYOLIGOTRILETUM.
P.SERPENTINUM (TIMOFEEV 1959). FORMERLY TRACHYOLIGOTRILETUM.
P.VERMIA (TIMOFEEV 1969). FORMERLY PROTOSPHAERIDIUM.
P.VESLJANICA (TIMOFEEV 1969). FORMERLY KILDINELLA.

SPHAEROMORPHITAE SET X

POORLY PRESERVED VESICLES.

*ABUNDACAPSA IMPAGES LICARI 1978.

*APHANOCAPSITES GRANULOSUS MASLOV 1956.

*ARCHAEOSPHAEROIDES BARBERTONENSIS SCHOPF AND BARGHOORN 1967.

Table 13. Subgroup Synaplomorphitae - attributed taxa

SYNAPLOMORPHITAE SET I

DIFFERENTIATED CELLS FORM TISSUES.

*AMELIAPHYCUS CROXFORDII MUIR 1976.

*KIDSTONIELLA FRITSCHI CROFT AND GEORGE 1959.

*LITOSTROMA OKLAHOMENSE MAMAY 1959.

*MYXOMORPHA JANECEKII MUIR 1976.

SYNAPLOMORPHITAE SET II

BASAL TISSUE PRODUCES DIFFERENTIATED SPORES.

*MAJAPHYTON ANTIQUAUM TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.
M.CERATUM TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.
M.CYATUM TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.

SYNAPLOMORPHITAE SET III

CELLS OCCUR IN AN ASCUS-LIKE STRUCTURE.

SYNAPLOMORPHITAE SET IV

CELLS HAVE INCIPIENT SUTURE LINES OR OTHER LOCALISED STRUCTURES.

*PALAMBAGES MORULOSA WETZEL 1961 EMEND GOCHT AND WILLE 1972.

SYNAPLOMORPHITAE SET V

INDIVIDUAL CELLS OF DISTINCTIVE SHAPE.

*PLAESIODICTYON MOSELLANUM WILLE 1970.
P.MOSELLANUM SSP DIVERGENS WILLE 1970.
P.MOSELLANUM SSP MOSELLANUM WILLE 1970.
P.MOSELLANUM SSP PERFORATUM WILLE 1970.
P.MOSELLANUM SSP SINUOSUM WILLE 1970.

*TREMATOPHORA RADIATA EISENACK 1965.

SYNAPLOMORPHITAE SET VI

CELLS HAVE PROCESSES.

SYNAPLOMORPHITAE SET VII

CELLS HAVE SURFACE DECORATION.

SYNAPLOMORPHITAE SET VIII

SPECIAL SPATIAL ARRANGEMENT OF CELLS IN COLONY.

*BIGEMINOCOCCUS LAMELLOSUS SCHOPF AND BLACIC 1971.
CROSS TETRADS.
B.MUCIDUS SCHOPF AND BLACIC 1971.
PRESERVATION POOR.

*EOSPHAERA TYLERI BARGHOORN 1965.

*EOTETRAHEDRION PRINCEPS SCHOPF AND BLACIC 1971.

*EOVOLVOX SILESIENSIS KAZMIERCZAK 1975.

*MYRIASPORELLA PYRIFORMIS OEHLER 1978.
PYRIFORM COLONY.

TETRAPHYCUS ACINULUS OEHLER 1978.
T.DIMINUTIVUS OEHLER 1978.
*T.GREGALIS OEHLER 1978.
CELLS IN TETRADS.
T.MAJOR OEHLER 1978.

/Table 13 continued

SYNAPLOMORPHITAE SET IX

CELLS SEPARATED WITHIN COLONY.

*BALBIRINIELLA PRAESTANS OEHLER 1978.

*EOENTOPHYSALIS BELCHERENSIS HOFMANN 1976.

*EOZYGION GRANDE SCHOPF AND BLACIC 1971.
TWO CELLS WITHIN COMMON SHEATH.
EOZYGION MINUTUM SCHOPF AND BLACIC 1971.

*LEPTOTEICHOS GOLUBICII KNOLL ET AL 1978.
CELLS WITH INCLUSIONS IN COMMON MUCILAGE.

*MELASMATOSPHAERA MAGNA HOFMANN 1976.
M.MEDIA HOFMANN 1976.
M.PARVA HOFMANN 1976.

MYXOCOCCOIDES INORNATA SCHOPF 1968.
M.MINUTUS MUIR 1976.
M.RENIFORMIS MUIR 1976.

*NANOCOCCUS VULGARIS OEHLER 1977.
CELLS IN COMMON MUCILAGE.

*OSTIANA MICROCYSTIS HERMANN IN TIMOFEEV ET AL 1976.
CARBONISED CELLS IN COMMON MUCILAGE.

*PYRITOSPHAERA BARBARIA LOVE 1957.
P.FAVEOLATA (SHEPELEVA 1962).
FORMERLY BAVLINELLA.
P.VARIABILIS (MOORMAN 1974).
FORMERLY SPHAEROCONGREGUS.

SYNAPLOMORPHITAE SET X

SEPTA BETWEEN CELLS CONSTRICTED.

*CORYMBOCOCCUS HODGKISSII AWRAMIK AND BARGHOORN 1977.

MYXOCOCCOIDES CONGOENSIS MAITHY 1975.
M.RETICULATA SCHOPF 1968.

*PALAEOANACYSTIS VULGARIS SCHOPF 1968.

*SYNSPHAERIDIUM GOTLANDICUM EISENACK 1965.

SYNAPLOMORPHITAE SET XI

SEPTA BETWEEN CELLS NOT CONSTRICTED.

BISACCULOIDES GRANDIS OEHLER 1977.
*B.TABEOVISCUS OEHLER 1977.
CELLS CONTAIN MEMBRANE AND SPOT.
B.VACUA OEHLER 1977.

CLONOPHYCUS BIATTINA OEHLER 1978.
*C.ELEGANS OEHLER 1977.
C.VULGARIS OEHLER 1978.

*CONGLOBOCELLA TROXELII OEHLER 1977.

EOSYNECHOCOCCUS MOOREI (PART) HOFMANN 1976.

*GLENOBOTRYDION AENIGMATIS (PART) SCHOPF 1968.
TYPE SPECIMEN = ELONGATE MEMBRANE-BOUND COLONY.

GLOEOCAPSOMORPHA HEBEICA TIMOFEEV 1966.
G.PRISCATA TIMOFEEV 1966.

*MICROCONCENTRICA ATAVA NAUMOVA 1960.

/Table 13 continued

MYXOCOCCOIDES CRACENS OEHLER 1978.
*M.MINOR SCHOPF 1968.
M.KONZALOVAE MUIR 1976.
M.VERRUCOSA MAITHY 1975.
ATTRIBUTION UNCERTAIN.

*PALAEOPLEUROCAPSA WOPFNERII KNOLL ET AL 1975.

*POLYEDROSPHAERIDIUM BULLATUM TIMOFEEV 1966.

*PYRITELLA POLYGONALIS LOVE 1957.

SYMPLASSOSPHAERIDIUM BUSHIMAYENSIS MAITHY 1975.
ASSIGNMENT DOUBTFUL.
*S.TUMIDULUM TIMOFEEV 1959 EX TIMOFEEV 1966.

SYNAPLOMORPHITAE SET XII

POOR PRESERVATION.

Table 14. Subgroup Nematomorphitae - attributed taxa

NEMATOMORPHITAE SET I

BRANCHED ACELLULAR FILAMENTS OR HOLLOW TUBES.

*ARCHAEORESTIS SCHREIBERENSIS BARGHOORN IN BARGHOORN AND TYLER 1965.
A.MAGNA AWRAMIK AND BARGHOORN 1977.

NEMATOMORPHITAE SET II

UNBRANCHED ACELLULAR FILAMENTS, HOLLOW TUBES, OR RODS.

A. SOLITARY, STRAIGHT OR GENTLY CURVED.

*ANIMIKIEA SEPTATA BARGHOORN IN BARGHOORN AND TYLER 1965 EMEND AWRAMIK AND BARGHOORN 1978. TRANSVERSE WRINKLES.

ARCHAEOTHRIX CONTEXTA KIDSTON AND LANG 1921.

*SIPHONOPHYCUS KESTRON SCHOPF 1968.
8-15 MICRONS WIDE.
S.PUNCTATUS MAITHY 1975.
40-50 MICRONS WIDE.

*TAWUIA DALENSIS HOFMANN IN HOFMANN + AITKEN 1979.

TORTUNEMA ENISEICA HERMANN IN TIMOFEEV ET AL 1976.
*T.SIBIRICA HERMANN IN TIMOFEEV ET AL 1976.

*XENOTHRIX INCONCRETA AWRAMIK AND BARGHOORN 1977.
EXPANDED AND CLOSED AT BOTH ENDS.

B. SOLITARY, TWISTED, LESS THAN 1 MICRON WIDE.

*ARCHAEOTRICHION CONTORTUM SCHOPF 1968.

C. SOLITARY, TWISTED INTO A REGULAR HELIX, 2-3 MICRONS WIDE.

*HELICONEMA AUSTRALIENSE SCHOPF 1968.
H.FUNICULUM SCHOPF AND BLACIC 1971.

D. PAIRED, TWISTED TOGETHER.

*SPIRILLENEMA BENTORI SHIMRON AND HOROWITZ 1972.

NEMATOMORPHITAE SET III

CELLULAR FILAMENTS ARISE FROM BASAL TISSUE.

A. BASAL SYSTEM OF MASS OF CELLS, FILAMENTS UP TO 24 MICRONS WIDE.

*KIDSTONIELLA FRITSCHI CROFT AND GEORGE 1959.

B. BASAL SYSTEM OF MULTISERIATE FILAMENTS, ERECT FILAMENTS UP TO 16 MICRONS WIDE.

*LANGIELLA SCOURFIELDI CROFT AND GEORGE 1959.

NEMATOMORPHITAE SET IV

CELLULAR OR SEPTATE FILAMENTS GIVE RISE TO SPORES.

PALAEOMYCES AGGLOMERATA KIDSTON AND LANG 1921.
P.ASTEROXYLI KIDSTON AND LANG 1921.
P.GORDONI KIDSTON AND LANG 1921.
P.GORDONI VAR MAJOR KIDSTON AND LANG 1921.
*P.GRACILIS RENAULT 1896.
P.HORNEAE KIDSTON AND LANG 1921.
P.SIMPSONI KIDSTON AND LANG 1921.
P.VESTITA KIDSTON AND LANG 1921.

NEMATOMORPHITAE SET V

BRANCHED MULTISERIATE FILAMENTS.

NOT REPORTED.

/Table 14 continued

NEMATOMORPHITAE SET VI

CELLULAR FILAMENTS, MULTISERIATE, UNBRANCHED.

A. NUMEROUS CELLS TOUCH EACH OTHER TO FORM A FILAMENT WITHIN A SHEATH.

*GLENOBOTRYDION AENIGMATIS SCHOPF 1968.
G.KANSHIENSIS MAITHY 1975.

*RHYNIELLA VERMIFORMIS CROFT AND GEORGE 1959.

B. VESICLES NOT USUALLY TOUCHING, IN A TUBE.

*ENTOSPHAEROIDES AMPLUS BARGHOORN IN BARGHOORN AND TYLER 1965.
E.BILINEARIS MAITHY 1975.
E.IRREGULARIS MAITHY 1975.

*THYMOS HALIS AWRAMIK AND BARGHOORN 1977.

C. NUMEROUS VESICLES IN A CHAIN, WITHOUT SHEATH.

*CHOLOROGLOEAOPSIS ZAIRENSIS MAITHY 1975.

POLYSPHAEROIDES CONTEXTUS HERMANN IN TIMOFEEV ET AL 1976.
*P.FILLIFORMIS HERMANN IN TIMOFEEV ET AL 1976.

D. NUMEROUS VESICLES IN MEMBRANE-BOUND COLONIES. COLONIES LINKED END TO END IN A CHAIN.

*PALAEOMICROCYSTIS SCHOPFII MAITHY 1975.

NEMATOMORPHITAE SET VII

UNISERIATE OR SEPTATE BRANCHED FILAMENTS.

*PALAEOSIPHONELLA CLOUDII LICARI 1978.
SEPTA RARE, FILAMENTS WIDE.

*PALYNOMORPHITES DIVERSIFORMIS MOORE 1963.
SEPTA COMMON, FILAMENT 0.75-1.5 MICRONS WIDE.

NEMATOMORPHITAE SET VIII.

UNISERIATE, UNBRANCHED FILAMENTS, CELL LENGTH/WIDTH RATIO OF VEGETATIVE CELLS LESS THAN 0.5.

A. NOT OR VERY LITTLE CONSTRICTED AT SEPTA, NO SHEATH.

*OSCILLATORITES WERNADSKII SHEPELEVA 1960.
GENUS MAY BE TUBE WITH ANNULAR THICKENINGS.

*OBCONICOPHYCUS AMADEUS SCHOPF 1968.
TERMINAL CELL BLUNTLY POINTED.

B. NOT OR VERY LITTLE CONSTRICTED AT SEPTA, THIN SHEATH, ESPECIALLY AT TIP OF FILAMENT.

*PALAEOLYNGBYA BARGHOORNIANA SCHOPF 1968.
TERMINAL CELL ROUNDED.
P.MINOR SCHOPF AND BLACIC 1971.

C. CELLS CONSTRICTED AT SEPTA, SEPTA THICKENED MARKEDLY NEAR TO CELL WALL, NO SHEATH.

*CALYPTOTHRIX ANNULATA SCHOPF 1968.

D. CELLS VERY CONSTRICTED AT SEPTA OR SEPARATE, FORMING A STRING WITHIN A SHEATH.

*ARCHAEOTHRIX OSCILLATORIFORMIS KIDSTON AND LANG 1921.

*NODULARITES CYLINDRICUS MASLOV 1956.
INTERPRETATION SOMEWHAT QUESTIONABLE.

E. CELLS CONSTRICTED AT SEPTA, SHEATH ABSENT OR INDISTINCT.

OSCILLATORIOPSIS BREVICONVEXA SCHOPF AND BLACIC 1971.

/Table 14 continued

NEMATOMORPHITAE SET IX

UNISERIATE, UNBRANCHED FILAMENTS WITH MORE OR LESS EQUIDIMENSIONAL CELLS (LENGTH/WIDTH RATIO BETWEEN 0.5 AND 2.0).

A. NOT CONSTRICTED AT SEPTA.

*ARCTACELLULARIA DOLIIFORMIS HERMANN IN TIMOFEEV ET AL 1976.
A.ELLIPSOIDEA HERMANN IN TIMOFEEV ET AL 1976.

*BECKSPRINGIA COMMUNIS LICARI 1978.
PRESERVATION POOR.

CAUDICULOPHYCUS ACUMINATUS SCHOPF AND BLACIC 1971.
*C.RIVULARIOIDES SCHOPF 1968.
TERMINAL HAIR.

CEPHALOPHYTARION CONSTRICTUM SCHOPF AND BLACIC 1971.
C.DELICATULUM SCHOPF AND BLACIC 1971.
*C.GRANDE SCHOPF 1968 EMEND SCHOPF AND BLACIC 1971.
TERMINAL HAIR.
C.LATICELLULOSUM SCHOPF AND BLACIC 1971.
C.MINUTUM SCHOPF 1968.
C.VARIABILE SCHOPF AND BLACIC 1971.

*CONTORTOTHRIX VERMIFORMIS SCHOPF 1968.
TRICHOME COILED.

*CYANONEMA ATTENUATA SCHOPF 1968.
FILAMENT TAPERS TOWARDS TIP.
C.INFLATUM OEHLER 1977.
PRESERVATION POOR. TERMINAL CELLS NOT SEEN.
C.MINOR OEHLER 1977.

EOMYCETOPSIS SEPTATA MAITHY 1975.

GLENOBOTRYDION TETRAGONALUM MAITHY 1975.

GUNFLINTIA GRANDIS BARGHOORN IN BARGHOORN AND TYLER 1965.
G.KANSHIENSIS MAITHY 1975.
*G.MINUTA BARGHOORN IN BARGHOORN AND TYLER 1965.
PRESERVATION POOR - GRANULAR CARBON.

NODULARITES MASLOVI SHEPELEVA 1960.
INTERPRETATION SOMEWHAT UNCERTAIN.

*OSCILLATORIOPSIS OBTUSA SCHOPF 1968.
TERMINAL CELL OBTUSE-ROUNDED.
O.SCHOPFII OEHLER 1977.

*PARTITIOFILUM GONGYLOIDES SCHOPF AND BLACIC 1971.
TERMINAL CELL BLUNT-ROUNDED.

*TENUOFILUM SEPTATUM SCHOPF 1968.
PRESERVATION POOR - GRANULAR CARBON.

*TRACHYTHRICHOIDES OVALIS HERMANN IN TIMOFEEV ET AL 1976.

B. CONSTRICTED AT SEPTA.

*ANABAENIDIUM JOHNSONII SCHOPF 1968.
FILAMENT COILED.

BIOCATENOIDES PERTENUIS OEHLER 1977.
*B.SPHAERULA SCHOPF 1968.
LESS THAN 2 MICRONS WIDE.

*COLEOBACTER PRIMUS OEHLER 1977.
CELLS SHORT ROD-SHAPED.

FILICONSTRICTOSUS DIMINUTUS SCHOPF AND BLACIC 1971.
*F.MAJUSCULUS SCHOPF AND BLACIC 1971.
CELLS WIDER THAN LONG BUT L/W GREATER THAN 0.5.

*RHICNONEMA ANTIQUUM HOFMANN 1976.
SHEATH WITH SHRUNKEN CELLS.

*VETERONOSTOCALE AMOENUM SCHOPF AND BLACIC 1971.
CELLS MORE OR LESS SPHEROIDAL.

/Table 14 continued

C. CELLS SEPARATED AT SEPTA.

*HALYTHRIX NODOSA SCHOPF 1968.
CELL WALLS CONCAVE.

NEMATOMORPHITAE SET X

UNISERIATE UNBRANCHED FILAMENTS, CELL LENGTH/WIDTH RATIO OF VEGETATIVE CELLS (MEDIAL CELLS) GREATER THAN 2.0.

*ARCHAEONEMA LONGICELLULARIS SCHOPF 1968.

BIOCATENOIDES RHABDOS SCHOPF 1968.

EOMYCETOPSIS CYLINDRICA MAITHY 1975.
PRESERVATION POOR, INTERPRETATION UNCERTAIN.
E.FILIFORMIS SCHOPF 1968.
*E.ROBUSTA SCHOPF 1968.
MARKEDLY GRANULAR OR HAIRY SURFACE, SEPTA RARE.
E.RUGOSA MAITHY 1975.
PRESERVATION POOR, INTERPRETATION UNCERTAIN.

*EOTAENIOPSIS ARTICULATA EISENACK 1955.
CELLS LARGE, MEMBRANOUS, NOT CONSTRICTED AT SEPTA.
E.MAGNA (MAITHY 1975). FORMERLY GUNFLINTIA.

GUNFLINTIA BARGHOORNII MAITHY 1975.
G.OEHLERAE MUIR 1976.

NEMATOMORPHITAE SET XI

PRESERVATION NOT GOOD ENOUGH TO DISTINGUISH CELLS, WALLS ETC.

A. OBSCURED BY METALLIC MINERALS.

BIOCATENOIDES INCRUSTATA OEHLER 1977.

*FERRIMONILIS VARIABILE OEHLER 1977.
FILAMENT REPLACED BY IRON.

*RAMACIA CARPENTARIANA OEHLER 1977.
ENCRUSTED WITH FINE-GRAINED METALLIC MINERALS.

B. PRESERVATION POOR, NAMING NOT JUSTIFIED.

*PALAEOSPIRALIS CANADENSIS EDHORN 1973.

*PALAEOSPIRULINA ARCUATA EDHORN 1973.
P.MINUTA EDHORN 1973.

C. CELLS AND WALLS NOT PRESERVED, BUT FILAMENT REMNANTS OR HABIT JUSTIFIES NAME.

*GIRVANELLA PROBLEMATICA NICHOLSON AND ETHERIDGE.

NEMATOMORPHITAE SET XII

FILAMENTS ARISE FROM A CENTRAL BODY.

EOASTRION BIFURCATUM BARGHOORN IN BARGHOORN AND TYLER 1965.
FILAMENTS BRANCH.
*E.SIMPLEX BARGHOORN 1965.
FILAMENTS NOT BRANCHED.

Table 15. Taxa considered in this treatment

ABUNDACAPSA LICARI 1978.
GENOTYPE A.IMPAGES LICARI 1978. PRESERVATION POOR. VESICLE WALL PRESERVED AS GRANULAR FLAKES.
ABUNDACAPSA IMPAGES LICARI 1978. SPH-X.
ACANTHOSPHAERIDIUM N.GEN.
GENOTYPE A CITRINUM (DOWNIE 1963). FORMERLY LOPHOSPHAERIDIUM. DIAGNOSIS - SPHAEROMORPH CRYPTARCHS WITH WALLS LESS THAN 2 MICRONS THICK AND A SURFACE DECORATION OF SMALL SPINES.
ACANTHOSPHAERIDIUM CITRINUM (DOWNIE 1963). FORMERLY LOPHOSPHAERIDIUM. SPH-VII-A.
ACANTHOSPHAERIDIUM GRANULATUM (MAITHY 1975). FORMERLY LOPHOSPHAERIDIUM. SPH-VII-A.
ACANTHOSPHAERIDIUM JAINII (SALUJHA ET AL 1971). FORMERLY LOPHOSPHAERIDIUM. SPH-VII-A.
ACANTHOSPHAERIDIUM JANSONIUSII (SALUJHA ET AL 1971). FORMERLY LOPHOSPHAERIDIUM. SPH-VII-A.
ACANTHOSPHAERIDIUM LAUFELDI (VIDAL 1976).
FORMERLY TRACHYSPHAERIDIUM. SPH-VII-A.
ACANTHOSPHAERIDIUM MICROSAETOSUM (STAPLIN 1961). SPH-VII-A.
ACANTHOSPHAERIDIUM PAPILLATUM (STAPLIN 1961). SPH-VII-A.
ACANTHOSPHAERIDIUM PILOSUM (DOWNIE 1963). FORMERLY LOPHOSPHAERIDIUM. SPH-VII-A.
ACANTHOSPHAERIDIUM TRIANGULATUM (DOWNIE 1963).
FORMERLY LOPHOSPHAERIDIUM. SPH-VII-A.
ACANTHOTRILETES NAUMOVA 1949.
GENOTYPE A.PRIMIGENUS NAUMOVA 1949.
TRILETE MARK INDICATES POLLEN OR SPORE. NOT CLASSIFIED HERE.
AMELIAPHYCUS MUIR 1976.
GENOTYPE A.CROXFORDII MUIR 1976.
AMELIAPHYCUS CROXFORDII MUIR 1976. SYN-I.
ANABAENIDIUM SCHOPF 1968.
GENOTYPE A.JOHNSONII SCHOPF 1968.
ANABAENIDIUM BARGHOORNII EDHORN 1973.
PRESERVATION POOR, INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
ANABAENIDIUM JOHNSONII SCHOPF 1968. NEM-IX-B.
ANGULARIA SAMOILOVICH IN MALYAVKINA ET AL 1961.
INVALID - GROUP NOT RECOGNISED BY ICBN.
VESICLES COULD BE POLYGONOMORPH ACRITARCHS OR DEFORMED SPHAEROMORPH CRYPTARCHS. NOT CLASSIFIED HERE.
ANIMIKIEA BARGHOORN IN BARGHOORN AND TYLER 1965 EMEND AWRAMIK AND BARGHOORN 1977. GENOTYPE A.SEPTATA BARGHOORN IN BARGHOORN AND TYLER 1965.
ANIMIKIEA SEPTATA BARGHOORN IN BARGHOORN AND TYLER 1965 EMEND AWRAMIK AND BARGHOORN 1977. NEM-II-A.
ANTROSPHAERA SARJEANT 1961.
GENOTYPE A.CALLOVIENSIS SARJEANT 1961.
ANTROSPHAERA CALLOVIENSIS SARJEANT 1961. SPH-V.
APHANOCAPSITES MASLOV 1956.
GENOTYPE A.GRANULOSUS MASLOV 1956.
INTERPRETATION UNCERTAIN. COULD BE CARBONATE OR ORGANIC. HERE TREATED AS POORLY PRESERVED ORGANIC.
APHANOCAPSITES GRANULOSUS MASLOV 1956. SPH-X.
ARABISPHAERA HEMER AND NYGREEN 1967.
GENOTYPE A.BELLULA HEMER AND NYGREEN 1967.
ARABISPHAERA BELLULA HEMER AND NYGREEN 1967. SPH-III.
ARABISPHAERA FOSSILIS HEMER AND NYGREEN 1967. SPH-III.
ARCHAEODISCINA NAUMOVA 1960.
GENOTYPE A.GRANULATA NAUMOVA 1960. HERE INTERPRETED AS A THIN WALLED SPHAEROMORPH CRYPTARCH WITH THIN TO MEDIUM FOLDS, CONTAINING A SMALL INNER BODY. NATURE OF INNER BODY UNCERTAIN. HERE REFERRED TO SPH-VIII-D.
ARCHAEODISCINA GRANULATA NAUMOVA 1960. SPH-VIII-D.
ARCHAEOFAVOSINA NAUMOVA 1960.
GENOTYPE A.SIMPLEX NAUMOVA 1960.
HERE INTERPRETED AS - VESICLE THIN WALLED, FLATTENED, MORE OR LESS ROUND WITH IRREGULAR OUTLINE, SURFACE SMOOTH. VESICLE WALL IS FOLDED INTO A RETICULATION OF NUMEROUS CRISS-CROSSING SMALL FOLDS. FOLDS ARE MORE FREQUENT AWAY FROM THE EDGE OF THE VESICLE.
ARCHAEOFAVOSINA COMPTA. NOM.NUD.
NAME ATTRIBUTED TO SALUJHA ET AL 1971 BY MAITHY 1975,P.142, BUT NOT MENTIONED BY THEM.
ARCHAEOFAVOSINA NAUMOVAE MAITHY 1975.
INTERPRETATION DOUBTFUL BUT INCLUDED HERE ON BASIS OF ORIGINAL DESCRIPTION. SPH-IX-J.
ARCHAEOFAVOSINA SIMPLEX NAUMOVA 1960. SPH-IX-J.
ARCHAEOFAVOSINA SINUTA MAITHY 1975.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
ARCHAEOFAVOSINA VENUSTA SALUJHA ET AL 1971.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.

/Table 15 continued

ARCHAEONEMA SCHOPF 1968.
GENOTYPE A.LONGICELLULARIS SCHOPF 1968.
ARCHAEONEMA LONGICELLULARIS SCHOPF 1968. NEM-X.
ARCHAEOPERISACCUS NAUMOVA 1960.
GENOTYPE A.BALTICUS NAUMOVA 1960.
ORIGINAL DESCRIPTION AMBIGUOUS, INTERPRETATION UNCERTAIN. FOSSIL COULD HAVE A LARGE CIRCULAR PYLONE (SEEN FROM ABOVE), A WING LAMELLA (LIKE PTEROSPERMOPSIS), OR A CURIOUSLY STRUCTURED OR DEFORMED OUTER LAYER. HERE INTERPRETED AS SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCHS WITH A LARGE HOLLOW INNER BODY.
ARCHAEOPERISACCUS BALTICUS NAUMOVA 1960. SPH-VIII-A.
ARCHAEOPERTUSINA NAUMOVA 1960.
GENOTYPE A.ATAVA NAUMOVA 1960. PITS ARE PROBABLY OF DIAGENETIC ORIGIN. HERE INTERPRETED AS A SMOOTH SPHAEROMORPH CRYPTARCH WITH A FEW CURVED FOLDS OF NARROW OR MEDIUM WIDTH RESTRICTED TO NEAR THE MARGIN OF THE VESICLE.
ARCHAEOPERTUSINA ATAVA NAUMOVA 1960. SPH-IX-E.
ARCHAEORESTIS BARGHOORN IN BARGHOORN AND TYLER 1965.
GENOTYPE A.SCHREIBERENSIS BARGHOORN IN BARGHOORN AND TYLER 1965.
ARCHAEORESTIS MAGNA AWRAMIK AND BARGHOORN 1977. NEM-I.
ARCHAEORESTIS SCHREIBERENSIS BARGHOORN IN BARGHOORN AND TYLER 1965. NEM-I.
ARCHAEOSPHAEROIDES SCHOPF AND BARGHOORN 1967.
GENOTYPE A.BARBERTONENSIS SCHOPF AND BARGHOORN 1967.
VESICLE WALL PRESERVED ONLY AS CARBONACEOUS GRANULES. HERE CLASSIFIED AS A SPHAEROMORPH CRYPTARCH.
ARCHAEOSPHAEROIDES BARBERTONENSIS SCHOPF AND BARGHOORN 1967. SPH-X.
ARCHAEOTHRIX KIDSTON AND LANG 1921.
GENOTYPE A.OSCILLATORIFORMIS KIDSTON AND LANG 1921.
THIS GENUS COULD USEFULLY BE RESTRICTED TO SHEATHS WITH DEGRADED CELLS.
ARCHAEOTHRIX CONTEXTA KIDSTON AND LANG 1921. ATTRIBUTION TO ARCHAEOTHRIX DOUBTFUL. NEM-II-A.
ARCHAEOTHRIX OSCILLATORIFORMIS KIDSTON AND LANG 1921. NEM-VIII-D.
ARCHAEOTRICHION SCHOPF 1968.
GENOTYPE A.CONTORTUM SCHOPF 1968.
ARCHAEOTRICHION CONTORTUM SCHOPF 1968. NEM-II-B.
ARCTACELLLULARIA HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE A.DOLIIFORMIS HERMANN IN TIMOFEEV ET AL 1976.
ARCTACELLULARIA DOLIIFORMIS HERMANN IN TIMOFEEV ET AL 1976. NEM-IX-A.
ARCTACELLULARIA ELLIPSOIDEA HERMANN IN TIMOFEEV ET AL 1976. NEM-IX-A.
ASPERATOPSOPHOSPHAERA SHEPELEVA AND TIMOFEEV 1963.
NOM.NUD. SEE FOSCAT.
ASPERATOPSOPHOSPHAERA UMISHANENSIS SIN AND LIU 1973.
POOR ILLUSTRATION. INTERPRETATION DOUBTFUL. NOT LISTED HERE.
ASPERATOPSOPHOSPHAERA UMISHANENSIS VAR MINOR SIN AND LIU 1973.
POOR ILLUSTRATION. INTERPRETATION DOUBTFUL. NOT LISTED HERE.
BALBIRINIELLA OEHLER 1978.
GENOTYPE B.PRAESTANS OEHLER 1978.
BALBIRINIELLA PRAESTANS OEHLER 1978. SYN-IX.
BAVLINELLA SHEPELEVA 1962.
GENOTYPE B.FAVEOLATUS SHEPELEVA 1962.
PROBABLY = FRAMBOIDAL PYRITE DEVELOPED WITHIN AN ORGANIC VESICLE. REGARDED AS CONGENERIC (POSSIBLY CONSPECIFIC) WITH PYRITOSPHAERA LOVE 1957. SEE FOSCAT FOR COMMENTS.
BAVLINELLA FAVEOLATUS SHEPELEVA 1962. NOW PYRITOSPHAERA FAVEOLATA.
BECKSPRINGIA LICARI 1978.
GENOTYPE B.COMMUNIS LICARI 1978.
PRESERVATION NOT GOOD. CELLS JUST PLAUSIBLE, HETEROCYSTS DUBIOUS.
BECKSPRINGIA COMMUNIS LICARI 1978. NEM-IX-A.
BIGEMINOCOCCUS SCHOPF AND BLACIC 1971.
GENOTYPE B.LAMELLOSUS SCHOPF AND BLACIC 1971.
ORIGINAL DIAGNOSIS FOLLOWED HERE. THIS GENUS IS (DOUBTFULLY) DISITNGUISHED BY THE ARRANGEMENT OF THE VESICLES IN CROSS TETRADS.
BIGEMINOCOCCUS LAMELLOSUS SCHOPF AND BLACIC 1971. SYN-VIII.
BIGEMINOCOCCUS MUCIDUS SCHOPF AND BLACIC 1971. SYN-VIII.
BIOCATENOIDES SCHOPF 1968.
GENOTYPE B.SPHAERULA SCHOPF 1968.
BIOCATENOIDES INCRUSTATA OEHLER 1977. NEM-XI-A.
BIOCATENOIDES PERTENUIS OEHLER 1977. NEM-IX-B.
BIOCATENOIDES RHABDOS SCHOPF 1968. NEM-X.
BIOCATENOIDES SPHAERULA SCHOPF 1968. NEM-IX-B.
BISACCULOIDES OEHLER 1977.
GENOTYPE B.TABEOVISCUS OEHLER 1977.
HERE RESTRICTED TO COLONIAL CELLS. SOLITARY CELLS CAN PROBABLY BE REFERRED TO CARYOSPHAEROIDES.
BISACCULOIDES GRANDIS OEHLER 1977. SYN-XI.
BISACCULOIDES TABEOVISCUS OEHLER 1977. SYN-XI.
BISACCULOIDES VACUA OEHLER 1977. SYN-XI.

/Table 15 continued

BOHEMIFORA PACLTOVA 1977.
GENOTYPE B.PRAGENSIS PACLTOVA 1977.
INTERPRETED AS CRYSTALLINE INFILLING OF ORGANIC VESICLES. NOT CLASSIFIED HERE.
BULLASPHAERA LICARI 1978.
GENOTYPE B.VARIEGATA LICARI 1978.
PLUGS AND SPINES ARE PROBABLY DIAGENETIC CRYSTALS. ORIGINAL DIAGNOSIS FOLLOWED HERE.
BULLASPHAERA VARIEGATA LICARI 1978. SPH-II.
CALYPTOTHRIX SCHOPF 1968.
GENOTYPE C.ANNULATA SCHOPF 1968.
CALYPTOTHRIX ANNULATA SCHOPF 1968. NEM-VIII-C.
CARYOSPHAEROIDES SCHOPF 1968.
GENOTYPE C.PRISTINA SCHOPF 1968.
HERE RESTRICTED TO SOLITARY AND CLUMPED VESICLES AND INTERPRETED AS A SMOOTH SPHAEROMORPH CRYPTARCH WITH DOUBLE INCLUSIONS. COLONIES OF CLOSELY PACKED VESICLES ARE PROBABLY BEST REFERRED TO BISACCULOIDES.
CARYOSPHAEROIDES PRISTINA SCHOPF 1968. SPH-VIII-E.
CARYOSPHAEROIDES TETRAS SCHOPF 1968. SPH-VIII-E.
CAUDICULOPHYCUS SCHOPF 1968.
GENOTYPE C.RIVULARIOIDES SCHOPF 1968.
CAUDICULOPHYCUS ACUMINATUS SCHOPF AND BLACIC 1971. NEM-IX-A.
CAUDICULOPHYCUS RIVULARIOIDES SCHOPF 1968. NEM-IX-A.
CEPHALOPHYTARION SCHOPF 1968.
GENOTYPE C.GRANDE SCHOPF 1968 EMEND SCHOPF AND BLACIC 1971.
CEPHALOPHYTARION CONSTRICTUM SCHOPF AND BLACIC 1971. NEM-IX-A.
CEPHALOPHYTARION DELICATULUM SCHOPF AND BLACIC 1971. NEM-IX-A.
CEPHALOPHYTARION GRANDE SCHOPF 1968 EMEND SCHOPF AND BLACIC 1971. NEM-IX-A.
CEPHALOPHYTARION LATICELLULOSUM SCHOPF AND BLACIC 1971. NEM-IX-A.
CEPHALOPHYTARION MINUTUM SCHOPF 1968. NEM-IX-A.
CEPHALOPHYTARION VARIABILE SCHOPF AND BLACIC 1971. NEM-IX-A.
CHLAMYDOMONOPSIS EDHORN 1973.
GENOTYPE C.PRIMORDIALIS EDHORN 1973.
GENUS IS PROBABLY HETEROGENOUS, CONSISTING OF -
1. SOLITARY CELLS 5.5-11.4 MICRONS IN DIAMETER.
2. SMALL SPHERICAL COLONIAL CELLS 1.2-2.5 MICRONS IN DIAMETER.
ON THE BASIS OF THE TYPE SPECIMEN, THE GENUS IS HERE RESTRICTED TO (1) ABOVE AND IS PROBABLY A JUNIOR SYNONYM OF HURONIOSPORA. SEE FOSCAT. NOT CONSIDERED HERE.
CHLAMYDOSPHAERIDIA EISENACK 1971.
GENOTYPE C.BALTICA EISENACK 1971.
CHLAMYDOSPHAERIDIA BALTICA EISENACK 1971. SPH-VIII-A.
CHLOROGLOEAOPSIS MAITHY 1975.
GENOTYPE C.ZAIRENSIS MAITHY 1975.
CHLOROGLOEAOPSIS ZAIRENSIS MAITHY 1975. NEM-VI-C.
CHUARIA WALCOTT 1899.
GENOTYPE C.CIRCULARIS WALCOTT 1899. HERE INTERPRETED AS LARGE SMOOTH SPHAEROMORPH CRYPTARCHS WITH MANY CURVED MARGINAL THIN FOLDS AND WRINKLES.
CHUARIA CIRCULARIS WALCOTT 1899. SPH-IX-C.
CIRCULISPORITES JERSEY 1962.
GENOTYPE C.PARVUS JERSEY 1962.
CIRCULISPORITES PARVUS JERSEY 1962. SPH-VII-F-3.
CLONOPHYCUS OEHLER 1977 EMEND OEHLER 1978.
GENOTYPE C.ELEGANS OEHLER 1977.
CLONOPHYCUS BIATTINA OEHLER 1978. SYN-XI.
CLONOPHCUS ELEGANS OEHLER 1977. SYN-XI.
CLONOPHYCUS OSTIOLUM OEHLER 1978.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
CLONOPHYCUS REFRINGENS OEHLER 1978. SPH-VIII-A.
CLONOPHYCUS VULGARIS OEHLER 1978. SYN-XI.
COLEOBACTER OEHLER 1977.
GENOTYPE C.PRIMUS OEHLER 1977.
COLEOBACTER PRIMUS OEHLER 1977. NEM-IX-B.
CONCENTRICYSTES ROSSIGNOL 1962.
GENOTYPE C.RUBINUS ROSSIGNOL 1962. INVALID. TYPE SPECIMEN NOT DESIGNATED. FORM A MAY BE REFERRABLE TO CIRCULISPORITES.
CONCENTRICYSTES RUBINUS ROSSIGNOL 1962. INVALID. SPH-VII-F-3.
CONGLOBOCELLA OEHLER 1977.
GENOTYPE C.TROXELII OEHLER 1977.
CONGLOBOCELLA TROXELII OEHLER 1977. SYN-XI.
CONTORTOTHRIX SCHOPF 1968.
GENOTYPE C.VERMIFORMIS SCHOPF 1968.
CONTORTOTHRIX VERMIFORMIS SCHOPF 1968. NEM-IX-A.
CORNUTOSPHAERA SIN IN SIN AND LIU 1973.
GENOTYPE C.POLYCORNUTA SIN IN SIN AND LIU 1973.
INTERPRETATION DOUBTFUL. HERE REFERRED TO THE OOMORPHITAE ON THE BASIS OF THE ORIGINAL DESCRIPTION.

/Table 15 continued

CORYMBOCOCCUS AWRAMIK AND BARGHOORN 1977.
GENOTYPE C.HODGKISSII AWRAMIK AND BARGHOORN 1977.
CORYMBOCOCCUS HODGKISSII AWRAMIK AND BARGHOORN 1977. STH-X.
CRASSOSPHAERA COOKSON AND MANUM 1960.
GENOTYPE C.CONCINNA COOKSON AND MANUM 1960.
CRASSOSPHAERA CONCINNA COOKSON AND MANUM 1960. SPH-III.
CRASSOSPHAERA COOKSONI KRIVAN-HUTTER 1963. SPH-III.
CRASSOSPHAERA DIGITATA COOKSON AND MANUM 1960. SPH-III.
CRASSOSPHAERA MANUMI KRIVAN-HUTTER 1963. SPH-III.
CRASSOSPHAERA MINOR KRIVAN-HUTTER 1963. SPH-III.
CRASSOSPHAERA STELLULATA COOKSON AND MANUM 1960. SPH-III.
CRASSOSPHAERA STELLULATA VAR MINOR KEDVES 1962. SPH-III.
CUMULOSPHAERA EDHORN 1973.
GENOTYPE C.LAMELLOSA EDHORN 1973.
INTERPRETATION AS A FOSSIL IS VERY DOUBTFUL. SEE FOSCAT.
TYPE SPECIMEN RESEMBLES A CONCRETION. NOT CLASSIFIED HERE.
CYANONEMA SCHOPF 1968.
GENOTYPE C.ATTENUATA SCHOPF 1968.
CYANONEMA ATTENUATA SCHOPF 1968.
L/W RATIO OF MEDIAL CELLS IS 1.5-2.5. OTHER SPECIES ATTRIBUTED TO THIS GENUS HAVE MORE OR LESS EQUIDIMENSIONAL CELLS, SO THIS SPECIES HAS BEEN ATTRIBUTED TO NEMATOMORPHITAE SET IX-A.
CYANONEMA INFLATUM OEHLER 1977. NEM-IX-A.
CYANONEMA MINOR OEHLER 1977. NEM-IX-A.
DICTYOSPHAERA SIN AND LIU 1973.
GENOTYPE D.MACRORETICULATA SIN AND LIU 1973.
ILLUSTRATION OF TYPE SPECIMEN DOES NOT SHOW THE FEATRUES DISCUSSED IN THE DIAGNOSIS. TYPE SPECIMEN LOOKS POORLY PRESERVED.
GENUS NOT FURTHER CONSIDERED HERE.
DICTYOSPHAERIDIUM TIMOFEEV 1969.
GENOTYPE D.TUNGUSUM TIMOFEEV 1969.
HERE INTERPRETED AS SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCHS WITH MEDIUM FOLDS WHICH TRUNCATE EACH OTHER.
DICTYOSPHAERIDIUM ENISEICUM TIMOFEEV 1969. SPH-IX-I.
DICTYOSPHAERIDIUM TUNGUSUM TIMOFEEV 1969. SPH-IX-I.
DICTYOSPHAERIDIUM VITTAFORME TIMOFEEV 1969.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
DICTYOTIDIUM EISENACK 1955.
GENOTYPE D.DICTYOTUM EISENACK 1955.
INTERMEDIATE BETWEEN ACRITARCHS WITH CRESTS AND CRYPTARCHS WITH LOW RIDGES. HERE CLASSIFIED AS A CRYPTARCH.
DICTYOTIDIUM AREOLATUS SALUJHA ET AL 1971.
INTERPRETATION DOUBTFUL. NOT CLASSIFIED HERE.
DICTYOTIDIUM DICTYOTUM (EISENACK 1938) EISENACK 1955. FORMERLY LEIOSPHAERA. SPH-VII-F-2.
DICTYOTIDIUM POLOSYMMETRIUM STAPLIN 1961. SPH-VII-F-2.
DICTYOTIDIUM POLYGONIUM STAPLIN 1961. SPH-VII-F-2.
DICTYOTIDIUM SUPERBUM SALUJHA ET AL 1971.
POOR PRESERVATION OR ILLUSTRATION. NOT CLASSIFIED HERE.
DICTYOTIDIUM TENUIORNATUM EISENACK 1955. SPH-VII-F-2.
DISPHAERIA COOKSON AND EISENACK 1960.
GENOTYPE D.MACROPYLA COOKSON AND EISENACK 1960.
THERE ARE NO FEATURES BY WHICH AN UNOPENED PYLOME COULD BE RECOGNISED. TYPE SPECIMEN DOES NOT SHOW SPINULES, AND THIS GENUS IS HERE CLASSIFIED AS A SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCH.
DISPHAERIA MACROPYLA COOKSON AND EISENACK 1960. SPH-VIII-A.
ENTOSPHAEROIDES BARGHOORN IN BARGHOORN AND TYLER 1965.
GENOTYPE E.AMPLUS BARGHOORN IN BARGHOORN AND TYLER 1965.
ENTOSPHAEROIDES AMPLUS BARGHOORN IN BARGHOORN AND TYLER 1965. NEM-VI-B.
ENTOSPHAEROIDES BILINEARIS MAITHY 1975. NEM-VI-B.
ENTOSPHAEROIDES IRREGULARIS MAITHY 1975. NEM-VI-B.
EOASTRION BARGHOORN IN BARGHOORN AND TYLER 1965.
GENOTYPE E.SIMPLEX BARGHOORN IN BARGHOORN AND TYLER 1965.
EOASTRION BIFURCATUM BARGHOORN IN BARGHOORN AND TYLER 1965. NEM-XII.
EOASTRION SIMPLEX BARGHOORN IN BARGHOORN AND TYLER 1965. NEM-XII.
EOBACTERIUM BARGHOORN AND SCHOPF 1966.
GENOTYPE E.ISOLATUM BARGHOORN AND SCHOPF 1966.
DOUBTFULLY AN ORGANIC FOSSIL AND TOO SMALL TO BE RELIABLY IDENTIFIED BY LIGHT MICROSCOPY. HERE LISTED AS A SPHAEROMORPH.
EOBACTERIUM ISOLATUM BARGHOORN AND SCHOPF 1966. SPH-I.
EOENTOPHSALIS HOFMANN 1976.
GENOTYPE E.BELCHERENSIS HOFMANN 1976.
EOENTOPHYSALIS BELCHERENSIS HOFMANN 1976. SYN-IX.
EOMYCETOPSIS SCHOPF 1968.
GENOTYPE E.ROBUSTA SCHOPF 1968.
EOMYCETOPSIS CYLINDRICA MAITHY 1975. NEM-X.
EOMYCETOPSIS FILIFORMIS SCHOPF 1968. NEM-X.
EOMYCETOPSIS ROBUSTA SCHOPF 1968. NEM-X.
EOMYCETOPSIS RUGOSA MAITHY 1975. NEM-X.
EOMYCETOPSIS SEPTATA MAITHY 1975.
DOES NOT BELONG TO EOMYCETOPSIS. NEM-IX-A.

EOSPHAERA BARGHOORN IN BARGHOORN AND TYLER 1965.
GENOTYPE E.TYLERI BARGHOORN. POSSIBLY A COLONIAL ORGANISM.
HERE TREATED AS A SYNAPLOMORPH.
EOSPHAERA TYLERI BARGHOORN IN BARGHOORN AND TYLER 1965. SYN-VIII.
EOSYNECHOCOCCUS HOFMANN 1976.
GENOTYPE E.MOOREI HOFMANN 1976.
HERE TREATED AS A SPHAEROMORPH SINCE IT OCCURS SOLITARY AND IN LOOSE ASSOCIATIONS RATHER THAN IN REGULAR CLOSE COLONIES.
EOSYNECHOCOCCUS GRANDIS HOFMANN 1976. SPH-VIII-B.
EOSYNECHOCOCCUS MEDIUS HOFMANN 1976. SPH-VIII-B.
EOSYNECHOCOCCUS MOOREI HOFMANN 1976. SPH-VIII-B. ALSO LISTED UNDER SYN-XI.
EOTAENIOPSIS EISENACK 1955.
GENOTYPE E.ARTICULATA EISENACK 1955.
EOTAENIOPSIS ARTICULATA EISENACK 1955. NEM-X.
EOTAENIOPSIS MAGNA (MAITHY 1975). FORMERLY GUNFLINTIA. NEM-X.
EOTETRAHEDRION SCHOPF AND BLACIC 1971.
GENOTYPE E.PRINCEPS SCHOPF AND BLACIC 1971.
EOTETRAHEDRION PRINCEPS SCHOPF AND BLACIC 1971. SYN-VIII.
EOVOLVOX KAZMIERCZAK 1975.
GENOTYPE E.SILESIENSIS KAZMIERCZAK 1975.
EOVOLVOX SILESIENSIS KAZMIERCZAK 1975. SYN-VIII.
EOZYGION SCHOPF AND BLACIC 1971.
GENOTYPE E.GRANDE SCHOPF AND BLACIC 1971.
PROBABLY REPRESENTS A SOLITARY SPHAEROMORPH IN DIVISION RATHER THAN A COLONIAL DYAD. THE ORIGINAL DIAGNOSIS IS FOLLOWED HERE, AND THE GENUS LISTED AS A SYNAPLOMORPH.
EOZYGION GRANDE SCHOPF AND BLACIC 1971. SYN-IX.
EOZYGION MINUTUM SCHOPF AND BLACIC 1971. SYN-IX.
EXOCHOBRACHIUM AWRAMIK AND BARGHOORN 1977.
GENOTYPE E.TRIANGULUM AWRAMIK AND BARGHOORN 1977.
POSITION UNCERTAIN. NOT LISTED HERE.
FAVOSOSPHAERIDIUM TIMOFEEV 1966.
GENOTYPE F.SCANDICUM TIMOFEEV 1966.
FAVOSOSPHAERIDIUM BOTHNICUM TIMOFEEV 1966. SPH-VII-F-2.
FAVOSOSPHAERIDIUM FAVOSUM TIMOFEEV 1966. SPH-VII-F-2.
FAVOSOSPHAERIDIUM KAZLOWSKII TIMOFEEV 1966. SPH-VII-F-2.
FAVOSOSPHAERIDIUM SCANDICUM TIMOFEEV 1966. SPH-VII-F-2.
FERRIMONILIS OEHLER 1977.
GENOTYPE F.VARIABILE OEHLER 1977.
FERRIMONILIS VARIABILE OEHLER 1977. NEM-XI-A.
FILICONSTRICTOSUS SCHOPF AND BLACIC 1971.
GENOTYPE F.MAJUSCULUS SCHOPF AND BLACIC 1971.
FILICONSTRICTOSUS DIMINUTUS SCHOPF AND BLACIC 1971. NEM-IX-B.
FILICONSTRICTOSUS MAJUSCULUS SCHOPF AND BLACIC 1971. NEM-IX-B.
GALAXIOPSIS AWRAMIK AND BARGHOORN 1977.
GENOTYPE G.MELANOCENTRA AWRAMIK AND BARGHOORN 1977.
HERE INTERPRETED AS A SPHAEROMORPH CRYPTARCH WITHIN IRREGULAR MUCILAGE.
GALAXIOPSIS MELANOCENTRA AWRAMIK AND BARGHOORN 1977. SPH-VIII-A.
GIRVANELLA NICHOLSON AND ETHERIDGE.
ORIGINAL REFERENCE NOT YET CHECKED. NEM-XI-C.
GLENOBOTRYDION SCHOPF 1968.
ON THE BASIS OF THE TYPE SPECIMEN (SCHOPF,1968) THIS GENUS IS HERE RESTRICTED TO COLONIAL CRYPTARCHS WHERE VESICLES CONTAINING SPOTS OCCUR WITHIN WELL-DEFINED MUCILAGE OR CONNECTED IN COLONIES. THE GENUS IS
BEST CLASSIFIED AS A SYNAPLOMORPH BUT IS ALSO LISTED HERE AS A MULTISERIATE NEMATOMORPH. SOLITARY SPOT CELLS ARE HERE REFERRED TO NUCELLOSPHAERIDIUM TIMOFEEV 1966. UNISERIATE FILAMENTS OF SPOT CELLS ARE CLASSIFIED AS NEMATOMORPHS.
GLENOBOTRYDION AENIGMATIS SCHOPF 1968.
SOLITARY VESICLES ARE HERE REFERRED TO NUCELLOSPHAERIDIUM GLENOS. COLONIAL VESICLES ARE CLASSIFIED AS NEM-VI-A. ALSO LISTED UNDER SYN-XI.
GLENOBOTRYDION KANSHIENSIS MAITHY 1975.
HERE CLASSIFIED AS A NEMATOMORPH, NEM-VI-A.
GLENOBOTRYDION MAJORINUM SCHOPF AND BLACIC 1971.
NOW NUCELLOSPHAERIDIUM.
GLENOBOTRYDION TETRAGONALUM MAITHY 1975.
HERE CLASSIFIED AS A NEMATOMORPH. NEM-IX-A.
GLOBOPHYCUS SCHOPF 1968.
GENOTYPE G.RUGOSUM SCHOPF 1968.
GLOBOPHYCUS MINOR OEHLER 1977.
POORLY PRESERVED. SPH-VIII-A.
GLOBOPHYCUS RUGOSUM SCHOPF 1968. SPH-VIII-A.
GLOEOCAPSOMORPHA.
ORIGINAL DESCRIPTION NOT YET LOCATED. GENUS PROBABLY CONTAINS SEVERAL DIFFERENT SYNAPLOMORPHS.
GLOEOCAPSOMORPHA HEBEICA TIMOFEEV 1966. SYN-XI.
GLOEOCAPSOMORPHA PRISCATA TIMOFEEV 1973. SYN-XI.

GLOEODINIOPSIS SCHOPF 1968.
GENOTYPE G.LAMELLOSA SCHOPF 1968.
GLOEODINIOPSIS LAMELLOSA SCHOPF 1968. SPH-VIII-F.
GLOTTIMORPHA TIMOFEEV 1966.
GENOTYPE G.ASIATICA TIMOFEEV 1966.
MAY BE A FRAGMENT OF A LARGER ORGANISM. POSITION UNCERTAIN.
NOT CLASSIFIED HERE.
GORYNIELLA TIMOFEEV 1973.
GENOTYPE G.GIBBOSA TIMOFEEV 1973.
INTERPRETATION UNCERTAIN, NOT CLASSIFIED HERE.
GRANOMARGINATA NAUMOVA 1960.
GENOTYPE G.PRIMA NAUMOVA 1960.
HERE INTERPRETED AS THICK WALLED SPHAEROMORPH CRYPTARCHS WITH
GRANULAR SURFACE TEXTURE BUT NO DECORATION.
GRANOMARGINATA MINUTA MAITHY 1975.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
GRANOMARGINATA PRIMA NAUMOVA 1960. SPH-V.
GRANOMARGINATA PRIMITIVA SALUJHA ET AL 1971.
POOR ILLUSTRATION. ORIGINAL DESCRIPTION FOLLOWED HERE. SPH-V.
GUNFLINTIA BARGHOORN IN BARGHOORN AND TYLER 1965.
GENOTYPE G.MINUTA BARGHOORN IN BARGHOORN AND TYLER 1965.
GUNFLINTIA BARGHOORNII MAITHY 1975.
ATTRIBUTION TO GUNFLINTIA IS DOUBTFUL. NEM-X.
GUNFLINTIA GRANDIS BARGHOORN IN BARGHOORN AND TYLER 1965. NEM-IX-A.
GUNFLINTIA KANSHIENSIS MAITHY 1975. NEM-IX-A.
GUNFLINTIA MAGNA MAITHY 1975. NOW EOTAENIOPSIS.
GUNFLINTIA MINUTA BARGHOORN IN BARGHOORN AND TYLER 1965. NEM-IX-A.
GUNFLINTIA OEHLERAE MUIR 1976.
ELLIPTICAL CROSS SECTION AND ELONGATE CELLS. ATTRIBUTION TO
GUNFLINTIA IS DOUBTFUL. NEM-X.
HALOPHORIDIA COOKSON AND EISENACK 1962.
GENOTYPE H.XENA COOKSON AND EISENACK 1962.
POSITION UNCERTAIN, PROBABLY NOT A CRYPTARCH. NOT CLASSIFIED
HERE.
HALYTHRIX SCHOPF 1968.
GENOTYPE H.NODOSA SCHOPF 1968.
HALYTHRIX NODOSA SCHOPF 1968. NEM-IX-C.
HELICONEMA SCHOPF 1968.
GENOTYPE H.AUSTRALIENSE SCHOPF 1968.
HELICONEMA AUSTRALIENSE SCHOPF 1968. NEM-II-C.
HELICONEMA FUNICULUM SCHOPF AND BLACIC 1971. NEM-II-C.
HEMISPHAERIUM HEMER AND NYGREEN 1967.
GENOTYPE H.INOMINATUM HEMER AND NYGREEN 1967.
HEMISPHAERIUM GERMANUM HEMER AND NYGREEN 1967. SPH-II.
HEMISPHAERIUM INOMINATUM HEMER AND NYGREEN 1967. SPH-II.
HEMISPHAERIUM SIGNUM HEMER AND NYGREEN 1967. SPH-II.
HOEGISPHAERA STAPLIN 1961.
GENOTYPE H.GLABRA STAPLIN 1961.
HOEGISPHAERA GLABRA STAPLIN 1961. SPH-II.
HOROLOGINELLA COOKSON AND EISENACK 1962.
PROBABLY BEST REGARDED AS AN ACRITARCH. NOT CLASSIFIED HERE.
HUNGARODISCUS KRIVAN-HUTTER 1963.
GENOTYPE H.FRAGILIS KRIVAN-HUTTER 1963.
HUNGARODISCUS FRAGILIS KRIVAN-HUTTER 1963. SPH-III.
HURONIOSPORA BARGHOORN IN BARGHOORN AND TYLER 1965.
GENOTYPE H.MICRORETICULATA BARGHOORN IN BARGHOORN AND TYLER 1965.
NOT VERY WELL PRESERVED. RETICULATION PROBABLY A DIAGENETIC
FEATURE - SEE AWRAMIK AND BARGHOORN 1977. LISTED HERE AS
A DECORATED SPHAEROMORPH CRYPTARCH.
HURONIOSPORA MACRORETICULATA BARGHOORN IN BARGHOORN AND TYLER 1965.
SPH-VII-F-2.
HURONIOSPORA MICRORETICULATA BARGHOORN IN BARGHOORN AND TYLER 1965.
SPH-VII-F-2.
HURONIOSPORA ORNATA MUIR 1976. SPH-VII-G.
HURONIOSPORA PSILATA BARGHOORN IN BARGHOORN AND TYLER 1965. SPH-IX-A.
HYMENOPHACOIDES ROBLOT 1967.
INVALID. NO SPECIES ASSIGNED, NO GENOTYPE DESIGNATED.
NOT LISTED HERE.
KAKABEKIA BARGHOORN IN BARGHOORN AND TYLER 1965.
GENOTYPE K.UMBELLATA BARGHOORN IN BARGHOORN AND TYLER 1965.
POSITION UNCERTAIN. HERE CLASSIFIED AS A SPHAEROMORPH CRYPTARCH WITH
AN ATTACHED STRUCTURE (THE UMBRELLA).
KAKABEKIA FLABELLIFORMIS MAITHY 1975.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
KAKABEKIA RAREA MAITHY 1975.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
KAKABEKIA UMBELLATA BARGHOORN IN BARGHOORN AND TYLER 1965. SPH-II.
KIDSTONIELLA CROFT AND GEORGE 1959.
GENOTYPE K.FRITSCHI CROFT AND GEORGE 1959.
HERE CLASSIFIED AS A NEMATOMORPH, BUT ALSO LISTED AS A
SYNAPLOMORPH.
KIDSTONIELLA FRITSCHI CROFT AND GEORGE 1959. NEM-III-A. ALSO
LISTED UNDER SYN-1.

/Table 15 continued

KILDINELLA SHEPELEVA AND TIMOFEEV 1963 EX TIMOFEEV 1966.
GENOTYPE K.HYPERBOREICA TIMOFEEV IN SHEPELEVA AND TIMOFEEV 1963 EX TIMOFEEV 1966 (=K.GIPERBOREICA TIMOFEEV IN SHEPELEVA AND TIMOFEEV 1963,P.1158,PL.1,F.11.). GIPERBOREICA IS HERE REGARDED AS A ERROR IN TRANSLITERATION FOR HYPERBOREICA. THE TYPE SPECIMEN ILLUSTRATED IN TIMOFEEV 1966 (PL.V,F.3) IS THE SAME SPECIMEN AS ONE ILLUSTRATED BY SHEPELEVA AND TIMOFEEV (1963,PL.1,F.11). THE GENUS WAS THEREFORE VALIDATED IN 1966 BY THE LATER DISIGNATION OF AN ISOTYPE.
HERE RESTRICTED TO SMOOTH SPHAEROMORPH CRYPTARCHS WITH FEW TO MANY STRAIGHT OR CURVED FOLDS, OFTEN CROSSING, ARRANGED AROUND AND NEAR THE EDGE OF THE VESICLE.
KILDINELLA EXSCULPTA TIMOFEEV 1969. SPH-IX-D.
KILDINELLA FASTIGATIRUGOSA (STAPLIN 1971). FORMERLY LEIOSPHAERIDIUM. SPH-IX-D.
KILDINELLA HYPERBOREICA TIMOFEEV IN SHEPELEVA AND TIMOFEEV 1963 EX TIMOFEEV 1966. SPH-IX-D.
KILDINELLA JACUTICA TIMOFEEV 1966. SPH-IX-D.
KILDINELLA MAGNA TIMOFEEV 1969. SPH-IX-D.
KILDINELLA MIROEDICHIA TIMOFEEV 1969.
CONTAINS INNER BODIES OF UNCERTAIN STRUCTURE. RESEMBLES PSEUDOZONOSPHAERA RATHER THAN KILDINELLA. HERE REFERRED TO SPH-VIII-D ON THE BASIS OF THE ILLUSTRATION OF THE TYPE SPECIMEN.
KILDINELLA NORDIA TIMOFEEV 1969. SPH-IX-D.
KILDINELLA PELLUCIDA (SALUJHA ET AL 1971). FORMERLY LEIOSPHAERIDIA. SPH-IX-D.
KILDINELLA RIFEICA TIMOFEEV 1969. SPH-IX-D.
KILDINELLA SINICA TIMOFEEV 1966. SPH-IX-D.
KILDINELLA TIMANICA TIMOFEEV 1969.
ORIGINAL DIAGNOSIS FOLLOWED HERE. SPECIES COULD POSSIBLY BE TRANSFERRED TO PODOLIELLA. SPH-IX-D.
KILDINELLA TIMOFEEVII MAITHY 1975. SPH-IX-D.
KILDINELLA TSCHAPOMICA TIMOFEEV 1966.
ORIGINAL DESIGNATION FOLLOWED HERE. DECORATED FORMS SHOULD BE ATTRIBUTED ELSEWHERE. SMOOTH FORMS CLASSIFIED UNDER SPH-IX-D.
KILDINELLA UNDULATA (TIMOFEEV 1973). FORMERLY LEIOSPHAERIDIA. SPH-IX-D.
KILDINELLA VESLJANICA TIMOFEEV 1969.
HERE ATTRIBUTED TO PODOLIELLA.
KILDINELLA VOLYNICA (TIMOFEEV 1973). FORMERLY LEIOSPHAERIDIA. SPH-IX-D.
LACUNALITES HEMER AND NYGREEN 1967.
GENOTYPE L.SPHAERICUS HEMER AND NYGREEN 1967.
LACUNALITES SPHAERICUS HEMER AND NYGREEN 1967. SPH-II.
LANGIELLA CROFT AND GEORGE 1959.
GENOTYPE L.SCOURFIELDI CROFT AND GEORGE 1959.
LANGIELLA SCOURFIELDI CROFT AND GEORGE 1959. NEM-III-B.
LATERILITES HEMER AND NYGREEN 1967.
GENOTYPE L.LATERCULUS HEMER AND NYGREEN 1967.
POSITION UNCERTAIN, BUT PROBABLY AN ACRITARCH. NOT CLASSIFIED HERE.
LATISPHAERA LICARI 1978.
GENOTYPE L.WRIGHTII LICARI 1978.
HERE RESTRICTED TO SOLITARY VESICLES AND CLASSED AS A SPHAEROMORPH.
LATISPHAERA WRIGHTII LICARI 1978. SPH-VIII-B.
LECANIELLA COOKSON AND EISENACK 1962.
INTERPRETATION UNCERTAIN. MAY BE A SINGLE VALVE FROM THE SPLITTING OF A SPHAEROMORPH CRYPTARCH. NOT CLASSIFIED HERE.
LEIOMARGINATA NAUMOVA 1960.
GENOTYPE L.SIMPLEX NAUMOVA 1960.
HERE INTERPRETED AS SMALL THIN WALLED SPHAEROMORPH CRYPTARCHS WITH A SINGLE MARGINAL FOLD.
LEIOMARGINATA SIMPLEX NAUMOVA 1960. SPH-IX-B.
LEIOMINUSCULA NAUMOVA 1960.
GENOTYPE L.MINUTA NAUMOVA 1960.
HERE INTERPRETED AS THIN WALLED SPHAEROMORPH CRYPTARCHS WITH FEW THIN CROSSING FOLDS ARRANGED AT RANDOM.
LEIOMINUSCULA INCRASSATA SIN AND LIU 1973. SPH-IX-G.
LEIOMINUSCULA MINUTA NAUMOVA 1960. SPH-IX-G.
LEIOMINUSCULA ORIENTALIS SIN AND LIU 1973.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
LEIOMINUSCULA PELLUCENTIS SIN AND LIU 1973. SPH-IX-G.
LEIOMINUSCULA RUGOSA NAUMOVA 1960. SPH-IX-G.
LEIOPSOPHOSPHAERA NAUMOVA 1960.
GENOTYPE L.MICRORUGOSA NAUMOVA 1960.
HERE INTERPRETED AS SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCHS WITH CROSSING SINUOUS FOLDS OF MEDIUM WIDTH.
LEIOPSOPHOSPHAERA MICRORUGOSA NAUMOVA 1960. SPH-IX-H.
LEIOPSOPHOSPHAERA SIMPLICISSIMA NAUMOVA 1960. SPH-IX-H.

/Table 15 continued

LEIOSPHAERA EISENACK 1938.
GENOTYPE L.SOLIDA (EISENACK 1931).
TYPE SPECIES IS A JUNIOR SUBJECTIVE (HOMOTYPIC) SYNONYM OF TASMANITES HURONENSIS (DAWSON 1871) SCHOPF, WILSON AND BENTALL 1944.
LEIOSPHAERA SOLIDA (EISENACK 1931) EISENACK 1938. FORMERLY LION SOLIDUM. NOW TASMANITES HURONENSIS (DAWSON 1871) SCHOPF, WILSON AND BENTALL 1944.
LEIOSPHAERIDIA EISENACK 1958.
GENOTYPE L.BALTICA EISENACK 1958.
ON THE BASIS OF THE GENOTYPE WHICH HAS A WALL 3-8 MICRONS THICK, THIS GENUS IS HERE RESTRICTED TO THICK (MORE THAN 2 MICRONS) WALLED SMOOTH SPHAEROMORPH CRYPTARCHS.
LEIOSPHAERIDIA BALTICA EISENACK 1958. SPH-V.
LEIOSPHAERIDIA BITUMINOSA TIMOFEEV 1966.
HERE INTERPRETED AS A SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCH AND ASSIGNED TO PROTOLEIOSPHAERIDIUM.
LEIOSPHAERIDIA BOREALIS BONEHAM + TAILLEUR 1972. SPH-IX-D.
LEIOSPHAERIDIA CERINA TIMOFEEV 1966.
HERE INTERPRETED AS A SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCH WITH FEW FOLDS. SPH-IX-N.
LEIOSPHAERIDIA DEFLANDREI STOCKMANS + WILLIERE 1963.
HERE REFERRED TO THE NEW GENUS FUNCTOSPHAERIDIUM.
LEIOSPHAERIDIA FRAGILE DOWNIE 1958.
ILLUSTRATION OF TYPE SPECIMEN SHOWS THAT THE VESICLE WALL IS UNLIKELY TO BE 2 MICRONS THICK, AS DESCRIBED. THIS VESICLE IS HERE CLASSIFIED AS A THIN-WALLED SPHAEROMORPH CRYPTARCH. SPH-IX-E.
LEIOSPHAERIDIA KANSHIENSIS MAITHY 1975.
HERE ASSIGNED TO PSEUDOZONOSPHAERA.
LEIOSPHAERIDIA LAEVIGATA STOCKMANS + WILLIERE 1963. SPH-IX-M.
LEIOSPHAERIDIA LEPTOTHECA EISENACK 1968. SPH-II.
LEIOSPHAERIDIA LINEBACKI BONEHAM 1969. SPH-IX-D.
LEIOSPHAERIDIA OCHROLEUCA TIMOFEEV 1966.
HERE INTERPRETED AS A SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCH WITH FEW LARGE FOLDS. SPH-IX-M.
LEIOSPHAERIDIA OELANDICA EISENACK 1962. SPH-II.
LEIOSPHAERIDIA PELLUCIDA SALUJHA ET AL 1971.
HERE ASSIGNED TO KILDINELLA.
LEIOSPHAERIDIA PLICATA FELIX 1965. SPH-VI.
LEIOSPHAERIDIA RALLA FELIX 1965. SPH-VI.
LEIOSPHAERIDIA RUGOSA BONEHAM + TAILLEUR 1972. SPH-VI.
LEIOSPHAERIDIA TENELLA SALUJHA ET AL 1971.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
LEIOSPHAERIDIA TENUISSIMA EISENACK 1958. SPH-IX-H.
LEIOSPHAERIDIA TUBULOSA EISENACK 1963. SPH-II.
LEIOSPHAERIDIA UNDULATA TIMOFEEV 1973.
HERE ASSIGNED TO KILDINELLA.
LEIOSPHAERIDIA VINDHYANA SALUJHA ET AL 1971.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
LEIOSPHAERIDIA VOIGTI EISENACK 1958. SPH-II.
LEIOSPHAERIDIA VOLYNICA TIMOFEEV 1973.
HERE ASSIGNED TO KILDINELLA.
LEIOSPHAERIDIA WENLOCKIA DOWNIE 1958. SPH-IX-C.
LEIOSPHAERIDIUM TIMOFEEV 1959.
JUNIOR HOMOTYPIC SYNONYM OF LEIOSPHAERIDIA.
SEE FOSCAT FOR COMMENT.
LEIOSPHAERIDIUM (TIMOFEEV 1959) STAPLIN 1961.
REJECTED. SEE FOSCAT FOR COMMENT.
LEIOSPHAERIDIUM EISENACKI TIMOFEEV 1959.
NOW LEIOSPHAERIDIA EISENACKI. HERE TRANSFERRED TO TRACHYSPHAERIDIUM.
LEIOSPHAERIDIUM FASTIGATIRUGOSUM STAPLIN 1961.
HERE ASSIGNED TO KILDINELLA.
LEIOTRILETES NAUMOVA 1949.
INVALID - GENOTYPE NOT DESIGNATED. NOT CLASSIFIED HERE.
LEPTOTEICHOS KNOLL ET AL 1978.
GENOTYPE L.GOLUBICII KNOLL ET AL 1978.
HERE RESTRICTED TO CELLS IN MUCILAGE AND CLASSIFIED AS A SYNAPLOMORPH. SUGGEST RE-DEFINITION TO EXCLUDE SOLITARY CELLS.
LEPTOTEICHOS GOLUBICII KNOLL ET AL 1978. SYN-IX.
LIGNUM
ATTRIBUTED TO SIN 1962 BY SIN AND LIU 1973. REFERENCE TO ORIGINAL DESCRIPTION (IN CHINESE) NOT YET LOCATED. SPECIES DESCRIBED BY SIN AND LIU ARE ALL FRAGMENTARY DEBRIS AND NOT CLASSIFIED HERE.
LIGNUM NEMATOIDEUM SIN IN SIN AND LIU 1973.
FRAGMENTARY DEBRIS. NOT CLASSIFIED HERE.
LIGNUM PUNCTULOSUM SIN AND LIU 1973.
FRAGMENTARY DEBRIS. NOT CLASSIFIED HERE.
LIGNUM STRIATUM SIN AND LIU 1973.
FRAGMENTARY DEBRIS. NOT CLASSIFIED HERE.
LINOTOLYPA EISENACK 1962. PROBABLY CONTAMINATION. NOT CLASSIFIED HERE.

/Table 15 continued

LITOSTROMA MAMAY 1959.
GENOTYPE L.OKLAHOMENSE MAMAY 1959.
LITOSTROMA OKLAHOMENSE MAMAY 1959. SYN-I.
LOPHOMINUSCULA NAUMOVA 1960.
GENOTYPE L.PRIMA NAUMOVA 1960.
HERE INTERPRETED AS THIN WALLED SPHAEROMORPH CRYPTARCHS WITH TUBERCULAR SURFACE DECORATION.
LOPHOMINUSCULA PRIMA NAUMOVA 1960. SPH-VII-B.
LOPHOMINUSCULA VERRUCOSA (NAUMOVA 1960). FORMERLY MARGOMINUSCULA. SPH-VII-B.
LOPHOSPHAERIDIUM TIMOFEEV 1959 EX DOWNIE 1963.
GENOTYPE L.RARUM TIMOFEEV 1959 EX DOWNIE 1963,P.630 = L.RARUM TIMOFEEV 1959,P.29,PL.II,F.5.
HERE RESTRICTED TO THIN WALLED SPHAEROMORPH CRYPTARCHS WITH TUBERCULATE SURFACE DECORATION.
LOPHOSPHAERIDIUM CITRINUM DOWNIE 1963.
HERE ASSIGNED TO ACANTHOSPHAERIDIUM.
LOPHOSPHAERIDIUM GIBBEROSUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM GRANULATUM MAITHY 1975.
HERE ASSIGNED TO ACANTHOSPHAERIDIUM.
LOPHOSPHAERIDIUM JAINII SALUJHA ET AL 1971.
HERE ASSIGNED TO ACANTHOSPHAERIDIUM.
LOPHOSPHAERIDIUM JANSONIUSII SALUJHA ET AL 1971.
HERE ASSIGNED TO ACANTHOSPHAERIDIUM.
LOPHOSPHAERIDIUM MICROGRANULOSUM THUSU 1973. SPH-VII-B.
LOPHOSPHAERIDIUM PARVERARUM STOCKMANS + WILLIERE 1963. SPH-VII-B.
LOPHOSPHAERIDIUM PARVIGRANULOSUM (STAPLIN 1961). FORMERLY PROTOLEIOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM PARVUM STOCKMANS + WILLIERE 1963. SPH-VII-B.
LOPHOSPHAERIDIUM PILOSUM DOWNIE 1963.
HERE ASSIGNED TO ACANTHOSPHAERIDIUM.
LOPHOSPHAERIDIUM PODOLICUM (TIMOFEEV 1966). FORMERLY NUCELLOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM RARUM TIMOFEEV 1959 EX DOWNIE 1963. SPH-VII-B.
LOPHOSPHAERIDIUM RUGOSUM THUSU 1973. SPH-VII-B.
INTERPRETATION UNCERTAIN.
LOPHOSPHAERIDIUM SCABRIDUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM TALLINICUM (TIMOFEEV 1966). FORMERLY TYLOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM TORTULOSUM (TIMOFEEV 1966). FORMERLY STICTOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM TORULOSUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM TRIANGULATUM DOWNIE 1963.
HERE ASSIGNED TO ACANTHOSPHAERIDIUM. COULD EQUALLY WELL BE ASSIGNED TO THE ACANTHOMORPHITAE.
LOPHOSPHAERIDIUM TUBERCULATUM (EISENACK 1965). FORMERLY SYNSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM TUBERCULIFERUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-VII-B.
LOPHOSPHAERIDIUM VETULUM SALUJHA ET AL 1971. SPH-VII-B.
LOPHOTRILETES NAUMOVA 1949.
INVALID - GENOTYPE NOT DESIGNATED. NOT CLASSIFIED HERE.
MACROPTYCHA TIMOFEEV 1973 EX TIMOFEEV IN TIMOFEEV ET AL 1976.
GENOTYPE M.UNIPLICATA TIMOFEEV 1973 EX TIMOFEEV IN TIMOFEEV ET AL 1976.
GENOTYPE NOT DESIGNATED IN TIMOFEEV 1973. PROBABLY = SINGLE FOLDED VALVE, HERE CLASSIFIED AS A FOLDED SPHAEROMORPH.
MACROPTYCHA BIPLICATA TIMOFEEV IN TIMOFEEV ET AL 1976. SPH-IX-L.
MACROPTYCHA MULTIPLICATA TIMOFEEV IN TIMOFEEV ET AL 1976. SPH-IX-L.
MACROPTYCHA TRIPLICATA TIMOFEEV IN TIMOFEEV ET AL 1976. SPH-IX-L.
MACROPTYCHA UNIPLICATA TIMOFEEV IN TIMOFEEV ET AL 1976. SPH-IX-L.
MACULOSPHAERA LICARI 1978.
GENOTYPE M.KINGSTONENSIS LICARI 1978.
HERE RESTRICTED TO SOLITARY, PAIRED AND LOOSELY CLUMPED VESICLES AND CLASSIFIED AS A SPHAEROMORPH.
MACULOSPHAERA KINGSTONENSIS LICARI 1978. SPH-VIII-B.
MAJAPHYTON TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE M.ANTIQUAUM TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.
HERE INTERPRETED AS A MULTICELLULAR ORGANISM WITHOUT DIFFERENTIATED TISSUES WHICH PRODUCES SPORES.
MAJAPHYTON ANTIQUAUM TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.
SYN-II.
MAJAPHYTON CERATUM TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976. SYN-II.
MAJAPHYTON CYATUM TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976. SYN-II.

MARGOMINUSCULA NAUMOVA 1960.
GENOTYPE M.RUGOSA NAUMOVA 1960.
HERE INTERPRETED AS THIN WALLED SMOOTH SPHAEROMORPH CRYPTARCHS WITH A PROMINENT MARGINAL FOLD OR WRINKLE.
MARGOMINUSCULA ANTIQUA NAUMOVA 1960. SPH-IX-B.
MARGOMINUSCULA RUGOSA NAUMOVA 1960. SPH-IX-B.
MARGOMINUSCULA VERRUCOSA NAUMOVA 1960.
HERE ASSIGNED TO LOPHOMINUSCULA ON THE BASIS OF THE TUBERCULATE SURFACE DECORATION.
MEGALYTRUM KNOLL ET AL 1978.
GENOTYPE M.DIACENUM KNOLL ET AL 1978.
TYPE SPECIMEN PROBABLY = DIVIDING VESICLE. HERE CLASSIFIED AS A SPHAEROMORPH WITH SHEATH.
MEGALYTRUM DIACENUM KNOLL ET AL 1978. SPH-VIII-A.
MEGASACCULINA NAUMOVA 1960.
GENOTYPE M.ATAVA NAUMOVA 1960.
HERE INTERPRETED AS THIN WALLED SPHAEROMORPH CRYPTARCHS WITH FEW CIRCULAR FOLDS. COULD BE A DOUBLE LAYERED VESICLE.
MEGASACCULINA ATAVA NAUMOVA 1960. SPH-IX-F.
MELASMATOSPHAERA HOFMANN 1976.
GENOTYPE M.MAGNA HOFMANN 1976. HOFMANNS ORIGINAL INTERPETATION IS FOLLOWED HERE, AND THESE VESICLES ARE CLASSIFIED AS SPHAEROMORPHS WITH INCLUSIONS. THEY COULD ALSO BE STRICTLY INTERPRETED AS SYNAPLOMORPHS, THE INNER BODIES BEING THE REMAINS OF SMALL CELLS.
MELASMATOSPHAERA MAGNA HOFMANN 1976. SPH-VIII-C.
ALSO LISTED UNDER SYN-IX.
MELASMATOSPHAERA MEDIA HOFMANN 1976. SPH-VIII-C.
ALSO LISTED UNDER SYN-IX.
MELASMATOSPHAERA PARVA HOFMANN 1976. SPH-VIII-C.
ALSO LISTED UNDER SYN-IX.
MEMBRANOLIMBUS SAMOILOVICH IN MALYAVKINA ET AL 1961. INVALID.
NOT CLASSIFIED HERE. VESICLES MAY BE PTEROMORPH ACRITARCHS.
MEMBRANOSPHAERA SAMOILOVICH IN MALYAVKINA ET AL 1961 EX NORRIS + SARJEANT 1965. GENOTYPE M.MAASTRICHTICA SAMOILOVICH IN MALYAVKINA ET AL 1961 EX NORRIS + SARJEANT 1965. SEE FOSCAT FOR COMMENTS.
MEMBRANOSPHAERA BULLULINIFORMIS SPHAERICA MALYAVKINA IN MALYAVKINA ET AL 1961. INVALID ART 43 ICBN. NOT CLASSIFIED HERE.
MEMBRANOSPHAERA BULLULINIFORMIS TYPICA MALYAVKINA IN MALYAVKINA ET AL 1961. INVALID ART 43 ICBN. NOT CLASSIFIED HERE.
MEMBRANOSPHAERA MAASTRICHTICA SAMOILOVICH IN MALYAVKINA ET AL 1961 EX NORRIS + SARJEANT 1965. INTERPRETATION UNCERTAIN. CLASSIFIED HERE AS A DECORATED SPHAEROMORPH CRYPTARCH. SPH-VII-B.
MEMBRANOSPHAERA MAASTRICHTICA PILATA SAMOILOVICH IN MALYAVKINA ET AL 1961. INVALID ART 43 ICBN. NOT CLASSIFIED HERE.
MEMBRANOSPHAERA TUBERCULATA MALYAVKINA IN MALYAVKINA ET AL 1961. INVALID ART 43 ICBN. NOT CLASSIFIED HERE.
MICROCONCENTRICA NAUMOVA 1960.
GENOTYPE M.ATAVA NAUMOVA 1960. HERE INTERPRETED AS A COLONY OF SPHERICAL CELLS WITHIN A MEMBRANE AND CLASSIFIED AS A SYNAPLOMORPH.
MICROCONCENTRICA ATAVA NAUMOVA 1960. SYN-XI.
MICROCONCENTRICA INDUPLICATA LIU AND SIN IN SIN AND LIU 1973.
POOR PRESERVATION OR POOR ILLUSTRATION. INTERPRETATION QUESTIONABLE. NOT CLASSIFIED HERE.
MYRIASPORELLA OEHLER 1978.
GENOTYPE M.PYRIFORMIS OEHLER 1978.
MYRIASPORELLA PYRIFORMIS OEHLER 1978. SYN-VIII.
MYXOCOCCOIDES SCHOPF 1968.
GENOTYPE M.MINOR SCHOPF 1968.
NOT A WELL DEFINED TAXON. ON THE BASIS OF THE TYPE SPECIMEN IT IS HERE RESTRICTED TO COLONIES OF CLOSELY ADPRESSED VESICLES WITHIN A LAYER OF NON-LAMELLATED MUCILAGE.
MYXOCOCCOIDES CONGOENSIS MAITHY 1975. SYN-X.
CELLS LARGE AND CONSTRICTED AT SEPTA. MUCILAGE NOT EVIDENT IN ILLUSTRATION OF TYPE SPECIMEN. IS A LOOSE CLUMP OF SPHAEROMORPHS RATHER THAN A COLONY, BUT ORIGINAL DIAGNOSIS FOLLOWED HERE.
MYXOCOCCOIDES CRACENS OEHLER 1978. SYN-XI.
MYXOCOCCOIDES INORNATA SCHOPF 1968. SYN-IX
CELLS ARE SEPARATED AT SEPTA. ATTRIBUTION TO MYXOCOCCOIDES IS DOUBTFUL.
MYXOCOCCOIDES KINGII MUIR 1976.
INVALID. TYPE SPECIMEN NOT ILLUSTRATED.
MYXOCOCCOIDES KONZALOVAE MUIR 1976. SYN-XI.
MYXOCOCCOIDES MINOR SCHOPF 1968. SYN-XI.
MYXOCOCCOIDES MINUTUS MUIR 1976. SYN-IX.
CELLS SEPARATED AND EACH HAS ITS OWN SHEATH. ATTRIBUTION DOUBTFUL. RESEMBLES EOSYNECHOCOCCUS HOFMANN 1976.
MYXOCOCCOIDES RENIFORMIS MUIR 1976. SYN-IX.
CELLS ARE SEPARATED AND HAVE INDIVIDUAL SHEATHS. ATTRIBUTION DOUBTFUL.
MYXOCOCCOIDES RETICULATA SCHOPF 1968. SYN-X.
CELLS CONSTRICTED AT SEPTA. ATTRIBUTION DOUBTFUL. RESEMBLES LEPTOTEICHOS.
MYXOCOCCOIDES VERRUCOSA MAITHY 1975. SYN-XI.

/Table 15 continued

MYXOMORPHA MUIR 1976.
GENOTYPE M.JANECEKII MUIR 1976.
MYXOMORPHA JANECEKII MUIR 1976. SYN-I.
NANOCOCCUS OEHLER 1977.
GENOTYPE N.VULGARIS OEHLER 1977.
HERE RESTRICTED TO SEPARATE VESICLES IN COMMON MUCILAGE.
NANOCOCCUS VULGARIS OEHLER 1977. SYN-IX.
NODULARITES MASLOV 1956.
GENOTYPE N.CYLINDRICUS MASLOV 1956.
HERE INTERPRETED AS UNISERIATE FILAMENT.
NODULARITES CYLINDRICUS MASLOV 1956. NEM-VIII-D.
NODULARITES MASLOVI SHEPELEVA 1960. NEM-IX-A.
NOREMIA KEDVES 1962.
GENOTYPE N.MAJOR KEDVES 1962.
NOREMIA MAJOR KEDVES 1962. SPH-III.
NUCELLOHYSTRICHOSPHAERA TIMOFEEV AND HERMANN 1976 IN TIMOFEEV ET AL 1976.
GENOTYPE N.MEGALEA TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.
HAS SHORT HOLLOW SPINES. COULD BE REGARDED AS AN ACANTHOMORPH ACRITARCH. HERE CLASSIFIED AS A DECORATED SPHAEROMORPH CRYPTARCH.
NUCELLOHYSTRICHOSPHAERA MEGALEA TIMOFEEV IN TIMOFEEV ET AL 1976.
SPH-VII-A.
NUCELLOSPHAERIDIUM TIMOFEEV 1966.
EMEND. SPHAEROMORPH CRYPTARCHS WITH ROUND OPAQUE INCLUSIONS. THE DIAMETER OF THE INCLUSIONS IS LESS THAN 1/3 OF THE MEAN DIAMETER OF THE VESICLE. (RESTRICTED SIZE RANGE OF TIMOFEEV 1966 IS ABANDONED). NOW INCLUDES SOME SPECIMENS PREVIOUSLY ASSIGNED TO GLENOBOTRYDION SCHOPF.
GENOTYPE N.DEUNFFI TIMOFEEV 1966.
NUCELLOSPHAERIDIUM BELLUM TIMOFEEV 1969. SPH-VIII-B.
NUCELLOSPHAERIDIUM DEMINATUM TIMOFFEV 1969. SPH-VIII-B.
NUCELLOSPHAERIDIUM DEUNFFI TIMOFEEV 1966. SPH-VIII-B.
NUCELLOSPHAERIDIUM GLENOS. SPH-VIII-B.
SUGGESTED NEW SPECIES FOR SOLITARY AND CLUMPED VESICLES FORMERLY ASSIGNED TO GLENOBOTRYDION AENIGMATIS SCHOPF 1968.
SUGGESTED HOLOTYPE - G.AENIGMATIS SCHOPF 1968,TEXT FIG.6A.
SUGGESTED SYNONYMY - G.AENIGMATIS SCHOPF 1968, PL.83,F.9.
UNICELLS CONTAINING INTRACELLULAR BODIES, SCHOPF,1974,FIG.14.
NUCELLOSPHAERIDIUM MAGNUM MAITHY 1975. SPH-VIII-B.
NUCELLOSPHAERIDIUM MAJORINUM (SCHOPF AND BLACIC 1971). FORMERLY GLENOBOTRYDION. SPH-VIII-B.
NUCELLOSPHAERIDIUM MEDIANUM TIMOFEEV 1966. SPH-VIII-B.
NUCELLOSPHAERIDIUM MINUTUM TIMOFEEV 1966. SPH-VIII-B.
NUCELLOSPHAERIDIUM PODOLICUM TIMOFEEV 1966.
HERE TRANSFERRED TO LOPHOSPHAERIDIUM ON THE BASIS OF THE TUBERCULAR SURFACE DECORATION.
NUCELLOSPHAERIDIUM TRIANGULATUM MAITHY 1975.
ORIGINAL DESIGNATION FOLLOWED HERE. MIGHT BE ASSIGNABLE TO PTEROSPERMOPSIMORPHA. SPH-VIII-B.
NUCELLOSPHAERIDIUM ZONALE SIN AND LIU 1973. SPH-VIII-B.
NUCELLOSPHAERIDIUM ZONATUM MAITHY 1975.
HERE TRANSFERRED TO PTEROSPERMOPSIMORPHA.
OBCONICOPHYCUS SCHOPF 1968.
GENOTYPE O.AMADEUS SCHOPF 1968.
OBCONICOPHYCUS AMADEUS SCHOPF 1968. NEM-VIII-A.
ORYGMATOSPHAERIDIUM TIMOFEEV 1959.
GENOTYPE O.RUMINATUM TIMOFEEV 1959.
ONLY DIAGNOSTIC FEATURE IS POROUS PITTED SURFACE. HERE CLASSIFIED SEPARATELY ON THE BASIS OF THIS CHARACTER, BUT INTERPRETATION IS UNCERTAIN.
ORYGMATOSPHAERIDIUM DISTRIBUTUM TIMOFEEV 1973. SPH-VII-D.
ORYGMATOSPHAERIDIUM RUMINATUM TIMOFEEV 1959. SPH-VII-D.
ORYGMATOSPHAERIDIUM TRIZONATUM MAITHY 1975. INTERPRETATION UNCERTAIN.
ORIGINAL DIAGNOSIS FOLLOWED HERE. SPH-VII-D.
ORYGMATOSPHAERIDIUM VULGARUM MAITHY 1975. INTERPRETATION UNCERTAIN.
ORIGINAL DIAGNOSIS FOLLOWED HERE. SPH-VII-D.
OSCILLATORIOPSIS SCHOPF 1968.
GENOTYPE O.OBTUSA SCHOPF 1968.
OSCILLATORIOPSIS BREVICONVEXA SCHOPF AND BLACIC 1971. NEM-VIII-E.
OSCILLATORIOPSIS OBTUSA SCHOPF 1968. NEM-IX-A.
OSCILLATORIOPSIS SCHOPFII OEHLER 1977. NEM-IX-A.
OSCILLATORITES SHEPELEVA 1960.
GENOTYPE O.WERNADSKII SHEPELEVA 1960.
ORIGINAL DIAGNOSIS IS FOLLOWED HERE, THOUGH THE DESCRIBED CELLS COULD BE STRIATIONS OR ANNULAR THICKENINGS IN A HOLLOW TUBE OR SHEATH.
OSCILLATORITES WERNADSKII SHEPELEVA 1960. NEM-VIII-A.
OSTIANA HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE O.MICROCYSTIS HERMANN IN TIMOFEEV ET AL 1976.
OSTIANA MICROCYSTIS HERMANN IN TIMOFEEV ET AL 1976. SYN-IX.

/Table 15 continued

PALAEOANACYSTIS SCHOPF 1968.
GENOTYPE P.VULGARIS SCHOPF 1968.
PALAEOANACYSTIS IRREGULARIS EDHORN 1973.
DOUBTFULLY FOSSIL. NOT CLASSIFIED HERE (SEE AWRAMIK AND BARGHOORN 1977).
PALAEOANACYSTIS PSILATA MAITHY 1975.
POOR PRESERVATION OR POOR ILLUSTRATION. NOT CLASSIFIED HERE.
PALAEOANACYSTIS VULGARIS SCHOPF 1968. SYN-X.
PALAEOLYNGBYA SCHOPF 1968.
GENOTYPE P.BARGHOORNIANA SCHOPF 1968.
PALAEOLYNGBYA BARGHOORNIANA SCHOPF 1968. NEM-VIII-B.
PALAEOLYNGBYA MINOR SCHOPF AND BLACIC 1971. NEM-VIII-B.
PALAEOMICROCYSTIS MAITHY 1975.
GENOTYPE P.SCHOPFII MAITHY 1975.
CLASSIFIED AS A NEMATOMORPH, SET VI. INTERPRETED AS A UNISERIATE FILAMENT, THE VESICLES OF WHICH ARE FILLED WITH SMALL CELLS.
PALAEOMICROCYSTIS SCHOPFII MAITHY 1975. NEM-VI-D.
PALAEOMYCES.
ORIGINAL REFERENCE NOT YET CHECKED. ANDREWS 1970 CITES RENAULT 1896 WITH P.GRACILIS AS GENOTYPE.
PALAEOMYCES AGGLOMERATA KIDSTON AND LANG 1921. NEM-IV.
PALAEOMYCES ASTEROXYLI KIDSTON AND LANG 1921. NEM-IV.
PALAEOMYCES GORDONI KIDSTON AND LANG 1921. NEM-IV.
PALAEOMYCES GORDONI VAR MAJOR KIDSTON AND LANG 1921. NEM-IV.
PALAEOMYCES GRACILIS RENAULT 1896 (CITED BY ANDREWS 1970). NEM-IV.
PALAEOMYCES HORNEAE KIDSTON AND LANG 1921. NEM-IV.
PALAEOMYCES SIMPSONI KIDSTON AND LANG 1921. NEM-IV.
PALAEOMYCES VESTITA KIDSTON AND LANG 1921. NEM-IV.
PALAEOPLEUROCAPSA KNOLL ET AL 1975.
GENOTYPE P.WOPFNERII KNOLL ET AL 1975.
PALAEOPLEUROCAPSA WOPFNERII KNOLL ET AL 1975. SYN-XI.
PALAEOSCYTONEMA EDHORN 1973.
PROBABLY = AMBIENT PYRITE. NOT CLASSIFIED HERE.
PALAEOSIPHONELLA LICARI 1978.
GENOTYPE P.CLOUDII LICARI 1978.
PALAEOSIPHONELLA CLOUDII LICARI 1978. NEM-VII.
PALAEOSPIRALIS EDHORN 1973.
GENOTYPE P.CANADENSIS EDHORN 1973.
POORLY PRESERVED. NOT CLASSIFIED HERE. SEE FOSCAT.
PALAEOSPIRALIS CANADENSIS EDHORN 1973. NEM-XI-B.
PALAEOSPIRULINA EDHORN 1973.
GENOTYPE P.ARCUATA EDHORN 1973.
CLASSIFIED AS A NEMATOMORPH. IS PROBABLY SYNONYMOUS WITH GUNFLINTIA MINUTA. SEE FOSCAT FOR COMMENTS.
PALAEOSPIRULINA ARCUATA EDHORN 1973. NEM-XI-B.
PALAEOSPIRULINA MINUTA EDHORN 1973. NEM-XI-B.
PALAMBAGES WETZEL 1961 EMEND GOCHT AND WILLE 1972.
GENOTYPE P.MORULOSA WETZEL 1961.
PALAMBAGES MORULOSA WETZEL 1961 EMEND GOCHT AND WILLE 1972. SYN-IV.
PALYNOMORPHITES MOORE 1963.
GENOTYPE P.DIVERSIFORMIS MOORE 1963.
ON BASIS OF TYPE SPECIMEN, HERE INTERPRETED AS NARROW, BRANCHING, SEPTATE FILAMENTS CONSTRICTED AT SEPTA, SOMETIMES SEPARATED AT SEPTA. L/W RATIO OF MEDIAL CELLS BETWEEN 0.5 AND 2.0.
PALYNOMORPHITES DIVERSIFORMIS MOORE 1963. NEM-VII.
PARTITIOFILUM SCHOPF AND BLACIC 1971.
GENOTYPE P.GONGYLOIDES SCHOPF AND BLACIC 1971.
PARTITIOFILUM GONGYLOIDES SCHOPF AND BLACIC 1971. NEM-IX-A.
PETRAPHERA NAGY 1974.
GENOTYPE P.VIVESCENTICULA NAGY 1974.
DOUBTFULLY FOSSIL, SEE FOSCAT. NOT CLASSIFIED HERE.
PHANEROSPHAEROPS SCHOPF AND BLACIC 1971.
GENOTYPE P.CAPITANEUS SCHOPF AND BLACIC 1971.
PHANEROSPHAEROPS CAPITANEUS SCHOPF AND BLACIC 1971. SPH-IX-A.
PILAVIA OEHLER 1978.
GENOTYPE P.MACULATA OEHLER 1978.
PILAVIA MACULATA OEHLER 1978.
HERE CLASSIFIED AS SPH-VIII-B ON THE BASIS OF THE ILLUSTRATED TYPE SPECIMEN.
PLAESIODICTYON WILLE 1970.
GENOTYPE P.MOSELLANUM WILLE 1970.
PLAESIODICTYON MOSELLANUM WILLE 1970. SYN-V.
PLAESIODICTYON MOSELLANUM SSP DIVERGENS WILLE 1970. SYN-V.
PLAESIODICTYON MOSELLANUM SSP MOSELLANUM WILLE 1970. SYN-V.
PLAESIODICTYON MOSELLANUM SSP PERFORATUM WILLE 1970. SYN-V.
PLAESIODICTYON MOSELLANUM SSP SINUOSUM WILLE 1970. SYN-V.
PLEUROZONARIA WETZEL 1933 SENSU WETZEL 1961.
GENOTYPE P.GLOBULUS WETZEL 1933. CF ALSO WETZEL 1961.
PLEUROZONARIA GLOBULUS WETZEL 1933. SPH-III.

/Table 15 continued

PODOLIELLA TIMOFEEV 1973.
GENOTYPE P.IRREGULARE TIMOFEEV 1973.
AVAILABLE ILLUSTRATIONS OF POOR QUALITY. HERE INTERPRETED AS SMOOTH SPHAEROMORPH CRYPTARCHS WITH NUMEROUS CURVED WRINKLES WHICH OFTEN INTERDIGITATE.
PODOLIELLA IRREGULARE TIMOFEEV 1973. SPH-IX-O.
PODOLIELLA MULTANGULARE (TIMOFEEV 1959) TIMOFEEV 1973.
(=TRACHYOLIGOTRILETUM MULTANGULARE TIMOFEEV 1959). SPH-IX-O.
PODOLIELLA REGULARE TIMOFEEV (1959) 1973.
ERROR FOR P.MULTANGULARE. BASIONYM IS TRACHYOLIGOTRILETUM MULTANGULARE TIMOFEEV 1959.
PODOLIELLA SERPENTINA (TIMOFEEV 1959). FORMERLY TRACHYOLIGOTRILETUM SERPENTINUM SPH-IX-O.
PODOLIELLA VERMIA (TIMOFEEV 1969). FORMERLY PROTOSPHAERIDIUM VERMIUM. SPH-IX-O.
PODOLIELLA VESLJANICA (TIMOFEEV 1969). FORMERLY KILDINELLA. SPH-IX-O.
PODOLINA HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE P.MINUTA HERMANN IN TIMOFEEV ET AL 1976.
HERE INTERPRETED AS VALVES WITH MANY LINEAR FOLDS AND CLASSIFIED AS FOLDED SPHAEROMORPH CRYPTARCHS.
PODOLINA ANGULATA HERMANN IN TIMOFEEV ET AL 1976. SPH-IX-L.
PODOLINA ECHINATA HERMANN IN TIMOFEEV ET AL 1976. SPH-IX-L.
PODOLINA MINUTA HERMANN IN TIMOFEEV ET AL 1976. SPH-IX-L.
POLYEDROSPHAERIDIUM TIMOFEEV 1966.
GENOTYPE P.BULLATUM TIMOFEEV 1966.
HERE INTERPRETED AS TIGHT COLONIES OF POLYGONAL CELLS CONSTRICTED AT SEPTA. MUCILAGE OR OUTER SHEATH APPARENTLY ABSENT.
POLYEDROSPHAERIDIUM BULLATUM TIMOFEEV 1966. SYN-XI.
POLYNUCELLA SIN AND LIU 1973.
GENOTYPE P.BICONCENTRICA SIN AND LIU 1973.
POOR PRESERVATION OR ILLUSTRATION. INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
POLYPORATA SIN AND LIU 1973.
GENOTYPE P.OBSOLETA SIN AND LIU 1973.
NONDESCRIPT CARBONACEOUS DEBRIS. NOT CLASSIFIED HERE.
POLYSPHAEROIDES HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE P.FILLIFORMIS HERMANN IN TIMOFEEV ET AL 1976.
POLYSPHAEROIDES CONTEXTUS HERMANN IN TIMOFEEV ET AL 1976. NEM-VI-C.
POLYSPHAEROIDES FILLIFORMIS HERMANN IN TIMOFEEV ET AL 1976. NEM-VI-C.
POLYTHRICHOIDES TIMOFEEV ET AL 1976.
GENOTYPE P.LINEATUS HERMANN 1974. ORIGINAL DESCRIPTION CITED AS HERMANN 1974 BUT NOT YET LOCATED.
PORTALITES HEMER AND NYGREEN 1967.
GENOTYPE P.CONFERTUS HEMER AND NYGREEN 1967.
PORTALITES CONFERTUS HEMER AND NYGREEN 1967. SPH-II.
PRIMORIVULARIA EDHORN 1973.
GENOTYPE P.THUNDERBAYENSIS EDHORN 1973.
PROBABLY AN ARTIFACT, POSSIBLY INFILLED AMBIENT PYRITE TRAILS. NOT CLASSIFIED HERE. SEE FOSCAT FOR COMMENTS.
PROTOARCHAEOSACCULINA NAUMOVA 1960.
GENOTYPE P.ATAVA NAUMOVA 1960.
HERE INTERPRETED AS SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCHS WITH NUMEROUS CROSSING CURVED FOLDS OF MEDIUM WIDTH. THE MARGINAL REGION OF THE VESICLE IS WITHOUT FOLDS AND THE VESICLE CONTAINS A HOLLOW INNER BODY. THE DIAMETER OF THE INNER BODY IS ABOUT HALF THAT OF THE VESICLE.
PROTOARCHAEOSACCULINA ATAVA NAUMOVA 1960. SPH-VIII-A.
PROTOLEIOSPHAERIDIUM TIMOFEEV 1959 EX TIMOFEEV 1960.
GENOTYPE P.CONGLUTINATUM TIMOFEEV 1959 EX TIMOFEEV 1960 = P. CONGLUTINATUM TIMOFEEV 1959.
HERE RESTRICTED TO SMOOTH THIN WALLED SPHAEROMORPH CRYPTARCHS WITH A FEW CURVED FOLDS OF THIN TO MEDIUM WIDTH ARRANGED IN A CIRCULAR PATTERN. FOLDS ARE RARELY FOUND IN THE MARGINAL OR CENTRAL ZONES OF THE VESICLES.
PROTOLEIOSPHAERIDIUM ACIS (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-A.
PROTOLEIOSPHAERIDIUM ASAPHUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-G.
PROTOLEIOSPHAERIDIM BITUMINOSUM (TIMOFEEV 1966). FORMERLY LEIOSPHAERIDIA BITUMINOSA. SPH-IX-E.
PROTOLEIOSPHAERIDIUM CONGLUTINATUM TIMOFEEV 1959 EX TIMOFEEV 1960. SPH-IX-E.
PROTOLEIOSPHAERIDIUM CRYPTOGRANULOSUM STAPLIN 1961. SPH-IX-B.
PROTOLEIOSPHAERIDIUM DENSUM MAITHY 1975. SPH-IX-B.
PROTOLEIOSPHAERIDIUM DIAPHANIUM STAPLIN 1961. SPH-IX-E.
PROTOLEIOSPHAERIDIUM DIATRETUS SALUJHA ET AL 1971.
PRESERVATION POOR. SPH-IX-E.
PROTOLEIOSPHAERIDIUM FLEXUOSUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-VII-E.
PROTOLEIOSPHAERIDIUM GRANULOSUM STAPLIN 1961. SPH-IX-E.

PROTOLEIOSPHAERIDIUM LACCATUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-E.
PROTOLEIOSPHAERIDIUM LAEVIGATUM MAITHY 1975. ATTRIBUTION DOUBTFUL. SPH-IX-E.
PROTOLEIOSPHAERIDIUM MAJOR STAPLIN 1961. SPH-IX-E.
PROTOLEIOSPHAERIDIUM MICROGRANIFER STAPLIN 1961. SPH-IX-E.
PROTOLEIOSPHAERIDIUM MICROSAETOSUM STAPLIN 1961. NOW ACANTHOSPHAERIDIUM.
PROTOLEIOSPHAERIDIUM MINUTUM STAPLIN 1961. SPH-IX-E.
PROTOLEIOSPHAERIDIUM ORBICULATUM STAPLIN 1961. SPH-IX-E.
PROTOLEIOSPHAERIDIUM PALEACEUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-G.
PROTOLEIOSPHAERIDIUM PAPILLATUM STAPLIN 1961. NOW ACANTHOSPHAERIDIUM.
PROTOLEIOSPHAERIDIUM PAPYRACEUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-E.
PROTOLEIOSPHAERIDIUM PARVIGRANULOSUM STAPLIN 1961. NOW LOPHOSPHAERIDIUM.
PROTOLEIOSPHAERIDIUM PARVULUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-E.
PROTOLEIOSPHAERIDIUM PATELLIFORME (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-B.
PROTOLEIOSPHAERIDIUM PRISTINUM SALUJHA ET AL 1971. ATTRIBUTION UNCERTAIN. SPH-IX-E.
PROTOLEIOSPHAERIDIUM PUSILLUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-A.
PROTOLEIOSPHAERIDIUM RIGIDULUM (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM. SPH-IX-A.
PROTOLEIOSPHAERIDIUM SOLIDUM SIN AND LIU 1973. ATTRIBUTION TO PROTOLEIOSPHAERIDIUM DOUBTFUL. SPH-IX-A.
PROTOLEIOSPHAERIDIUM TIMOFEEVI (TIMOFEEV 1966). FORMERLY PROTOSPHAERIDIUM DENSUM. SPH-IX-E.
PROTOLEIOSPHAERIDIUM WIMANI TIMOFEEV 1960.
POOR PRESERVATION. INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
PROTOSPHAERIDIUM TIMOFEEV 1966.
JUNIOR HOMOTYPIC SYNONYM OF PROTOLEIOSPHAERIDIUM TIMOFEEV 1959 EX TIMOFEEV 1960.
PROTOSPHAERIDIUM ACIS TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM. FURROWS INTERPRETED AS DENTS. VESICLE HERE CLASSIFIED AS A SMOOTH SPHAEROMORPH CRYPTARCH.
PROTOSPHAERIDIUM ASAPHUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM. DIVERGENT FURROWS HERE INTERPRETED AS WRINKLES AND THE VESICLE CLASSIFIED AS A SMOOTH SPHAEROMORPH CRYPTARCH.
PROTOSPHAERIDIUM DENSUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM TIMOFEEVI.
PROTOSPHAERIDIUM FLEXUOSUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM.
PROTOSPHAERIDIUM GIBBEROSUM TIMOFEEV 1966. NOW LOPHOSPHAERIDIUM.
PROTOSPHAERIDIUM LACCATUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM.
PROTOSPHAERIDIUM PALEACEUM TIMOFEEV 1966. NOW PROTLEIOSPHAERIDIUM.
PROTOSPHAERIDIUM PAPYRACEUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM.
PROTOSPHAERIDIUM PARVULUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM.
PROTOSPHAERIDIUM PATELLIFORME TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM. HERE INTERPRETED AS HAVING A SINGLE MARGINAL FOLD.
PROTOSPHAERIDIUM PUSILLUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM. ILLUSTRATIONOF TYPE SPECIMEN SUGGESTS A FINELY RETICULATE SURFACE DECORATION. THE ORIGINAL DIAGNOSIS IS FOLLOWED HERE, AND THE VESICLE INTERPRETED AS A SMOOTH SPHAEROMORPH CRYPTARCH.
PROTOSPHAERIDIUM RIGIDULUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM. HERE INTERPRETED AS A SMOOTH SPHAEROMORPH CRYPTARCH.
PROTOSPHAERIDIUM SCABRIDUM TIMOFEEV 1966. NOW LOPHOSPHAERIDIUM.
PROTOSPHAERIDIUM TORULOSUM TIMOFEEV 1966. NOW LOPHOSPHAERIDIUM.
PROTOSPHAERIDIUM TUBERCULIFERUM TIMOFEEV 1966. NOW LOPHOSPHAERIDIUM.
PROTOSPHAERIDIUM VERMIUM TIMOFEEV 1969. NOW PODOLIELLA VERMIA.
PROTOTRACHYSPHAERIDIUM TIMOFEEV 1964.
JUNIOR HOMOTYPIC SYNONYM OF PROTOLEIOSPHAERIDIUM TIMOFEEV 1959 EX TIMOFEEV 1960. SEE FOSCAT FOR COMMENTS.
PSEUDOZONOSPHAERA SIN AND LIU 1973.
GENOTYPE P.VERRUCOSA SIN AND LIU 1973.
PSEUDOZONOSPHAERA KANSHIENSIS (MAITHY 1975). FORMERLY LEIOSPHAERIDIA. SPH-IX-C.
PSEUDOZONOSPHAERA SINICA SIN AND LIU 1973. SPH-IX-C.
PSEUDOZONOSPHAERA VERRUCOSA SIN AND LIU 1973. SPH-IX-C.
PTEINOSPHAERIDIUM RETICULATUM VIDAL 1976.
MAY REPRESENT A DEGRADED COLONY OF SMALL VESICLES. NOT CLASSIFIED HERE.
PTEROSPERMOPSIMORPHA TIMOFEEV 1966.
GENOTYPE P.PILEIFORMIS TIMOFEEV 1966.
PTEROSPERMOPSIMORPHA ANNULARE TIMOFEEV 1969. SPH-VIII-A.
PTEROSPERMOPSIMORPHA BINATA TIMOFEEV 1966. SPH-VIII-A.
PTEROSPERMOPSIMORPHA CONCENTRICA VIDAL 1976.
VESICLE WALL NOT WELL DEFINED. INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
PTEROSPERMOPSIMORPHA QUERY DENSICORONATA VIDAL 1976.
POORLY PRESERVED. NOT CLASSIFIED HERE.
PTEROSPERMOPSIMORPHA INSOLITA TIMOFEEV 1969.
LISTED HERE, THOUGH INTERPRETATION UNCERTAIN. SPH-VIII-A.

PTEROSPERMOPSIMORPHA MOGILEVICA TIMOFEEV 1969.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
PTEROSPERMOPSIMORPHA PILEIFORMIS TIMOFEEV 1966. SPH-VIII-A.
PTEROSPERMOPSIMORPHA ZONATA (MAITHY 1975). FORMERLY NUCELLOSPHAERIDIUM ZONATUM. SPH-VIII-A.
PTEROSPERMOPSIS CONCENTRICUS SIN AND LIU 1973.
INTERPRETATION UNCERTAIN. EQUATORIAL LAMELLA VERY DOUBTFUL. MAY BE REFERRABLE TO PTEROSPERMOPSIMORPHA OR NUCELLOSPHAERIDIUM.
PTEROSPERMOPSIS OCULATUS SIN AND LIU 1973.
INTERPRETATION UNCERTAIN. EQUATORIAL LAMELLA VERY DOUBTFUL. MAY BE REFERRABLE TO PTEROSPERMOPSIMORPHA OR NUCELLOSPHAERIDIUM.
PTEROSPERMOPSIS TYPICAUS SALUJHA ET AL 1971.
VERY POOR PRESERVATION AND POOR ILLUSTRATION. NOT CLASSIFIED HERE.
PULVINOMORPHA TIMOFEEV 1966.
GENOTYPE P.ANGULATA TIMOFEEV 1966.
CLASSIFIED AS A POLYGONOMORPH ACRITARCH AND NOT CONSIDERED HERE.
PUNCTOSPHAERIDIUM GEN.NOV.
GENOTYPE P.RIFEJICUS (YANKAUSKAS 1978). FORMERLY TASMANITES.
DIAGNOSIS - SPHAEROMORPH CRYPTARCHS WITH WALLS LESS THAN 2 MICRONS THICK AND PENETRATED BY NUMEROUS PORES.
PUNCTOSPHAERIDIUM DEFLANDREI (STOCKMANS + WILLIERE 1963). SPH-VII-C.
PUNCTOSPHAERIDIUM RIFEJICUS (YANKAUSKAS 1978). SPH-VII-C.
PYRITELLA LOVE 1957.
GENOTYPE P.POLYGONALIS LOVE 1957.
PYRITELLA POLYGONALIS LOVE 1957. SYN-XI.
PYRITOSPHAERA LOVE 1957.
GENOTYPE-P.BARBARIA LOVE 1957.
PROBABLY REPRESENTS ORGANIC VESICLES INFILLED WITH FRAMBOIDAL PYRITE, BUT LISTED HERE IN SYNAPLOMORPHITAE SET VI AS A USEFUL DUSTBIN GENUS FOR SIMILAR FORMS.
PYRITOSPHAERA BARBARIA LOVE 1957. SYN-IX.
PYRITOSPHAERA FAVEOLATA (SHEPELEVA 1962). FORMERLY BAVLINELLA. SYN-IX.
PYRITOSPHAERA VARIABILIS (MOORMAN 1974). FORMERLY SPHAEROCONGREGUS. SYN-IX.
QUADRATIMORPHA SIN AND LIU 1973.
GENOTYPE Q.ORDINATA SIN AND LIU 1973.
POOR PRESERVATION OR ILLUSTRATION. NOT CLASSIFIED HERE. MAY RESEMBLE OCTAEDRIXIUM. TENTATIVELY REFERRED TO THE POLYGONOMORPHITAE.
RAMACIA OEHLER 1977.
GENOTYPE R.CARPENTARIANA OEHLER 1977.
RAMACIA CARPENTARIANA OEHLER 1977. NEM-XI-A.
RETISPHAERIDIUM STAPLIN ET AL 1965.
GENOTYPE R.DICHAMERUM STAPLIN ET AL 1965.
RETISPHAERIDIUM DICHAMERUM STAPLIN ET AL 1965. SPH-VII-F-2.
RETISPHAERIDIUM VINDHYANENSIS MAITHY 1968. SPH-VII-F-2.
RHICNONEMA HOFMANN 1976.
GENOTYPE R.ANTIQUUM HOFMANN 1976.
RHICNONEMA ANTIQUUM HOFMANN 1976.
HERE CLASSIFIED AS A UNISERIATE NEMATOMORPH, EVEN THOUGH THE CELLULAR STRINGS ARE BROKEN AND DISTORTED. MOST DEGRADED FORM RESEMBLES ENTOSPHAEROIDES. NEM-IX-B.
RHYNIELLA CROFT AND GEORGE 1959.
GENOTYPE R.VERMIFORMIS CROFT AND GEORGE 1959.
RHYNIELLA VERMIFORMIS CROFT AND GEORGE 1959. NEM-VI-A.
SCAPHITA TIMOFEEV 1973 EX TIMOFEEV IN TIMOFEEV ET AL 1976.
GENOTYPE S.ENISEICA TIMOFEEV IN TIMOFEEV ET AL 1976 = S.ENISEICA TIMOFEEV 1973.
TIMOFEEV 1973 INVALID - NO DESCRIPTION, NO GENOTYPE.
SCAPHITA ENISEICA TIMOFEEV IN TIMOFEEV ET AL 1976. SPH-IX-L.
SCAPHOSPINOSA TIMOFEEV IN TIMOFEEV ET AL 1976.
GENOTYPE S.ISCHORICA TIMOFEEV IN TIMOFEEV ET AL 1976.
HERE INTERPRETED AS A FOLDED ACANTHOMORPH ACRITARCH. PROBABLY ASSIGNABLE TO BALTISPHAERIDIUM.
SCHISMATOSPHAERIDIUM STAPLIN ET AL 1965.
GENOTYPE S.PERFORATUM STAPLIN ET AL 1965.
SCHISMATOSPHAERIDIUM PERFORATUM STAPLIN ET AL 1965. SPH-II.
SCHIZOCYSTIA COOKSON AND EISENACK 1962.
GENOTYPE S.RUGOSA COOKSON AND EISENACK 1962.
REFERRED TO ACRITARCHA, SUBGROUP UNCERTAIN. NOT CLASSIFIED HERE.
SCHIZOTHRIX ATAVIA EDHORN 1973.
PROBABLY = INFILLED AMBIENT PYRITE TRAILS. NOT CLASSIFIED HERE. SEE FOSCAT.
SINAIICOCCUS SHIMRON AND HOROWITZ 1972.
GENOTYPE S.DELICATUS SHIMRON AND HOROWITZ 1972.
TRIPLE LAYERING OF VESICLE WALL IS HERE INTERPRETED AS AN EFFECT OF OPTICAL DIFFRACTION.
SINAIICOCCUS AVNIMELECHI SHIMRON AND HOROWITZ 1972. SPH-IX-A.
SINAIICICCUS DELICATUS SHIMRON AND HOROWITZ 1972. SPH-IX-A.
SINAIICOCCUS MINUTUS SHIMRON AND HOROWITZ 1972. SPH-IX-A.

/Table 15 continued

SIPHONOPHYCUS SHOPF 1968.
GENOTYPE S.KESTRON SCHOPF 1968.
SIPHONOPHYCUS KESTRON SCHOPF 1968. NEM-II-A.
SIPHONOPHYCUS PUNCTATUS MAITHY 1975. NEM-II-A.
SPHAEROCONGREGUS MOORMAN 1974.
GENOTYPE S.VARIABILIS MOORMAN 1974.
PROBABLY REPRESENTS VARIOUS CRYPTARCH VESICLES INFILLED WITH FRAMBOIDAL PYRITE (COLONY SHAPE VARIES FROM SPHEROIDAL TO ELONGATE). THE SPHERICAL COLONIES ARE PROBABLY CONSPECIFIC WITH PYRITOSPHAERA BARBARIA LOVE, BUT THE ELONGATE COLONIES ARE CERTAINLY NOT. THE ORIGINAL DIAGNOSIS IS FOLLOWED HERE, AND THE SPECIES TRANSFERRED TO PYRITOSPHAERA AS ORIGINALLY DEFINED, PENDING FURTHER STUDIES. SEE FOSCAT FOR COMMENTS.
SPHAEROCONGREGUS VARIABILIS MOORMAN 1974. NOW PYRITOSPHAERA.
SPHAEROPHYCUS SCHOPF 1968.
GENOTYPE S.PARVUM SCHOPF 1968.
SPHAEROPHYCUS DENSUS MAITHY 1975. SPH-IX-A.
SPHAEROPHYCUS GIGAS EDHORN 1973. SPH-IX-A.
SPHAEROPHYCUS PARVUM SCHOPF 1968. SPH-IX-A.
SPHAEROPHYCUS RETICULATUM MUIR 1976.
RETICULATION MAY BE DUE TO DIAGENESIS. HERE CLASSIFIED AS A DECORATED SPHAEROMORPH CRYPTARCH. SPH-VII-F-2.
SPHAEROPHYCUS TETRAGONALIS MUIR 1976. SPH-IX-A.
SPHAEROPORALITES HEMER AND NYGREEN 1967.
GENOTYPE S.SOLUS HEMER AND NYGREEN 1967.
SPHAEROPORALITES MULTIPLEX HEMER AND NYGREEN 1967. SPH-VII-C.
SPHAEROPORALITES SOLUS HEMER AND NYGREEN 1967. SPH-VII-C.
SPIRILLENEMA SHIMRON AND HOROWITZ 1972.
GENOTYPE S.BENTORI SHIMRON AND HOROWITZ 1972.
SPIRILLENEMA BENTORI SHIMRON AND HOROWITZ 1972. NEM-II-D.
SPIROMORPHA.
NOM.NUD. CAPTION TO PL.II,F.10, IN TIMOFEEV 1973.
STENOZONOMEZOTRILETES.
VALIDITY UNCERTAIN. TIMOFEEV IN TIMOFEEV ET AL 1976 CITES TIMOFEEV 1963 FOR DESCRIPTION OF GENUS. THIS REFERENCE NOT YET LOCATED - IS NOT EITHER OF THE TWO TIMOFEEV 1963 REFERENCES LISTED BY TIMOFEEV ET AL 1976.
STENOZONOMEZOTRILETES LAXUS TIMOFEEV IN TIMOFEEV ET AL 1976.
INTERPRETATION UNCERTAIN. TRILETE MARK SUGGESTS POLLEN OR SPORES. NOT CLASSIFIED HERE.
STICTOSPHAERIDIUM TIMOFEEV 1966.
GENOTYPE S.SINAPTICULIFERUM TIMOFEEV 1966.
STICTOSPHAERIDIUM BRAYENSE GARDINER AND VANGUESTAINE 1971. SPH-VII-F-1.
STICTOSPHAERIDIUM CONCENTRICUM TIMOFEEV 1973.
HERE INTERPRETED AS A SMOOTH SPHAEROMORPH CRYPTARCH WITH THIN CURVED FOLDS IN A CONCENTRIC PATTERN, AND TRANSFERRED TO TRACHYSPHAERIDIUM.
STICTOSPHAERIDIUM IMPLEXUM TIMOFEEV 1966. SPH-VII-F-1.
STICTOSPHAERIDIUM PECTINALE TIMOFEEV 1966. SPH-VII-F-1.
STICTOSPHAERIDIUM SIBIRICUM TIMOFEEV 1966. SPH-VII-F-1.
STICTOSPHAERIDIUM SINAPTICULIFERUM TIMOFEEV 1966. SPH-VII-F-1.
STICTOSPHAERIDIUM TORTULOSUM TIMOFEEV 1966.
RIDGES NOT OBVIOUS ON ILLUSTRATION OF TYPE SPECIMEN. HERE TRANSFERRED TO LOPHOSPHAERIDIUM.
STICTOSPHAERIDIUM VERRUCATUM VIDAL 1976.
ORIGINAL DESCRIPTION FOLLOWED HERE, ALTHOUGH VERRUCAE COULD BE VERY FINE WRINKLES. SPH-VII-F-1.
STIPULELLA MASLOV 1956.
GENOTYPE S.FASCICULARIS MASLOV 1956.
INTERPRETATION UNCERTAIN. APPARENTLY = STRAIGHT ASEPTATE FILAMENTS CLOSELY PACKED IN A CARBONATE MATRIX.
SYMPLASSOSPHAERIDIUM TIMOFEEV 1959 EX TIMOFEEV 1966.
GENOTYPE S.TUMIDULUM TIMOFEEV 1959 EX TIMOFEEV 1966 = S.TUMIDULUM TIMOFEEV 1959.
SYMPLASSOSPHAERIDIUM BUSHIMAYENSIS MAITHY 1975. SYN-XI.
SYMPLASSOSPHAERIDIUM TUMIDULUM TIMOFEEV 1959 EX TIMOFEEV 1966. SYN-XI.
SYNSPHAERIDIUM EISENACK 1965.
GENOTYPE S.GOTLANDICUM EISENACK 1965. DOUBTFULLY A COLONY. HERE INTERPRETED AS CLUSTERS OF DECORATED SPHAEROMORPHS.
SYNSPHAERIDIUM CONGLUTINATUM TIMOFEEV 1966. NOW PROTOLEIOSPHAERIDIUM.
SYNSPHAERIDIUM GOTLANDICUM EISENACK 1965. PROBABLY ASSIGNABLE TO ACANTHOSPHAERIDIUM. SPH-VII-A.
SYNSPHAERIDIUM TUBERCULATUM EISENACK 1965.
VERY LOOSE CLUMP RATHER THAN COLONY. HERE TRANSFERRED TO LOPHOSPHAERIDIUM ON THE BASIS OF THE TUBERCULAR SURFACE DECORATION.
SYNSPHAERIDIUM TIMOFEEV 1966 NON EISENACK 1965.
GENOTYPE S.CONGLUTINATUM TIMOFEEV 1959 EX TIMOFEEV 1966 EMEND TIMOFEEV 1966 (=PROTOLEIOSPHAERIDIUM CONGLUTINATUM TIMOFEEV 1959).
JUNIOR HETEROTYPIC HOMONYM OF SYNSPHAERIDIUM EISENACK 1965.
JUNIOR HOMOTYPIC SYNONYM OF PROTOLEIOSPHAERIDIUM TIMOFEEV 1959 EX TIMOFEEV 1960.

/Table 15 continued

TAENIATUM SIN 1962.
CITED IN SIN AND LIU 1973. ORIGINAL DESCRIPTION (IN CHINESE) NOT YET TRACED, TYPE SPECIES NOT YET KNOWN. T. CRASSUM IS CLASSIFIED HERE, THOUGH THE STATUS OF THE GENUS REMAINS UNCERTAIN.
TASMANITES NEWTON 1875.
GENOTYPE T.PUNCTATUS NEWTON 1875.
TASMANITES BALTEUS FELIX 1965. SPH-IV.
TASMANITES CORRUGATUS FELIX 1965. SPH-IV.
TASMANITES FISSURA FELIX 1965. SPH-IV.
TASMANITES FULGIDUS FELIX 1965. SPH-IV.
TASMANITES HURONENSIS (DAWSON 1871) SCHOPF, WILSON AND BENTALL 1944 EMEND WINSLOW 1962. SPH-IV.
TASMANITES KALJOI TIMOFEEV 1966.
APPARENTLY APORATE. HERE TRANSFERRED TO ZONOSPHAERIDIUM.
TASMANITES MANGASEUS TIMOFEEV 1966.
APPARENTLY APORATE. HERE TRANSFERRED TO ZONOSPHAERIDIUM.
TASMANITES MARTINSSONI EISENACK 1958. SPH-IV.
TASMANITES MINUTUS EISENACK 1965. SPH-IV.
TASMANITES NOREMI EISENACK 1962. SPH-IV.
TASMANITES POROSUS FELIX 1965. SPH-IV.
TASMANITES PUNCTATUS NEWTON 1875. SPH-IV.
TASMANITES RIFEJICUS YANKAUSKAS 1978.
WALL THIN (MUCH LESS THAN 2 MICRONS) SO ATTRIBUTION TO TASMANITES IS QUESTIONABLE. HERE REFERRED TO THE NEW GENUS PUNCTOSPHAERIDIUM.
TASMANITES SINUOSUS WINSLOW 1962.
TASMANITES SOMMERI WINSLOW 1962.
TASMANITES TARDUS EISENACK 1958. SPH-IV.
TASMANITES TREMATUS EISENACK 1962. SPH-IV.
TASMANITES USITATUS FELIX 1965. SPH-IV.
TASMANITES VALIDUS FELIX 1965. SPH-IV.
TASMANITES VERRUCOSUS EISENACK 1962. SPH-IV.
TAWUIA HOFMANN IN HOFMANN + AITKEN 1979.
GENOTYPE T.DALENSIS HOFMANN IN HOFMANN + AITKEN 1979.
TAWUIA DALENSIS HOFMANN IN HOFMANN + AITKEN 1979. NEM-II.
TENUOFILUM SCHOPF 1968.
GENOTYPE T.SEPTATUM SCHOPF 1968.
TENUOFILUM SEPTATUM SCHOPF 1968. NEM-IX-A.
TETRAEDRIXIUM TIMOFEEV 1973.
GENOTYPE T.ELEGANS TIMOFEEV 1973.
ACRITARCHA. POLYGONOMORPHITAE.
TETRAPHYCUS OEHLER 1978.
GENOTYPE T.GREGALIS OEHLER 1978.
TETRAPHYCUS ACINULUS OEHLER 1978. SYN-VIII.
TETRAPHYCUS DIMINUTIVUS OEHLER 1978. SYN-VIII.
TETRAPHYCUS GREGALIS OEHLER 1978. SYN-VIII.
TETRAPHYCUS MAJOR OEHLER 1978. SYN-VIII.
THAUMATOPHYCUS KORDE 1950.
GENOTYPE T.FURCATUS KORDE 1950. INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
THYMOS AWRAMIK AND BARGHOORN 1977.
GENOTYPE T.HALIS AWRAMIK AND BARGHOORN 1977.
HERE INTERPRETED AS HOLLOW TUBE ENCLOSING ISOLATED ROUNDED CELLS AND CLASSIFIED AS A NEMATOMORPH.
THYMOS HALIS AWRAMIK AND BARGHOORN 1977. NEM-VI-B.
TOROMORPHA.
NOM.NUD. CAPTION TO ILLUSTRATION (TIMOFEEV,1973,PL.II,F.9).
TORTUNEMA HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE T.SIBIRICA HERMANN.
ORIGINALLY DESCRIBED AS CELLULAR TRICHOMES. ON BASIS OF PUBLISHED ILLUSTRATION, HERE INTERPRETED AS HOLLOW TUBES WITH TRANSVERSE WRINKLES OR STRIATIONS.
TORTUNEMA ENISEICA HERMANN IN TIMOFEEV ET AL 1976. NEM-II-A.
TORTUNEMA SIBIRICA HERMANN IN TIMOFEEV ET AL 1976. NEM-II-A.
TRACHYHYSTRICHOSPHAERA TIMOFEEV AND HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE T.AIMICA HERMANN IN TIMOFEEV ET AL 1976.
MAY = ACANTHOMORPH ACRITARCH. HERE CLASSIFIED AS A DECORATED SPHAEROMORPH CRYPTARCH.
TRACHYHYSTRICHOSPHAERA AIMICA HERMANN IN TIMOFEEV ET AL 1976. SPH-VII-A.
TRACHYOLIGOTRILETUM.
CITED AS TIMOFEEV 1958 BY TIMOFEEV 1959. THIS REFERENCE NOT YET TRACED. GENOTYPE NOT DESIGNATED IN TIMOFEEV 1959.
TRACHYSPHAERIDIUM TIMOFEEV 1959 EX TIMOFEEV 1966.
GENOTYPE T.ATTENUATUM TIMOFEEV 1959 EX TIMOFEEV 1966 (=T. ATTENUATUM TIMOFEEV 1959).
HERE INTERPRETED AS A THIN WALLED SPHAEROMORPH CRYPTARCH WITH A CIRCULAR PATTERN OF CURVED WRINKLES.
TRACHYSPHAERIDIUM APERTUM VIDAL 1976.
INTERPRETATION UNCERTAIN. NOT CONSIDERED HERE.
APPARENTLY A VERY POORLY PRESERVED SPECIMEN.
TRACHYSPHAERIDIUM ATTENUATUM TIMOFEEV 1959 EX TIMOFEEV 1966. SPH-IX-E.
TRACHYSPHAERIDIUM CHIHSIENSE LIU AND SIN IN SIN AND LIU 1973.
POOR PRESERVATION OR ILLUSTRATION. NOT CONSIDERED HERE.

/Table 15 continued

TRACHYSPHAERIDIUM CONCENTRICUM (TIMOFEEV 1973). FORMERLY
STICTOSPHAERIDIUM. SPH-IX-E.
TRACHYSPHAERIDIUM EISENACKI (TIMOFEEV 1959). FORMERLY LEIOSPHAERIDIUM.
SPH-IX-E.
TRACHYSPHAERIDIUM HYALINUM SIN AND LIU 1973.
INTERPRETATION DOUBTFUL. NOT CONSIDERED HERE.
TRACHYSPHAERIDIUM LACHANDINUM TIMOFEEV 1966.
INTERPRETATION UNCERTAIN. NOT LISTED HERE.
TRACHYSPHAERIDIUM LAMINARITUM TIMOFEEV 1966 NON VIDAL 1976. SPH-IX-E.
TRACHYSPHAERIDIUM LAMINARITUM VIDAL 1976.
SURFACE DECORATED. HERE CLASSIFIED AS A DECORATED SPHAEROMORPH.
SPH-VII-E.
TRACHYSPHAERIDIUM LAUFELDI VIDAL 1976.
HERE TRANSFERRED TO ACANTHOSPHAERIDIUM BECAUSE OF ITS SPINY
SURFACE DECORATION.
TRACHYSPHAERIDIUM MAICUM TIMOFEEV 1969. SPH-IX-E.
TRACHYSPHAERIDIUM MINOR LIU AND SIN IN SIN AND LIU 1973.
INTERPRETATION DOUBTFUL. NOT CONSIDERED HERE.
TRACHYSPHAERIDIUM RUGOSUM SIN IN SIN AND LIU 1973.
INTERPRETATION DOUBTFUL. NOT CONSIDERED HERE.
TRACHYSPHAERIDIUM TIMOFEEVI VIDAL 1976.
HERE CLASSIFIED AS A SMOOTH SPHAEROMORPH CRYPTARCH WITHOUT FOLDS.
SPH-IX-A.
TRACHYSPHAERIDIUM VETTERNI TIMOFEEV 1966.
INTERPRETATION DOUBTFUL. NOT CLASSIFIED HERE.
TRACHYTHRICHOIDES HERMANN IN TIMOFEEV ET AL 1976.
GENOTYPE T.OVALIS HERMANN IN TIMOFEEV ET AL 1976.
TRACHYTHRICHOIDES OVALIS HERMANN IN TIMOFEEV ET AL 1976. NEM-IX-A.
TRACHYTRILETES NAUMOVA 1949.
INVALID. GENOTYPE NOT DESIGNATED.
TREMATOPHORA EISENACK 1965.
GENOTYPE T.RADIATA EISENACK 1965.
INTERPRETATION UNCERTAIN. HERE INTERPRETED AS A CIRCULAR COLONY
WITH THIN WEDGE-SHAPED VESICLES ARRANGED AS RADII.
TREMATOPHORA RADIATA EISENACK 1965. SYN-V.
TREMATOSPHAERIDIUM TIMOFEEV 1959.
GENOTYPE T.DECORATUM TIMOFEEV 1959.
DISTINGUISHING FEATURE = PITS. THESE MAY BE OF DIAGENETIC ORIGIN.
TIMOFEEV (1966) ATTEMPTED TO DESIGNATE T.HOLTEDAHLII AS GENOTYPE.
TREMATOSPHAERIDIUM DECORATUM TIMOFEEV 1959. SPH-VII-E.
TREMATOSPHAERIDIUM HOLTEDAHLII TIMOFEEV 1966. SPH-VII-E.
TREMATOSPHAERIDIUM INSPISSATUM SALUJHA ET AL 1971. SPH-VII-E.
TREMATOSPHAERIDIUM SINUATUM TIMOFEEV 1966. SPH-VII-E.
TREMATOSPHAERIDIUM ZAIRIENSIS MAITHY 1975. SPH-VII-E.
TREMATOTRILETES NAUMOVA 1949.
GENOTYPE T.OBRUTSCHEVII NAUMOVA 1949.
VALIDITY DOUBTFUL SINCE TYPE SPECIMEN NOT INDICATED.
NOT CLASSIFIED HERE.
TRIANGUMORPHA SIN AND LIU 1973.
GENOTYPE T.STRIATA SIN AND LIU 1973.
POOR ILLUSTRATION OR PRESERVATION. MAY = SPORE OR POLLEN GRAIN.
NOT CLASSIFIED HERE.
TRICHOSPHAERIDIUM TIMOFEEV 1966.
GENOTYPE T.ANNOLOVAENSE TIMOFEEV 1966.
ACANTHOMORPH ACRITARCH, NOT CLASSIFIED HERE. RESEMBLES
BALTISPHAERIDIUM MULTIPILOSUM (EISENACK 1931) EISENACK 1958 AND
B.MICROSPINOSUM (EISENACK 1954).
TURUCHANICA.
ORIGINAL GENERIC DESCRIPTION NOT YET LOCATED.
TIMOFEEV (1966) ATTRIBUTES THE GENUS TO RUDAVSKAJA (1964) WITH
T.ALARA RUDAVSKAJA AS GENOTYPE.
HERE INTERPRETED AS SPHAEROMORPH CRYPTARCHS WITH THREE SPLITS.
IF THE THREE LOBES WERE FOUND NOT TO BE THE RESULT OF SPLITTING
THIS GENUS WOULD HAVE TO BE REASSIGNED TO THE ACRITARCHA.
TURUCHANICA TERNATA TIMOFEEV 1966. SPH-IX-A.
TYLOSPHAERIDIUM TIMOFEEV 1966.
GENOTYPE T.TALLINICUM TIMOFEEV 1966.
HERE REGARDED AS A JUNIOR SUBJECTIVE SYNONYM OF LOPHOSPHAERIDIUM
(TIMOFEEV EX DOWNIE 1963) AS EMENDED HERE.
TYTTHODISCUS NOREM 1955.
GENOTYPE T.CALIFORNIENSIS NOREM 1955.
TYTTHODISCUS CALIFORNIENSIS NOREM 1955. SPH-IV.
TYTTHODISCUS CHONDROTUS NOREM 1955. SPH-IV.

/Table 15 continued

VAVOSOSPHAERIDIUM TIMOFEEV 1959.
GENOTYPE V.MICHAILOVSKYI TIMOFEEV 1959.
PERFORATE NETWORK SURFACE OF ORIGINAL DESCRIPTION HERE INTERPRETED AS FINELY RETICULATE.
VAVOSOSPHAERIDIUM BHARADWAJII SALUJHA ET AL 1971. SPH-VII-F-2.
VAVOSOSPHAERIDIUM DENSUM MAITHY 1975. SPH-VII-F-2.
VAVOSOSPHAERIDIUM MICHAILOVSKYI TIMOFEEV 1959. SPH-VII-F-2.
VAVOSPHAERIDIUM BHARADWAJII SALUJHA ET AL 1971.
ERROR FOR VAVOSOSPHAERIDIUM.
VAVOSPHAERIDIUM DENSUM MAITHY 1975.
ERROR FOR VAVOSOSPHAERIDIUM.
VETERONOSTOCALE SCHOPF AND BLACIC 1971.
GENOTYPE V.AMOENUM SCHOPF AND BLACIC 1971.
VETERONOSTOCALE AMOENUM SCHOPF AND BLACIC 1971. NEM-IX-B.
WENDIELLA TIMOFEEV 1962.
INVALID. SEE FOSCAT FOR COMMENTS.
XENOTHRIX AWRAMIK AND BARGHOORN 1977.
GENOTYPE X.INCONCRETA AWRAMIK AND BARGHOORN 1977.
HERE INTERPRETED AS A FILAMENT WITH CLOSED ENDS AND CLASSIFIED AS A NEMATOMORPH.
XENOTHRIX INCONCRETA AWRAMIK AND BARGHOORN 1977. NEM-II-A.
ZONOSPHAERIDIUM TIMOFEEV 1959 EX TIMOFEEV 1969.
GENOTYPE Z.LIMPATUM TIMOFEEV 1959 EX TIMOFEEV 1969 = Z.LIMPATUM TIMOFEEV 1959.
HERE INTERPRETED AS SMOOTH, THICK-WALLED SPHAEROMORPH CRYPTARCHS.
ZONOSPHAERIDIUM CRASSUM TIMOFEEV 1969. SPH-VI.
ZONOSPHAERIDIUM DENSUM MAITHY 1975.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
ZONOSPHAERIDIUM DIGNATUM SALUJHA ET AL 1971.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
ZONOSPHAERIDIUM FOVEOLATUM MAITHY 1975.
INTERPRETATION UNCERTAIN. NOT CLASSIFIED HERE.
POSSIBLY ASSIGNABLE TO PSEUDOZONOSPHAERA.
ZONOSPHAERIDIUM KALJOI (TIMOFEEV 1966). FORMERLY TASMANITES. SPH-VI.
ZONOSPHAERIDIUM LIMPATUM TIMOFEEV 1969. SPH-VI.
ZONOSPHAERIDIUM MANGASEUS (TIMOFEEV 1966). FORMERLY TASMANITES. SPH-VI.
ZONOSPHAERIDIUM MINUTUM SIN IN SIN AND LIU 1973.
POOR PRESERVATION AND ILLUSTRATION. NOT CLASSIFIED HERE.
ZONOTRACHYTRILETES TIMOFEEV AND KARIMOV 1953.
INVALID. GENOTYPE Z.INCRASSATUS DESIGNATED BUT NOT ILLUSTRATED. TYPE SPECIMEN NOT DESIGNATED.
ZOSTEROSPHAERA SCHOPF AND BLACIC 1971.
GENOTYPE Z.TRIPUNCTATA SCHOPF AND BLACIC 1971.
ONLY ONE SPECIMEN KNOWN.
PROBABLY REPRESENTS A DIVIDING CELL. NOT CLASSIFIED HERE.

Chapter 8

Foscat - a computerised catalogue of fossils

Foscat could not have been developed without the advice and help of Mr. P R Grant who modified and implemented the basic programme called SORTER and taught me how to write programmes in Fortran IV.

A. Reasons for development

The literature on Precambrian fossils and their possible relatives is very scattered, difficult to interpret, and impossible to synthesise in a literary review. I originally tried to keep track of the occurrence of Precambrian taxa with a card index system but this became very time consuming and inefficient in use. The three big drawbacks of manual data retrieval systems are:-

1. Inflexibility. It is rarely practicable to have more than one alphabetical or numerical sequence of data elements with more than minimal cross referencing.
2. Inefficiency. A lot of time is wasted in transcribing information, both when adding data to the system and in collating search results.
3. Size. Large manual card index systems require banks of filing cabinets in the working area.

In contrast, computerised data handling systems are:-

1. Very flexible if sensibly designed.
2. Fast in retrieving information if used on line. Retrieve the information while the user does something else if used batch.
3. Convenient. Search results can be quickly printed on paper, microfilm or microfiche, without error and in the exact format required.
4. Compact. Even punched cards take up less space than files, and they can be stacked and stored out of the way. Working copies of card decks are usually kept on disc or magnetic tape at a central computer site.

Table 16

Information Input for Foscat

Option Number	String Information	Input Mode
1	Author	Full
2	Fossil type	Coded
3	Radiometric age	Full*
4	Matrix of host rock	Full**
5	Name of fossil	Full
6	Comments, synonymy, page & figure references	Full
7	Title of publication	Full
8	Date of publication	Full
9	Reference to source	Full
10	Geographical & geological locality	Full***

* In standard format, when it can be interpreted.

** Selected from a series of general descriptive terms.

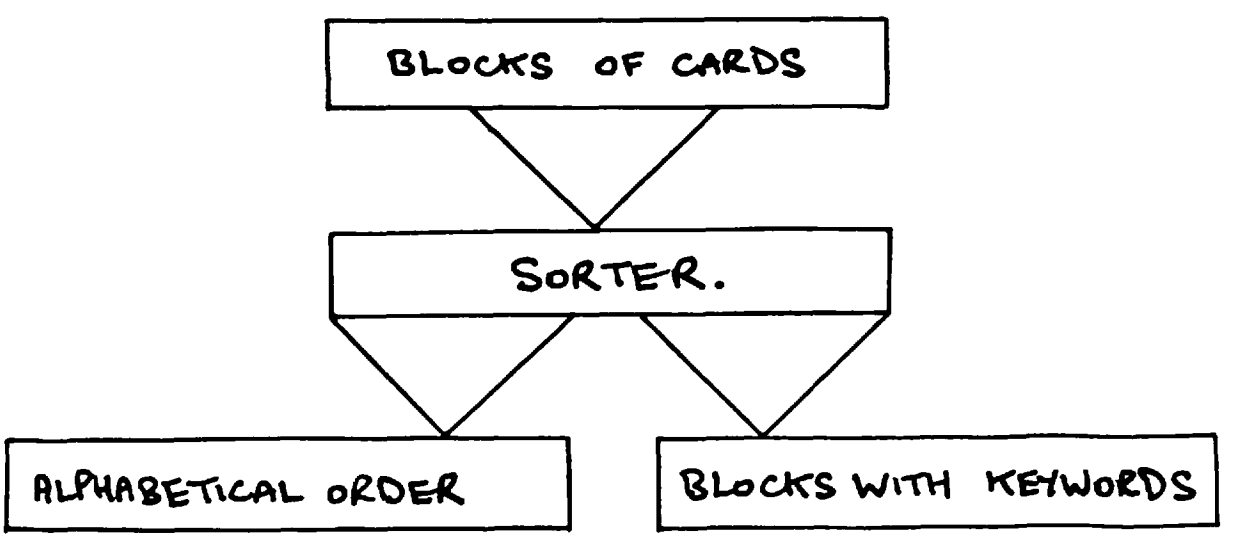
*** Usually to the level of formation and horizon in a small area.

For these reasons it was decided to try and develop a computerised data handling and retrieval system for Precambrian microfossils. Because of the uncertain interpretation of many described microfossils it was decided that wherever possible ten items of information would be collected for every possibly biogenic structure reported to occur in Precambrian rocks (Table 16).

Most of this information is in the form of character strings, names, or subjective statements of very variable length. It is possible to code this information in numerical form, but nuances of opinion and flexibility are thereby lost. A simple coding system may ignore information that is later found to be relevant, while comprehensive coding systems easily become complex and slow and difficult to use (See Deacon, 1972; Germeraad & Horst, 1978; Germeraad & Muller, 1974; Walker et al, 1968). It is also necessary to decode the data recovered from such systems which makes them difficult for outsiders to understand and use effectively.

For these reasons it was decided that Foscat should be based on written text and comment, and that it should be easily comprehensible to other workers. Available data base systems were not built to handle this sort of information, so we designed our own. Foscat is intended to be able to give an up to date assessment of the status, interpretation and occurrence of any possibly biogenic Precambrian structure (Peat & Grant, 1979).

FIGURE 30. OPERATION OF SORTER



At the core of the Foscat system is a programme called SORTER. This programme was developed and implemented by Paul Grant and is based on LIT6L, obtained from the University of London Computer Centre. As currently implemented in Foscat, SORTER can perform two operations very efficiently (Fig.30):-

1. Sort a file of data blocks according to the first 20 characters of each block.
2. Search parts of data blocks for keywords or character strings.

The way in which Foscat uses the data structure dictated by SORTER is described in Section B, below. The way in which SORTER is used in the Foscat system is described in Section C. Subsequent experience with Foscat has resulted in a novel approach to data storage and retrieval which is capable of generalisation and considerable development (See Section D).

B. Data input, searching and output

As implemented here, the programme SORTER requires input to be in the form of a file of card images. 80-column Fortran cards are coded in columns 1 and 2 and are arranged in blocks of between 3 and 10 cards. A data block must begin with one card coded A$\not b$ ($\not b$=blank) and end with one card coded C$\not b$. Within the block there must be at least one card coded T$\not b$, which may be followed by cards coded R$\not b$ and/or H$\not b$ (Fig.31). Only A-, T- and C-cards are searched for keywords at present, and sorting is carried out on the first 20 characters of the A-card.

The options selected for data input are arranged over these cards in a semi-structured way as shown in Figure 32. An example of actual data and the way in which it is arranged is shown diagrammatically in Figure 33. After a little practice it is very easy to punch cards directly from a copy of a paper and a few cryptic notes. The information punched can be regarded as answers to the questionnaire in Table 17.

This stage of data input is about as fast as writing file cards for species. If other workers became involved in data input it would be a simple matter to write an interactive programme which would accept free-format input from a remote terminal and transcribe it to card images in the precise format required. When punched, data blocks are tested for internal consistency and the information is tabulated in various ways

FIGURE 31. A BLOCK OF CARDS

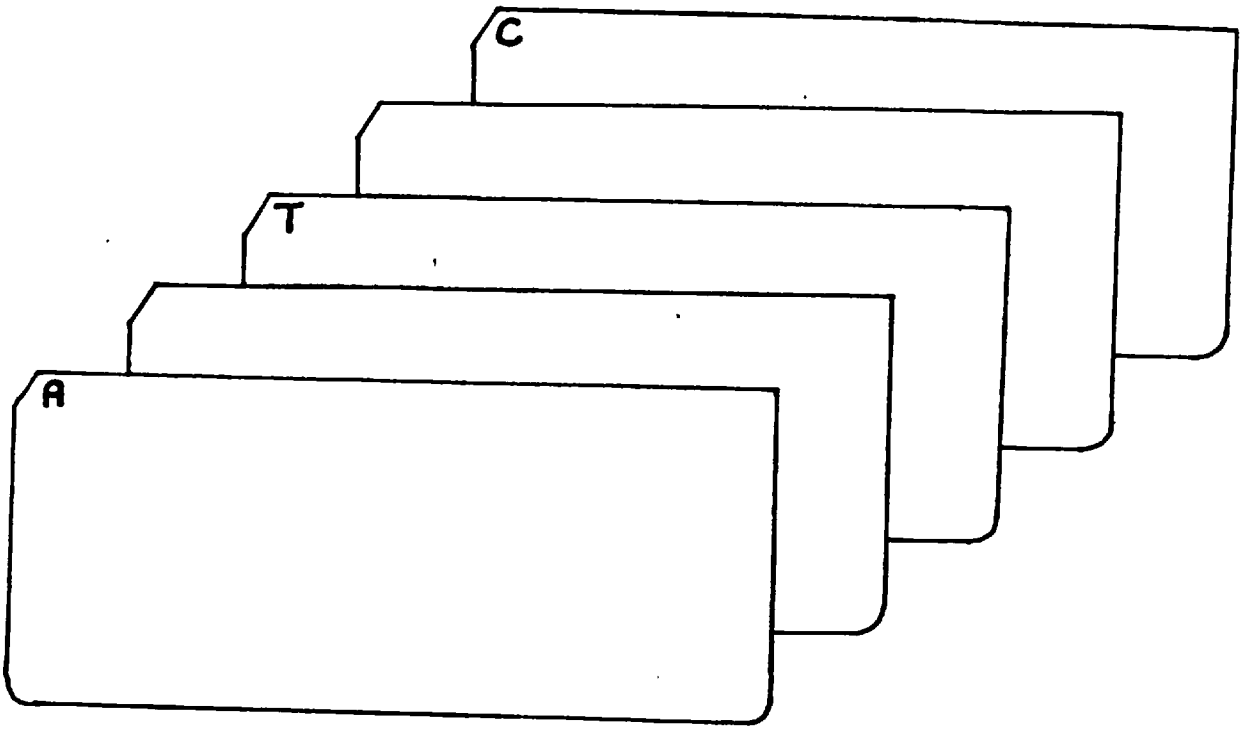


FIGURE 32. ARRANGEMENT OF OPTIONS OVER BLOCK

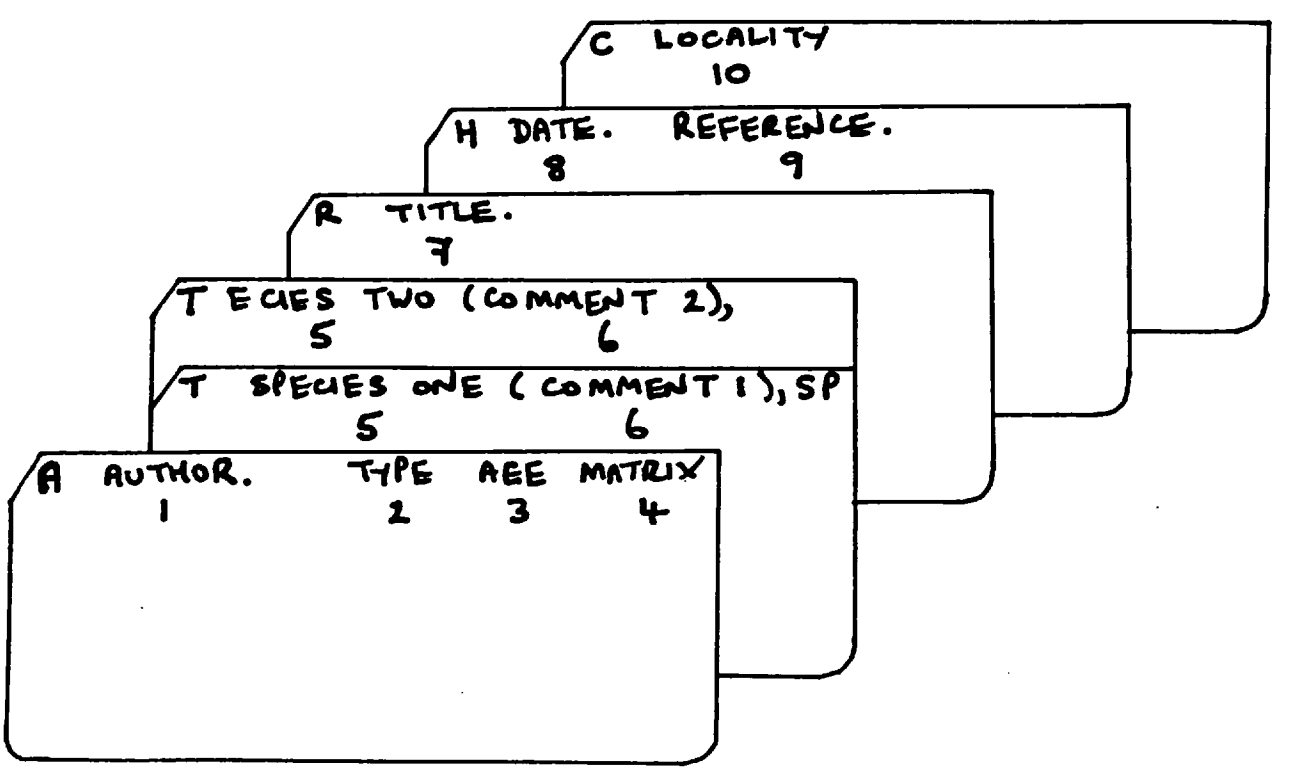


FIGURE 33. CODING OF DATA

Source reference: Andrews H. N. 1970. Index of generic names of fossil plants. United States Geol. Surv. Bull. 1300. Washington. LCCC 76-604645.

CHAMAECYPARITES Endlicher, 1847.
Chaemaecyparites hardtii (Goeppert) Endlicher, 1847, p. 277. For *Cupressites hardtii* Goeppert, 1837, p. 429; Oligocene; Bavaria.

CHAMAECYPARIXYLON Khudajberdyev, 1958.
Chamaecyparixylon polonicum (Kraüsel) Khudajberdyev, 1958a, p. 58, fig. 2a–d; wood, Cupressaceae; Upper Oligocene–Lower Miocene; Lake Smolino, near Chelyabinsk, South Urals, U.S.S.R.

CHANDLERA R. A. Scott, 1954.
Chandlera lacunosa R. A. Scott, 1954, p. 77, pl. 15, figs. 32–41; endocarp, Menispermaceae; Clarno formation, Eocene; Wheeler County, Oregon, U.S.A.

CHARNELIA Frenguelli, 1954.
Charnelia dichotoma Frenguelli, 1954, p. 368, pl. 6, figs. 1–3; "Sphenopterid" foliage; Devonian; San Juan, Argentina.

CHARNIA Ford, 1958.
Charnia masoni Ford, 1958, p. 211, pl. 13, fig. 1; plant?; Precambrian; Charnwood Forest, Leicestershire, England. *See also* Ford, 1963.

CHARNIODISCUS Ford, 1958.
Charniodiscus concentricus Ford, 1958, p. 213, pl. 13, fig. 2; plant?; Precambrian; Charnwood Forest, Leicestershire, England. *See also* Ford, 1963.

CHARPENTIERIA Unger, 1845.
Charpentieria nivium Unger, 1845 (1841–47), p. xc; wood; Pliocene; Lemberg, Galicia, Austria.

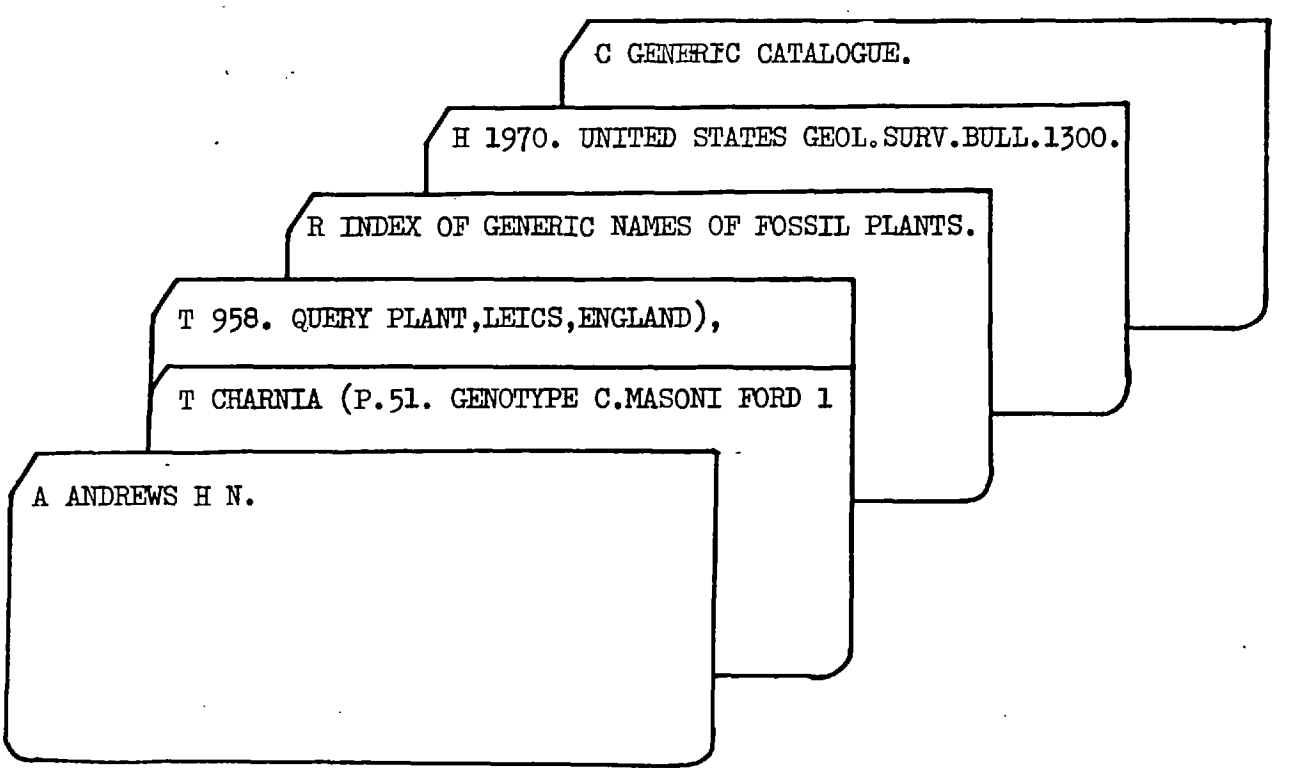


TABLE 17. CODING QUESTIONNAIRE

OUTLINE OF DATA INPUT AND BLOCK STRUCTURE

FIRST CARD (A-CARD)

1. AUTHOR OF THE COMMENT OR AUTHORITY FOR THE INFORMATION

IF A NEW LOCALITY OR NEW FOSSILS

2. THE FOSSIL TYPE (TABLE 1) (AL,AN,CA,MP-MS,MU,PL,QQ,ST,TR)

3. THE AGE OF THE FOSSILS IN MILLIONS OF YEARS (TABLES 2,3)

4. THE MATRIX IN WHICH THE FOSSILS ARE FOUND (TABLE 4)

T-CARDS

5. NAME OF THE FOSSIL OR STRUCTURE

6A. PAGE,TABLE,TEXT-FIG,PLATE, REFERENCES,COMMENTS.

6B. NEW GENUS OR SPECIES, GENOTYPE OR HOLOTYPE DESIGNATED,VALID.

6C. SYNONYMY ... (INCLUDES ...)

R-CARDS

7. TITLE OF PAPER,REPORT, PERSONAL COMMUNICATION.

H-CARDS

8. YEAR OF REPORT OR COMMENT

9. COMPLETE BIBLIOGRAPHIC CITATION OF ARTICLE ,INFORMATION SOURCE

FINAL CARD (C-CARD)

10A. AREA OF WORLD (SEE MAP)

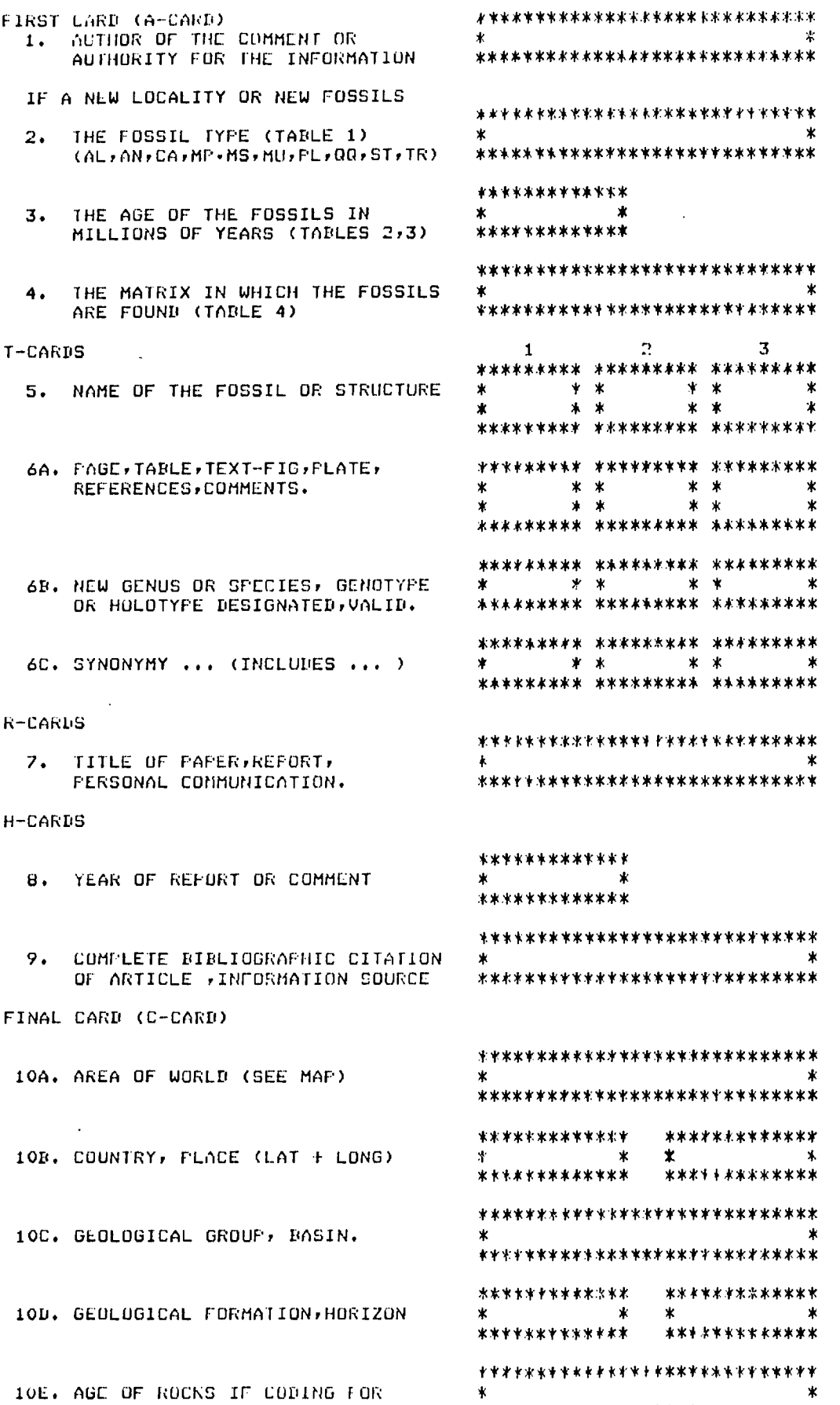
10B. COUNTRY, PLACE (LAT + LONG)

10C. GEOLOGICAL GROUP, BASIN.

10D. GEOLOGICAL FORMATION,HORIZON

10E. AGE OF ROCKS IF CODING FOR CARD 1 TAKEN FROM TABLES 2 OR 3

NUMBERS 1 - 10 REFER TO THE OPTIONS 1 - 10



for checking. Errors are corrected by re-punching the data cards and re-listing them. After correction the cards are stored in boxes. Complete boxes of cards are copied to magnetic tape as binary records and each box is sorted and tabulated for reference and as a final check for format errors. The data base is an amalgamated binary file of all data blocks, sorted into author order (first 20 characters of each block).

In any additive data-collecting exercise of this kind it is essential that the data is accurate and objective. For this reason any data block added to Foscat only refers to the original report indexed. Subsequent reports and opinions will be indexed separately, so that an objective history of interpretation and comment is presented, rather than a partisan view. This means that a critical appraisal of radiometric ages and attributions of fossils may be necessary.

The finer details of string delimiters and internal grammar can be obtained from the data base and will not be reviewed here. The structure of the data base is such that most reports can be punched efficiently - the usual arrangement is a set of lists of fossils from each of several localities which is why the species-comment strings are pushed together on the T-cards (Figs.32,33). Information about different localities is split over several blocks and information on the source of the data is duplicated for each block. The problem of redundancy deserves further study; with a large data base such as Foscat it might be more efficient to number references and arrange the bibliography as a separate sorted data file. At present the reference cards (R6 and H6) are merely carried by the system and transcribed when required.

Foscat works in two stages:-

1. a search for a keyword results in all data blocks with that keyword on the specified cards being written onto a file. Each data block is complete in itself and contains 10 strings of information.
2. the information required by the user is selected from each data block and arranged for output.

Searches are for complete words delimited by blanks, commas or stops, or for character strings. At the moment the A- and C- cards are searched for complete words while the T-cards are searched for strings. Work is in progress to enable the user to select word or string

Figure 34. Example of a search

```
 79/03/16. 18.43.10.
 I.C.C.C. NETWORK OPERATING SYSTEM.      NOS 1.1-430.4B
USER NUMBER: umfb031,
                        TERMINAL:    404,TTY
RECOVER/ SYSTEM:
                  $SETFL,20000.
/-foscat/un=umfb031


 **** **** **** **** **** *****    DATA BASE FOR FOSSIL INFORMATION
 *    *  * *    *    *  *   *
 ***  *  * **** *    ****   *           PROGRAMMES - PAUL GRANT
 *    *  *    * *    *  *   *
 *    **** **** **** *  *   *         DATA EDITING - CHRIS PEAT

 TYPE IN 1 FOR STAGE 1, 2 FOR STAGE 2, ZERO FOR INFORMATION.
? 0

 THE FOSCAT DATA BASE OPERATES IN TWO STAGES BECAUSE THE DATA FILE IS
 TOO LONG TO KEEP PERMANENTLY ON DISC ...

 STAGE 1
      A J4 JOB IS SET UP TO COPY THE DATA FROM MAGNETIC TAPE TO DISC
 AS A DIRECT ACCESS FILE.  THIS PROCESS USUALLY TAKES ABOUT TWO HOURS.
 YOU WILL NOT BE ABLE TO INITIATE THIS PROCESS WITHOUT THE
 APPROPRIATE PASSWORDS.  CONTACT CHRIS PEAT, RSM ROOM 2.26
 TO GET THIS DONE OR IF YOU WANT TO BECOME A REGULAR USER.

 STAGE 2
      THE DISC STORE IS INTERROGATED VIA TELEX.

      TO USE FOSCAT, ACTIVATE STAGE 1 EARLY IN THE MORNING AND
 THEN RETURN A FEW HOURS LATER TO UTILISE STAGE 2.
 THE DATA FILE WILL NORMALLY BE PURGED OVERNIGHT.

 NOW TYPE IN 1 FOR STAGE 1, 2 FOR STAGE 2, ...
? 2
 TYPE IN 1 TO SET UP SEARCHES, ZERO FOR GENERAL INSTRUCTIONS.
? 1
 MORE SOON ...
STOP
 HOW MANY OPTIONS TO BE USED IN THIS SEARCH.  TYPE IN ZERO FOR INFORMATION.
? 0


 SEARCH OPTIONS ARE

 1. AUTHOR              2. FOSSIL TYPE              3. AGE
 4. LITHOLOGY         5/6. FOSSIL NAME OR COMMENT   7. TITLE OF PAPER
 8. PUBLICATION DATE    9. REFERENCE               10. LOCALITY

 MULTIPLE OPTIONS OK.  RARE TOPICS FIRST.

 HOW MANY OPTIONS TO BE USED IN THIS SEARCH
? 1
 TYPE IN OPTION NUMBERS
? 5
  TYPE IN SPECIES/COMMENT
? charnia
 CHARNIA
? 1
  TYPE IN SPECIES/COMMENT
?
  1    SPECIE(S) TO BE SOUGHT
 TYPE IN 1 TO SET UP ANOTHER SEARCH, OTHERWISE ZERO.
 SEARCHES SET UP TOGETHER WILL PRODUCE A SINGLE OUTPUT FILE OR LISTING.
? 0
 TYPE IN 1 FOR QUICK LISTING OF COMPLETE DATA BLOCKS.
         2 FOR FURTHER PROCESSING.
         3 FOR BOTH.
         4 FOR AUTOMATIC BIBLIOG + SPECIES/LOC LIST + UP TO 10 CHARTS.
? 2
STOP
  HOW MANY OPTIONS TO BE OUTPUT. FOR INFORMATION TYPE ZERO.
? 0
  OPTIONS ARE...

  1-AUTHOR      2-FOSSIL TYPE 3-AGE INFO. 4-LITHOLOGY    5-FOSSIL NAME
  6-COMMENTS    7-REF.TITLE   8-REF.DATE  9-REFERENCE   10-LOCALITY
 11-QUICK BIBLIOGRAPHY (AUTHOR,DATE,TITLE,REF IN AUTHOR ORDER)

  ENTER NUMBERS AS ONE LINE LIKE 2,10,5,2,6,3,1,11

  OUTPUT IS SORTED ALPHABETICALLY (1ST.20 CHARS.OF BLOCK), AND ARRANGED IN
  A LIST OR TABLE.  TOO MANY OPTIONS WILL PRODUCE A TABLE WITH NARROW COLUMNS.
  STATEMENTS ARE NUMBERED - NUMBERS WILL ALSO REFER TO CHART.

    HOW MANY OPTIONS TO BE OUTPUT
? 6
  ENTER OPTION NUMBERS IN THE ORDER IN WHICH THEY ARE TO BE OUTPUT
? 11,5,6,1,8,3
```

/Figure 34 continued

FINDEX - BIBLIOGRAPHIC LISTING

ANDERSON M M. 1971. PHOTOGRAPHS SHOWN,DISCUSSION AT E.CANADA BIOSTRATIGRAPHY S EMINAR ON PRECAMBRIAN FOSSILS AT SUDBURY,ONTARIO,OCTOBER 10 TH,1970. REPORTED IN M F GLAESSNER - GEOGRAPHIC DISTRIBUTION AND TIME RANGE OF THE EDIACARAN PRECAMBRIAN FAUNA. BULL.GEOL.SOC.AMERICA. V.82, NO.2, P.509-513.

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FORD T D. 1968. THE PRECAMBRIAN PALAEONTOLOGY OF CHARNWOOD FOREST. P.12-14 IN THE GEOLOGY OF THE EAST MIDLANDS, ED. P C SYLVESTER-BRADLEY + T D FO RD. UNIVERSITY OF LEICESTER PRESS. ISBN 7185 1072 0.

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END OF RECORD ENCOUNTERED
23 DATA BLOCKS READ.

/Figure 34 continued

```
STOP 140
 IF YOU WANT ALL OUTPUT TO GO TO THE SAME PLACE
 TYPE IN 1 FOR HERE, 2 FOR ICCC LINE PRINTER, 3 FOR MICROFILM ...
 OTHERWISE ZERO.
? 1
 TYPE IN   1 FOR TABLE,  2 FOR BLOCKS,  ZERO FOR INFORMATION.
? 1
 TO DELETE DUPLICATE DATA STRINGS ENTER 1, OTHERWISE ZERO.
? 1
 TYPE IN 1 FOR CHART PLOTTING EVENTUALLY, ZERO FOR NO CHARTS AT ALL.
? 1
STOP



         96 DATA BLOCKS READ.          96 DATA BLOCKS WRITTEN.
            DATA FILE REDUCED BY    0 PERCENT.
STOP 99


 **PROGRAMME TABLER - ARRANGING DATA FOR TABULATION**

 PLEASE ENTER YOUR OUTPUT FORMAT - 80 FOR TELETYPE, 130 FOR LINE PRINTER.
? 80
   5 OPTIONS SELECTED FOR TABULATION. IN ORDER

  5  6  1  8  3
 TO OMIT OPTIONS ENTER 1, OTHERWISE ZERO.
 CHARTS CAN STILL BE PRODUCED IF OPTION 3 SUPPRESSED HERE.
? 0
 HOW MANY SPACES WOULD YOU LIKE BETWEEN COLUMNS IN YOUR OUTPUT
? 2
   5 COLUMNS REQUESTED. MAX.POSSIBLE NO. OF CHARACTERS =  62
 PLEASE ENTER NO. OF CHARACTERS FOR EACH OPTION. IE. COLUMN WIDTH.
? 14,21,14,4,9
 FOR NUMBERED OUTPUT STRINGS ENTER 1, OTHERWISE ZERO.
? 1

 OPTIONS SELECTED        5   6   1   8   3   0   0   0   0   0   0
                         0   0   0   0   0   0   0   0   0   0   0
 FORMATS SELECTED       14  21  14   4   9   0   0   0   0   0   0
                         0   0   0   0   0   0   0   0   0   0   0
 INTER COLUMN SPACING    2

 TABULATION COMPLETE.
STOP 238
```

FOSCAT - TABULATION

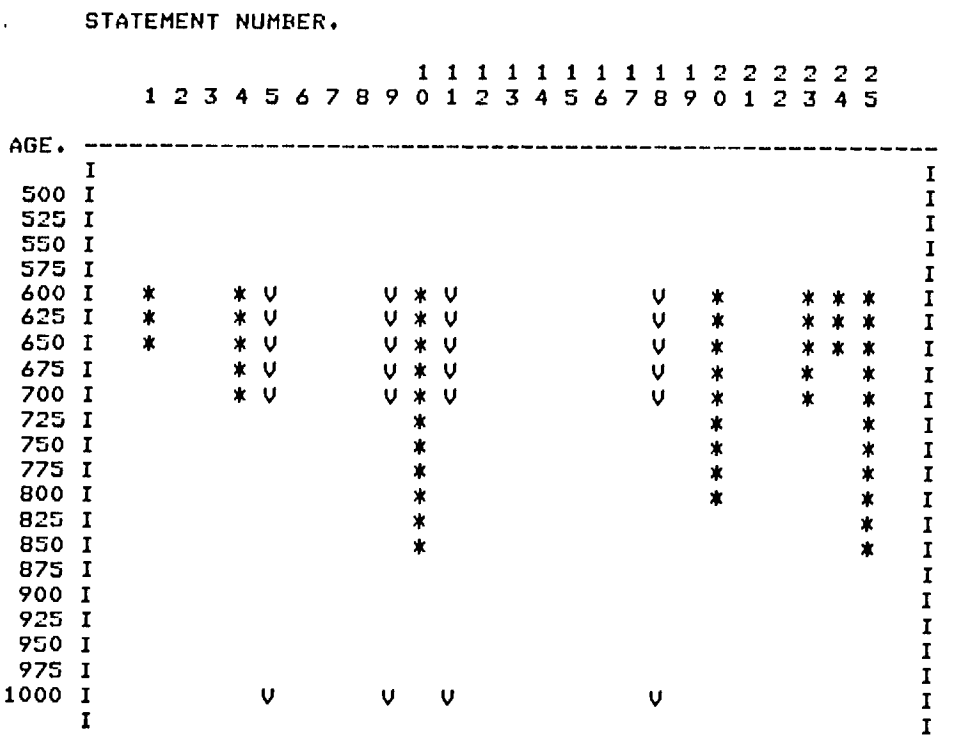
1	ALGAE	(T.F,P.72(8). HYPOTHETICAL.)	GLAESSNER M F.	1961	0650 0580
2	ARCHAEOCYATHA	(P.491.(HAUGHTON,1959). ARE CYLINDRICAL FILLED-IN TRACKS OF BURROWING ANIMALS WHICH TAPER ONLY WHERE THEY GRADUALLY DISAPPEAR INTO THE ROCK. SEE SLAB A,PL.IV,HAUGHTON,1959.)	GLAESSNER M F.	1962	
3	BELTANELLA GILESI	(PL.1,F.3)	GLAESSNER M F.	1962	
4	BELTANELLA	(P.59. RARE)	GLAESSNER M F.	1960	0700-0580
5	BOSS AND SPLODGE	(P.58-59. ORIGIN UNCERTAIN.)	FORD T D.	1963	XXXX-0600
6	CHANCELLORIA SPICULES	(P.22-23 - F.3. INCLUDES PORIFERA (F.3). FROM THE POLETA LIMESTONES, LOWER CAMBRIAN)	CLOUD P E.	1968	
7	CHARITES	(P.51.GENOTYPE-C.MOLASSICA (STRAUB) HORN A F RANIZIEN.1959A,P.59,PL.1,F.2-7. CHAROPHYTE,OLIGOCENE,SWITZERLAND.)	ANDREWS H N.	1970	
8	CHARNIA MASONI	(F.1A. DRAWING.)	GLAESSNER M F.	1959	
9	CHARNIA MASONI	(P.212-213,PL.13,F.1. HOLOTYPE)	FORD T D.	1958	XXXX-0600
10	CHARNIA MASONI	(P.12-13,PL.1A. RECONSTRUCTION PL.1D.)	FORD T D.	1968	0850-0580
11	CHARNIA MASONI	(PL.1A,P.59)	FORD T D.	1963	XXXX-0600
12	CHARNIA MASONI	(P.193-194,F.4,5. INCLUDES LEAF-LIKE IMPRESSIONS. IN ONE CASE A FROND OF CHARNIA APPEARS TO BE ATTACHED TO A DISC (CHARNIODISCUS) (F.5).)	FORD T D.	1962	
13	CHARNIA SP A	(PL.1,F.4)	GLAESSNER M F.	1962	
14	CHARNIA SP B	(PL.1,F.5)	GLAESSNER M F.	1962	
15	CHARNIA	(MAY HAVE HUNG BENEATH MEDUSOID FLOATS RATHER THAN ROOTED.)	CLOUD P E.	1968	
16	CHARNIA	(P.115 (FORD,1958). RESEMBLES RANGEA.)	DOWNIE C.	1975	
17	CHARNIA	(P.202,F.14.8A. FROM CHARNWOOD.)	HOUSE M R.	1972	
18	CHARNIA	(P.212. GENOTYPE CHARNIA MASONI.)	FORD T D.	1958	XXXX-0600
19	CHARNIA	(P.483)	GLAESSNER M F.	1962	
20	CHARNIA	(P.510,F.1,LOC.6)	GLAESSNER M F.	1971	0800-0580
21	CHARNIA	(P.511)	ANDERSON M M.	1971	
22	CHARNIA	(P.51.GENOTYPE-C.MASONI,FORD,1958,P.211,PL.13,F.1. QUERY PLANT. PRECAMBRIAN,CHARNWOOD FOREST,LEICESTERSHIRE,ENGLAND. CF ALSO FORD,1963.)	ANDREWS H N.	1970	
23	CHARNIA	(P.60,61. 1 SPEC.)	GLAESSNER M F.	1960	0700-0580
24	CHARNIA	(P.73-74,BOTTOM R FIG,P.75,T.F,P.72-73(7). INCLUDES SOFT CORALS RELATED TO LIVING SEA PENS,P.73. LEAF- OR FRONDLIKE STALKED FOSSILS,P.73. APPARENTLY INTERPRETED AS ALGAE BY SPRIGG. CF ALSO LIVING PENNATULA - P.	GLAESSNER M F.	1961	0650-0580

/Figure 34 continued

```
 AGE INFO BEING EDITED READY FOR PLOTTING
 READY FOR CHART PRODUCTION.
 NUMBER OF CHARTS PROJECTED =      4.
 TO SPECIFY FEWER CHARTS ENTER 1, OTHERWISE ZERO.
? 1
 PLEASE ENTER NUMBER OF CHARTS REQUIRED.
 ONE CHART PLOTS 25 RANGES.
 TO FORGO THIS OPTION ENTER ZERO.
? 1
 PLEASE ENTER FOUR INTEGERS.....
          (1) OUTPUT FORMAT - 80 OR 130 ONLY.
          (2) SCALE ORIGIN.
          (3) SCALE UPPER LIMIT.
          (4) SCALE INCREMENT.

 ONE LINE PRINTER/MICROFILM PAGE = 70 LINES OF PLOTTING, SO TO USE
 SPACE EFFICIENTLY MAKE  (3)-(2) / (4) = 70.
? 130,500,1000,25
 DATA TAPE READY FOR PLOTTING
STOP 110
```

FINDEX - PLOT OF AGE INFORMATION



KEY. * = RANGE OF OCCURRENCE.
Q = QUERY.
A = YOUNGER THAN LOWEST MARK.) SOLITARY SYMBOL
V = OLDER THAN HIGHEST MARK.) MEANS OFF SCALE.
. = OCCURRENCE DATED MORE PRECISELY THAN SCALE.

searching over any part of the data. At present an A-card search for 'Smith' will not find 'Smithers' or 'Smithson' whereas a T-card search for 'Protoleios' will find data blocks with 'Protoleiosphaera' and 'Protoleiosphaeridium'.

Because each data block is complete in itself any string of information can be retrieved from any block. For example, if a bibliography of references mentioning the fossil Charnia is required, a search for the keyword 'Charnia' recovers a set of data blocks. Because the data base is sorted in author order (first 20 characters of the A-card) the bibliography can be produced by copying the author string and R- and H-cards of each block and printing only different strings. If a tabulation of species and comments is required the species and comment strings would be selected from the T-cards, sorted into alphabetical order and listed. Because there are usually several species in each data block, this procedure results in the listing of unwanted extra species. For most practical purposes this is not a serious drawback but work is in progress to expand multiple species blocks into a set of new blocks and run through the expanded file again for the required keyword.

Exclusive searches (for any blocks containing keyword A or B or C) can be run at present on a single scan of the data base. Inclusive searches (only blocks containing keywords A and B and C) can only be run manually at present, though work is in progress to make this automatic. In this case a file of blocks with keyword A is generated and then searched again for keyword B ... etc.

With the current implementation of Foscat it is a simple matter to recall and check over the synonymy, status and interpretation of a fossil. After compiling a synonymy it is possible to search for the synonyms and recover and synthesise locality and age data to demonstrate the known geographic and stratigraphic distribution of any fossil or flora. Figure 34 shows a complete search for 'Charnia', producing a bibliography, species list and chart of age ranges.

Because of the search pattern and use of keywords, more subtle searches can be set up. For example the data for Figure 35 were recovered by two searches, for 'shale' and 'chert', listing the fossil type, age and locality for each. Occurrence of Precambrian microfossils in each area of the world were then counted up and plotted manually. Figure 35 shows up the dominance of shale microbiotas in the USSR and Europe and the dominance of chert microbiotas in Africa and Australia.

FIGURE 35. DISTRIBUTION OF SHALE AND CHERT MICROBIOTAS

SHALE – RED; CHERT – BLUE.

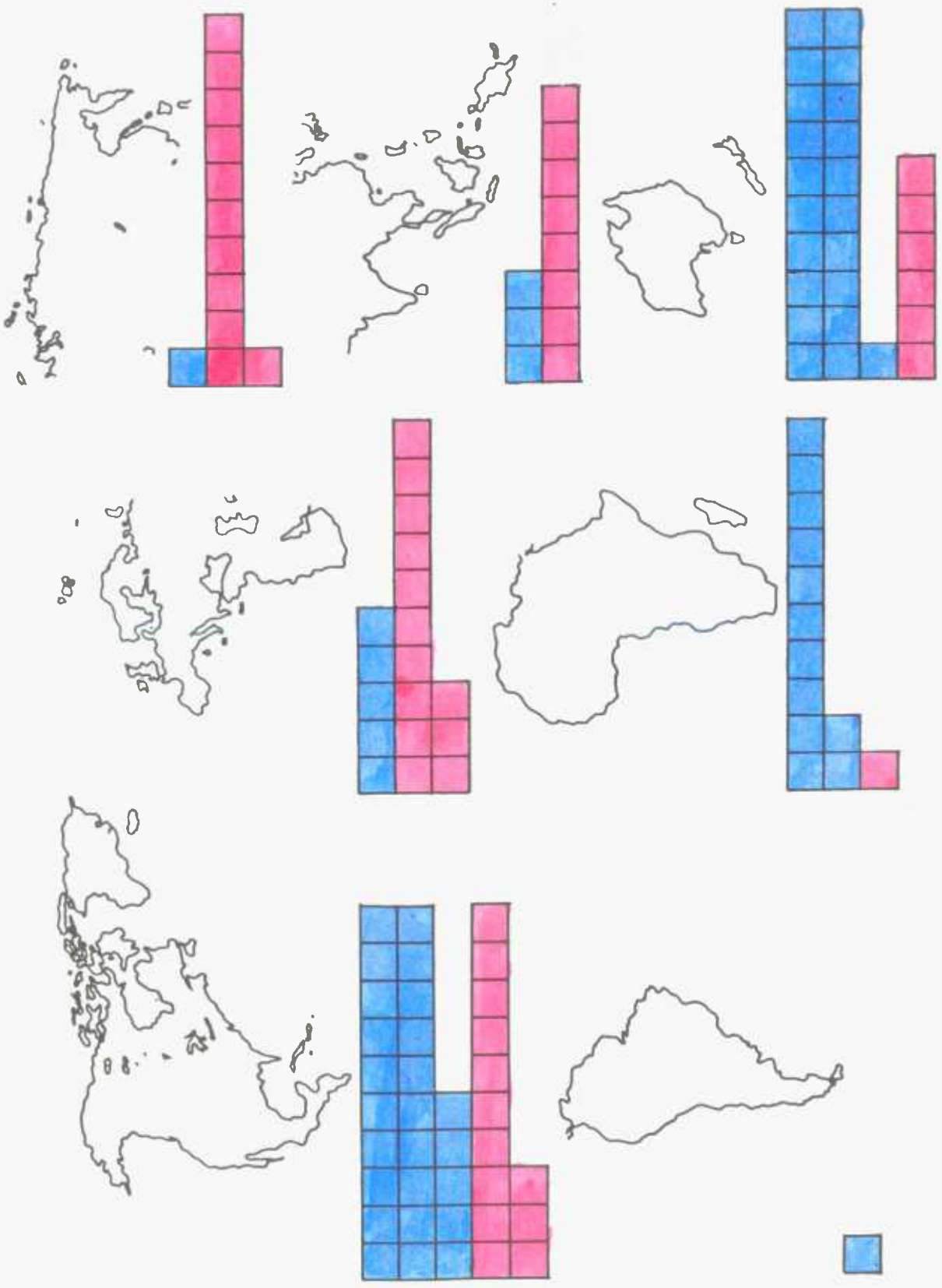


FIGURE 36.
SCHOPF AND TIMOFEEV:
MATRIX OF MICROBIOTAS

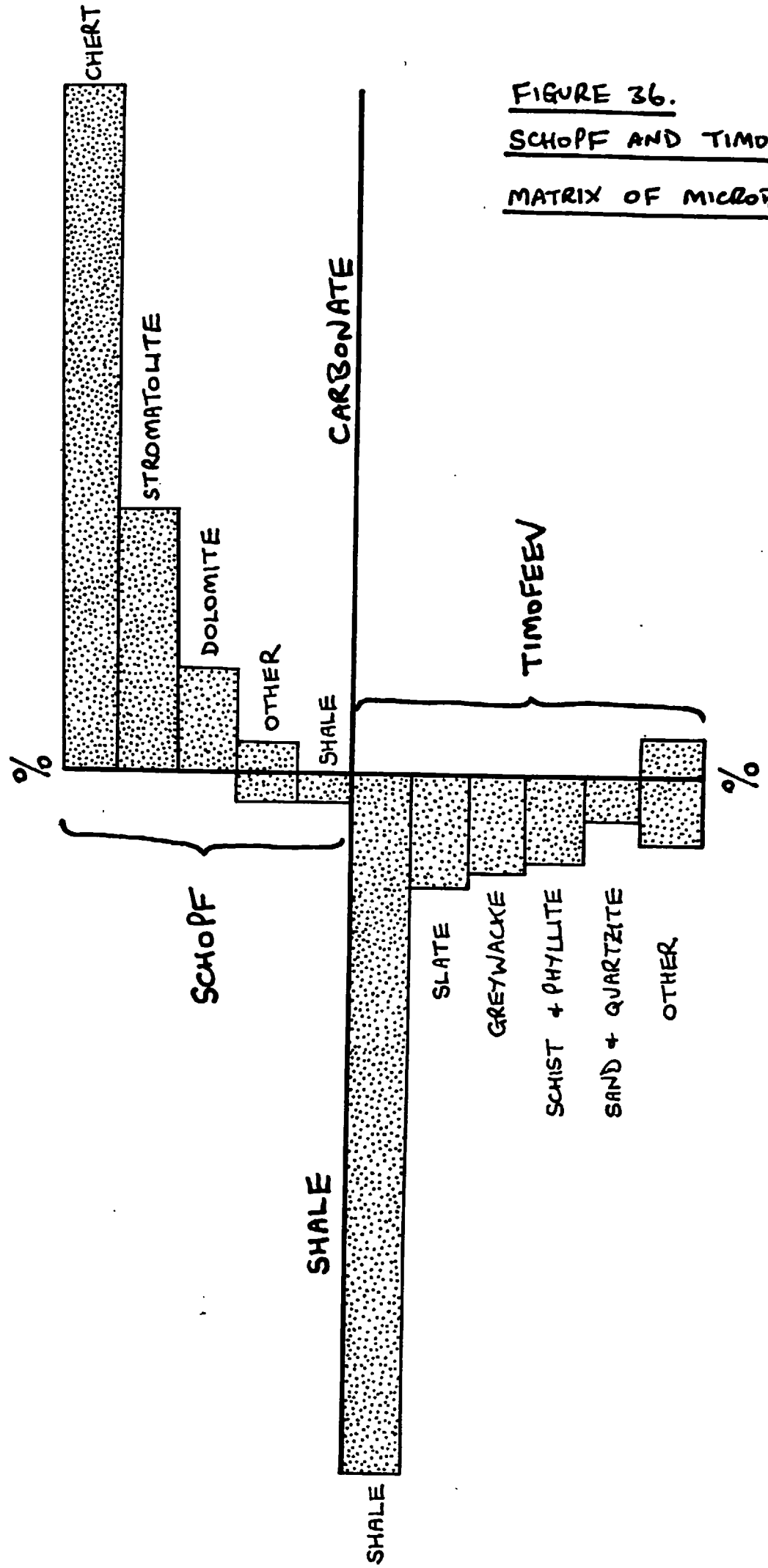
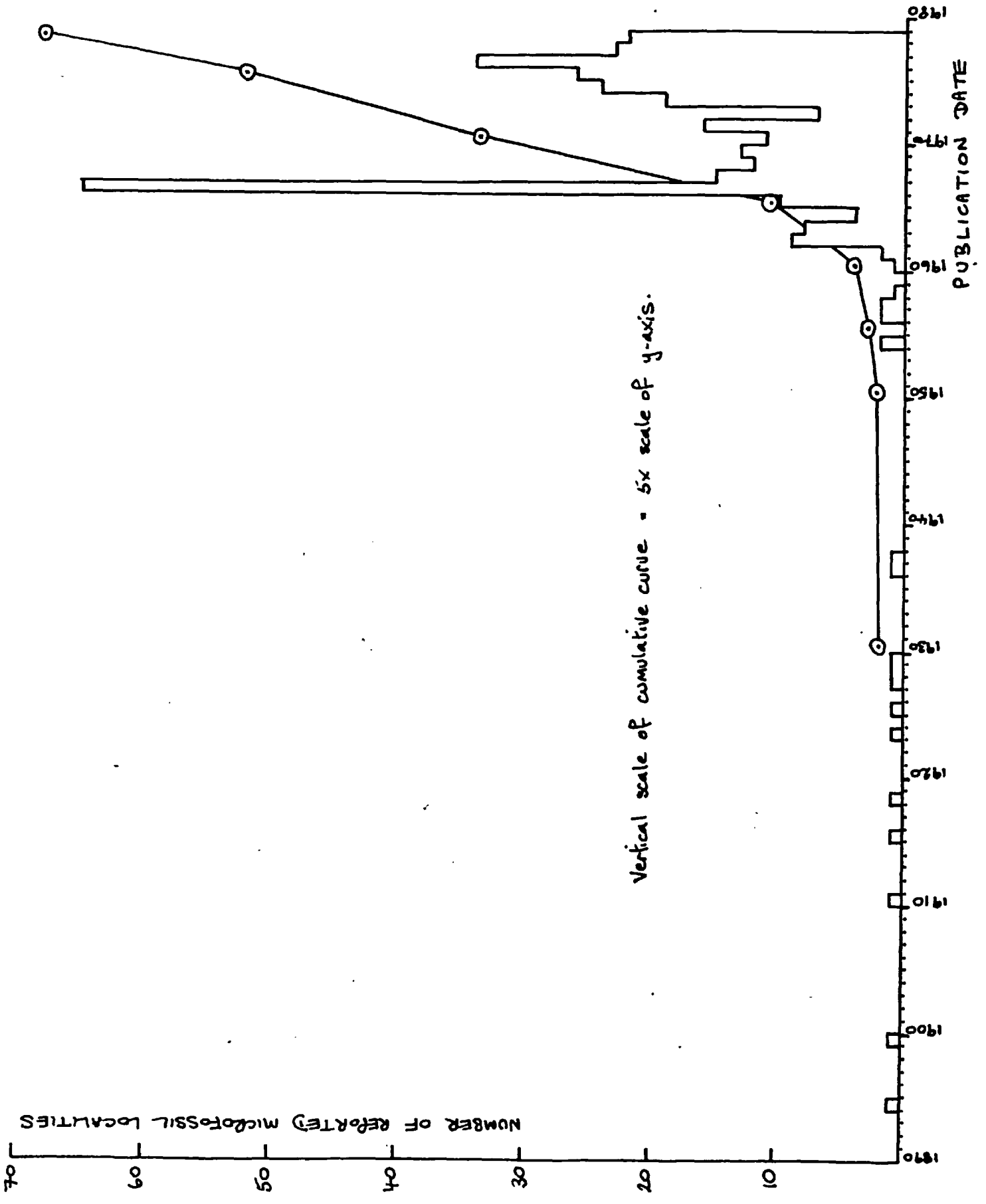


FIGURE 37
RECENT EXPANSION OF PRECAMBRIAN MICROPALAEONTOLOGY



This bias reflects the rocks selected for study rather than the localisation of a particular lithology in the areas concerned. Figure 35 also shows that S. America is an open field as far as Precambrian micropalaeontology is concerned though a preliminary reconnaissance programme has recently begun (T R Fairchild, pers.comm.).

The American tendency to study Precambrian stromatolitic cherts and the Russian predilection for shales has been discussed in Chapter 5. Taking Schopf and Timofeev as the authors of most taxa on each side, figure 36 was constructed by two searches, for 'Schopf' and 'Timofeev', then listing the matrix of each locality from which they describe new material. The emphasis of each worker is apparent; it is unfortunate for students of classification and evolution that they have only recently become aware of each other's work.

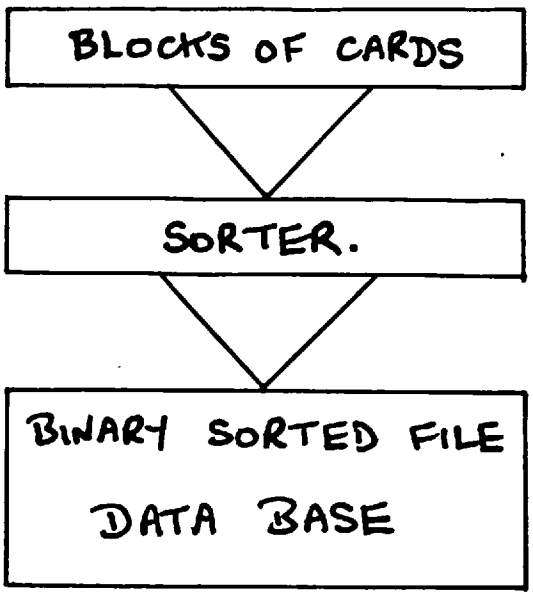
Figure 37 shows the recent expansion of studies in Precambrian micropalaeontology and was prepared by searching for 'mu' and listing the age, locality and reference of each occurrence in order of date of publication. Counts were made manually. The massive peak in 1966 is due to the complete indexing of the British Library translation of Timofeev 1959.

C. Development of Foscat

The Foscat system is built around the programme called SORTER (Fig.30) which operates in two modes. In mode 1 it can read blocks of cards, sort them, and write the sorted blocks onto a file either in binary code or as card images. In mode 2 it scans the sorted binary file or data base for keywords and writes data blocks containing keywords onto another file, again as card images or binary code.

Binary files can be read faster than card images, so the data base is maintained as a binary file (See Fig.38). To interrogate the data base, it is attached to SORTER together with a set of coded search instructions and keywords. Search results are written to output in the form of complete data blocks (Fig.39). This is the simplest implementation of the data base and the way in which SORTER was developed and tested.

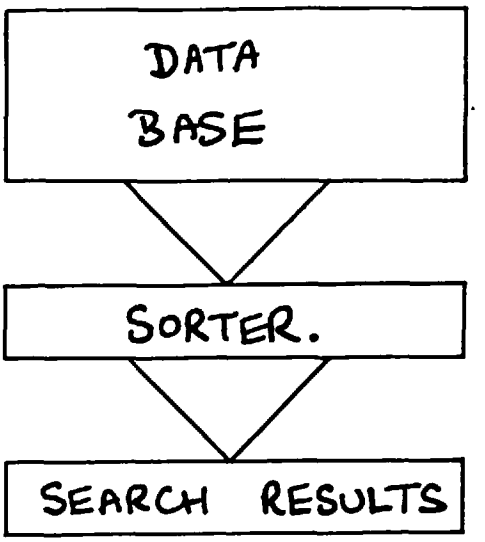
FIGURE 38. GENERATION OF A DATA BASE



This implementation was inconvenient because searches produced complete data blocks. In the next stage of development a set of small programmes was written to check data blocks before they were added to the data base, to select required data strings from data blocks, and to output the data in a convenient form (Fig.40). The programme EDITOR reads blocks of freshly-punched cards and checks them for internal grammar, length and order before addition to the data base. SELECT reads blocks of cards and selects strings of data (options) from them. These parts of the data are copied onto mock data blocks in any selected order as a continuous string of characters. These false data blocks can then be sorted into alphabetical order (first 20 characters of the first option) by using SORTER again in mode 1. The option strings from the sorted mock data blocks are then arranged for output as lists (LISTER) or tables (TABLER). Both LISTER and TABLER pass on age information, which is translated from hollerith characters to integer numbers and plotted as charts by PLOTTER (Fig.40).

This system was much more efficient than the first version, because data was listed for checking before addition to the data base, and searches produced only the information required. One drawback of using the system interactively from a remote terminal was that each operation required various control statements to be input by the user. For example, to tabulate or list a file of data it was necessary to type

FIGURE 39. INTERROGATING THE DATA BASE



in either

```
GET, TABLER
TABLER.
RETURN, TABLER
```

or

```
GET, LISTER
LISTER.
RETURN, LISTER
```

as well as making sure that the data was on the right input file, and returning used files. This all took time and was open to error.

The current version of the system was developed by writing three small interactive programmes which generated the appropriate control commands in response to simple questions addressed to the user. The general arrangement of such a programme is shown in Figure 41. These programmes allow information to be provided if required, and do not permit operator errors. Each of these programmes (SETUP, ASKER and ENDER) generate a control command procedural file which automatically calls up the programmes needed to do a particular job. Each procedural file ends by calling the next interactive programme and then executing the procedural file generated by it.

FIGURE 40. FIRST FULL IMPLEMENTATION OF FOSCAT WITH CONTROLLED OUTPUT

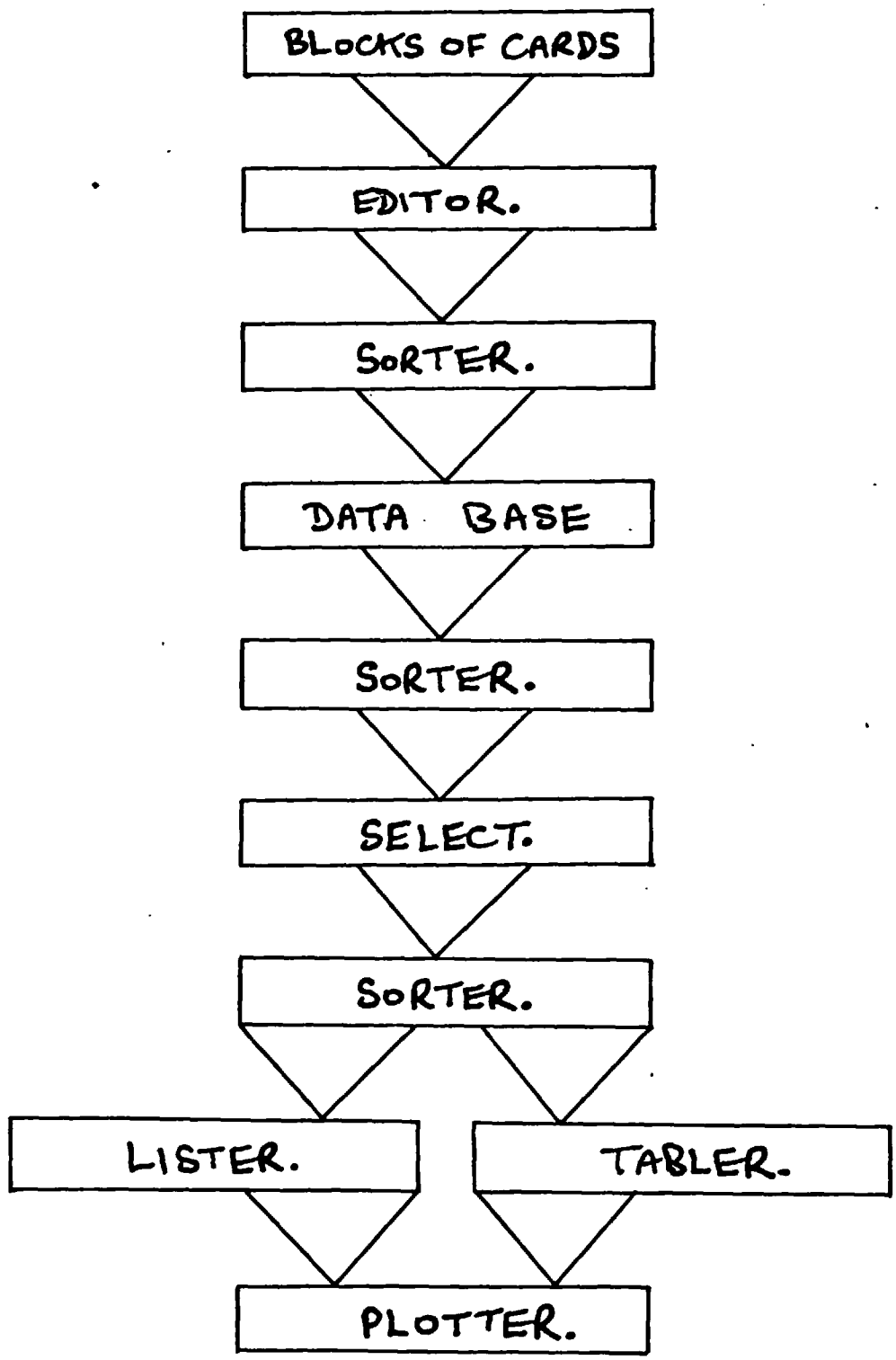
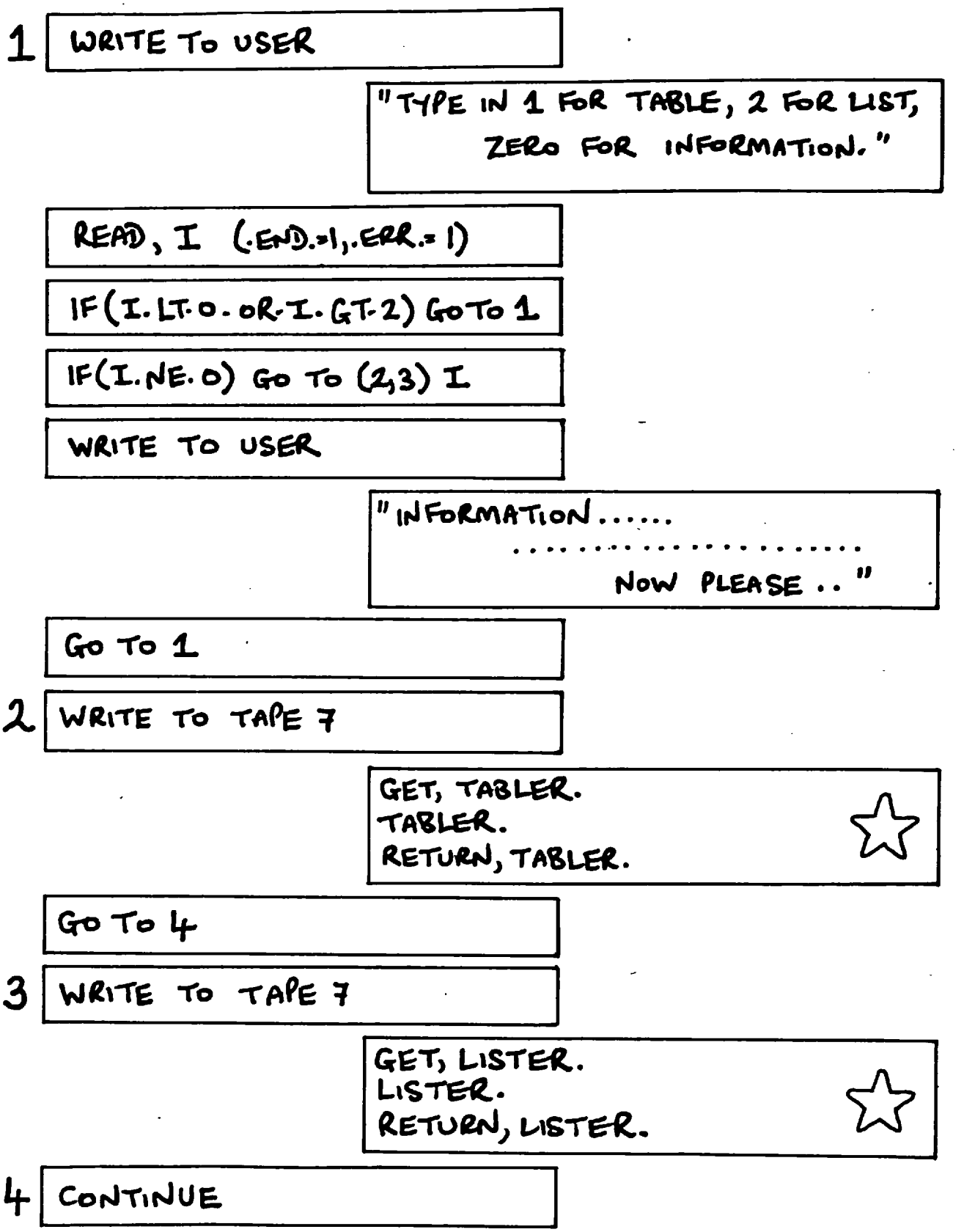


FIGURE 41. GENERAL ARRANGEMENT OF AN INTERACTIVE PROGRAMME



Thus the command -FOSCAT executes the procedural file FOSCAT, which sets up the system and calls SETUP which asks for keywords and arranges this information in a form suitable for SORTER. The instructions generated by SETUP are written onto TAPE7 which is then executed as a procedural file. The last four commands on TAPE7 are always

```
GET, ASKER
ASKER.
RETURN, ASKER
-TAPE9.
```

Similarly, the last four commands on TAPE9 are always

```
GET, ENDER
ENDER.
RETURN, ENDER
-TAPE3.
```

ENDER asks the user whether he wishes to make another search. If he does, the first instruction on TAPE3 will be to recall SETUP and start another run through the cycle. If no more searches are required, TAPE3 merely clears the system and tells the computer to stop. This system of operation is illustrated diagrammatically in Figure 42, and one set of actual procedural files is shown in Figure 43. The actual instructions executed by the computer in making the search for 'Charnia' (Fig.34) are shown in Figure 44. Most of these commands would have had to be typed in manually if the interactive programmes had not been developed.

Only a few of the available possibilities are shown in the examples here, but as well as saving time and reducing errors these interactive programmes make it very easy to get output in exactly the format required and allow a variety of options (Eg. output as microfilm or microfiche) to be available to users with no computing expertise.

D. Current status and potential of Foscat

Although by no means complete, Foscat is already the most comprehensive and detailed compilation of the occurrence and interpretation of Precambrian fossils. The data base currently

FIGURE 42. FOSCAT - PROCEDURAL FILE CYCLE USING INTERACTIVE PROGRAMMES

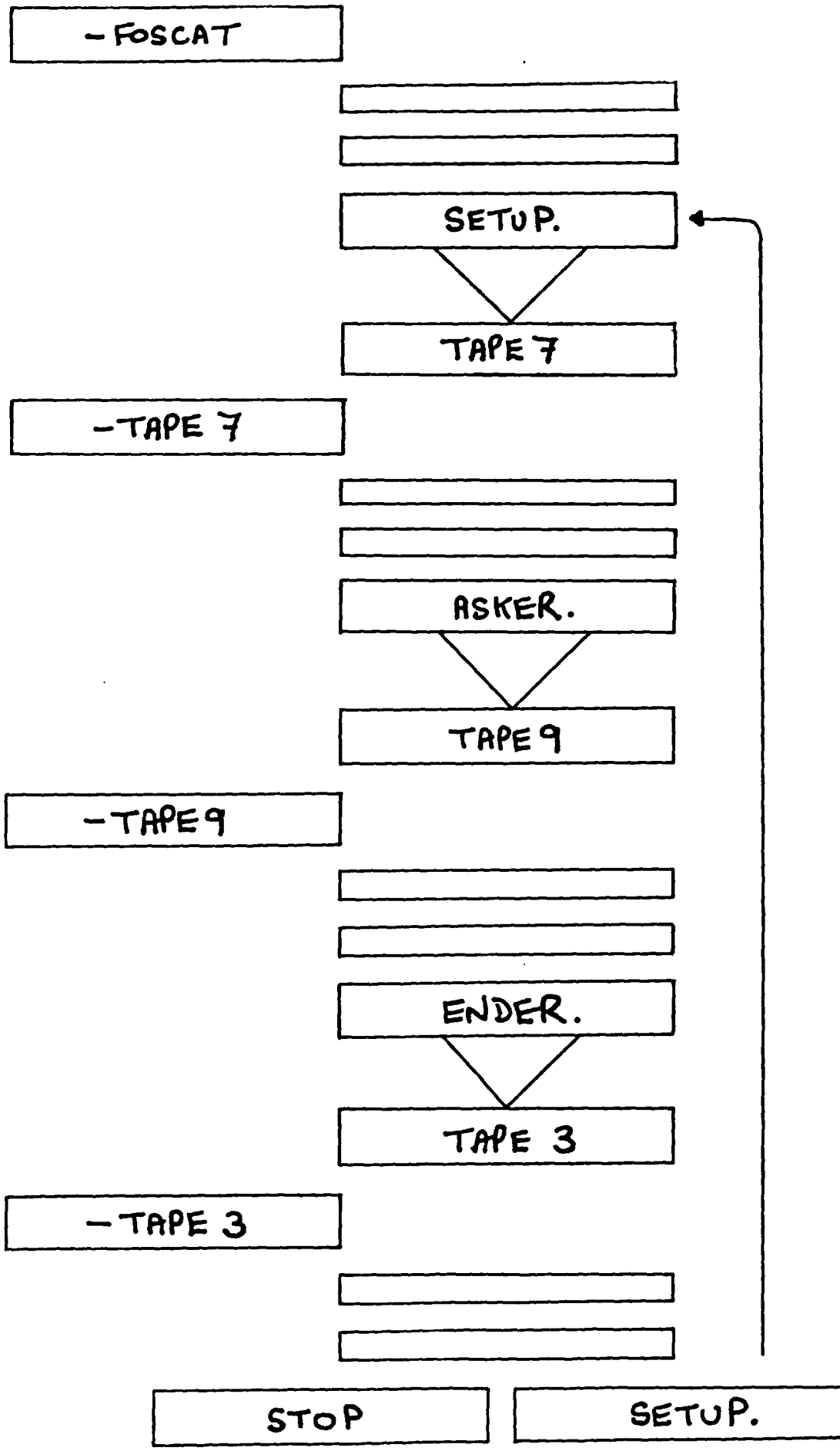


Figure 43. FOSCAT - one set of actual procedural files

```
 lnh,f=foscat
***FINDEX HEADER, INSTRUCTIONS***
GET,STARTER/UN=UMFB031
GET,TAPE99/UN=UMFB031
STARTER.
RETURN,TAPE99,STARTER
***SEARCH PROCEDURE FORMULATED***
GET,SETUP/UN=UMFB031
SETUP.
RETURN,SETUP,TAPE5,INPUT
***SEARCH PROCEDURE FILE EXECUTING***
SETTL,200
-TAPE7
/
```

```
 lnh,f=tape7

RETURN(FINDEX,ENDER)
REWIND(TAPE1)
GET(SORTER/UN=UMFB031)
***LITERATURE SEARCH IN ACTION***
ATTACH(TAPE20/UN=UMFB006)
SETFL(60000)
SORTER.
RETURN(TAPE1,TAPE3,TAPE11,TAPE5,TAPE20,TAPE2)
***DATA BLOCKS LISTED***
GET(LIST2/UN=UMFB031)
LIST2.
REWIND(TAPE50)
***PRINT QUEUED TO ICCC***
QUEUE(TAPE50=PRINT)
RETURN(LIST1,LIST2)
***DATA STRINGS SELECTED FROM DATA BLOCKS***
GET(SELECT/UN=UMFB031)
SELECT.
RETURN(TAPE4,SELECT)
***DATA STRINGS SORTED ALPHABETICALLY***
REWIND(SORTER,TAPE1)
SORTER.
RETURN(TAPE10,TAPE1,SORTER)
GET(ASKER/UN=UMFB031)
ASKER.
RETURN(ASKER)
-TAPE7.
/
```

/Figure 43 continued

```
 lnh,f=tape9


***DUPLICATE DATA BLOCKS BEING DELETED***
RENAME,TAPE6=TAPE2
GET,DELETE/UN=UMFB031
DELETE.
RETURN,DELETE,TAPE6
***SORTED DATA STRINGS TABLED***
GET,TABLER/UN=UMFB031
TABLER.
RETURN,TAPE8,TAPE2,TABLER
REWIND,TAPE50
QUEUE,TAPE50=PRINT
RETURN,TAPE4
RETURN,TAPE50
GET,ENDER/UN=UMFB031
ENDER.
RETURN,ENDER
-TAPE3
/


 ender.


 TYPE IN 1 FOR ANOTHER SEARCH, ZERO TO END.
? 1
STOP
/


 lnh,f=tape3


RETURN,TAPE9,TAPE7
***COMPLETED CYCLE OF FINDEX***
GET,SETUP/UN=UMFB031
SETFL,60000
SETUP.
RETURN,SETUP,INPUT,TAPE5
-TAPE7
/


 ender.


 TYPE IN 1 FOR ANOTHER SEARCH, ZERO TO END.
? 0
 TYPE IN 1 FOR DAYFILE, ZERO TO END.
? 1
STOP
/


lnh,f=tape3


RETURN,TAPE9,TAPE7
DAYFILE
***COMPLETED CYCLE OF FINDEX***
/
```

Figure 44

FOSCAT - commands required to run one search and edit output

```
 TYPE IN 1 FOR ANOTHER SEARCH, ZERO TO END.
? 0
 TYPE IN 1 FOR DAYFILE, ZERO TO END.
? 1
STOP
 18.44.00.$SETFL,20000.
 18.44.09.$CALL,FOSCAT/UN=UMFB031.
 18.44.10.***FINDEX HEADER, INSTRUCTIONS***
 18.44.10.GET,STARTER/UN=UMFB031
 18.44.11.GET,TAPE99/UN=UMFB031
 18.44.12.STARTER.
 18.46.15.STOP
 18.46.17.RETURN,TAPE99,STARTER
 18.46.17.***SEARCH PROCEDURE FORMULATED***
 18.46.17.GET,SETUP/UN=UMFB031
 18.46.18.SETUP.
 18.47.13.STOP
 18.47.15.RETURN,SETUP,TAPE5,INPUT
 18.47.15.***SEARCH PROCEDURE FILE EXECUTING***
 18.47.15.SETTL,200
 18.47.15.-TAPE7
 18.47.16.RETURN(FINDEX,ENDER)
 18.47.16.REWIND(TAPE1)
 18.47.16.GET(SORTER/UN=UMFB031)
 18.47.17.***LITERATURE SEARCH IN ACTION***
 18.47.17.ATTACH(TAPE20/UN=UMFB006)
 18.47.17.SETFL(60000)
 18.47.18.SORTER.
 18.48.44.      END  LIT6L
 18.48.44.     24.402 CP SECONDS EXECUTION TIME
 18.48.44.RETURN(TAPE1,TAPE3,TAPE11,TAPE5,TAPE20,T
 18.48.44.APE2)
 18.48.44.RETURN(LIST1,LIST2)
 18.48.45.***DATA STRINGS SELECTED FROM DATA BLOCK
 18.48.45.S***
 18.48.45.GET(SELECT/UN=UMFB031)
 18.48.46.SELECT.
 18.50.54.STOP 140
 18.51.25.RETURN(TAPE4,SELECT)
 18.51.25.***DATA STRINGS SORTED ALPHABETICALLY***
 18.51.25.REWIND(SORTER,TAPE1)
 18.51.25.SORTER.
 18.51.29.      END  LIT6L
 18.51.29.       .806 CP SECONDS EXECUTION TIME
 18.51.29.RETURN(TAPE10,TAPE1,SORTER)
 18.51.29.GET(ASKER/UN=UMFB031)
 18.51.30.ASKER.
 18.51.57.STOP
 18.51.58.RETURN(ASKER)
```

/Figure 44 continued

```
 18.51.59.-TAPE9.
 18.51.59.***DUPLICATE DATA BLOCKS BEING DELETED**
 18.51.59.*
 18.51.59.RENAME,TAPE6=TAPE2
 18.51.59.GET,DELETE/UN=UMFB031
 18.52.00.DELETE.
 18.52.06.STOP 99
 18.52.10.RETURN,DELETE,TAPE6
 18.52.10.***SORTED DATA STRINGS TABLED***
 18.52.10.GET,TABLER/UN=UMFB031
 18.52.11.TABLER.
 18.53.24.STOP 238
 18.53.25.RETURN,TAPE8,TAPE2,TABLER
 18.53.25.REWIND,TAPE50
 18.53.26.COPYSBF,TAPE50,OUTPUT
 19.04.13.  COPY COMPLETE.
 19.04.13.***AGE DATA PREPARED FOR PLOTTING***
 19.04.13.GET,PLODAT/UN=UMFB031
 19.04.14.PLODAT.
 19.04.57.STOP 110
 19.04.59.RETURN,PLODAT,TAPE7
 19.04.59.***AGE DATA BEING PLOTTED***
 19.04.59.GET,PLOTTER/UN=UMFB031
 19.05.00.PLOTTER.
 19.05.01.STOP 57
 19.05.01.RETURN,PLOTTER,TAPE4
 19.05.01.RENAME,TAPE50=TAPE6
 19.05.01.REWIND,TAPE50
 19.05.01.COPYSBF,TAPE50,OUTPUT
 19.06.21.  COPY COMPLETE.
 19.06.21.RETURN,TAPE50
 19.06.21.GET,ENDER/UN=UMFB031
 19.06.22.ENDER.
 19.06.31.STOP
 19.06.33.RETURN,ENDER
 19.06.33.-TAPE3
 19.06.33.RETURN,TAPE9,TAPE7
 19.06.33.DAYFILE
***COMPLETED CYCLE OF FINDEX***
```

```
/bye,-
UECP,      44.324 SECS.
UEMS,      24.183 KPRUS.
AESR,       0.628 UNITS.
UECU,       0.628 UNITS.
UE T,      20.706 SECS.
UECM,       0.105 KWHS.
BYE,-.


UMFB031    LOG OFF.   19.08.19.
UMFB031    CP        44.327 SEC.
```

holds information on over 18,000 fossils from about 6,000 localities, reported in more than 1,000 papers.

For the first time in palaeontology it is now possible to recall and check over the synonymy, status and interpretation of a fossil without following a laborious trail through the literature. Further, locality and age data can be recalled from diffuse reports and synthesised to demonstrate the known geographic and stratigraphic distribution of any fossil, biota or list of synonyms. Whether Foscat eventually develops into an on-line public system or is published in catalogue form, it is certain to become a major resource for Precambrian palaeontologists.

The labour of transcribing and editing information for input to Foscat is about the same as for any manual data retrieval system, and retrieval and data output are faster and more convenient. The actual cost of a search works out at about £0.20 in Imperial College; even buying computer time at commercial rates it would still only be about £2.00. With the advent of floppy discs and microprocessors these costs will fall drastically over the next few years. The Foscat system could now be accommodated on a floppy disc system as a personal desk-top reference file; expected hardware developments will soon make this a cheap and practicable proposition.

In the light of experience with Foscat it is suggested that other palaeontologists would probably find it well worth their while to apply this kind of data handling system to their own material.

Having made the point that data bases are a fantastically useful, convenient, cheap and time-saving way of handling palaeontological data, some general difficulties remain to be pointed out.

The biggest problem is that of reading and coding papers written in non-English alphabets, especially Russian and Chinese. First of all these publications are usually difficult to get hold of - for example, I have not yet traced Drobkova & Orlova (1966) who described 35 new species of Trachysphaeridium (according to Referativnyi Zhurnal, Geologiya, Ukatazel for 1967, p.744) which ought to have been considered here. Similarly, the

description of the genus and type species of Lignum (Sin, 1962; cited by Sin & Liu, 1973) is in Chinese and in a publication of which I cannot even transliterate the title.

Even when one of these publications can be found it is not practical at present to index it in the same detail as if it was written in English, simply because it would take too long. I have attempted to include the systematic parts of the most important Russian and Chinese papers as well as most of the available translations, but the coverage of Foscat is very patchy, though more comprehensive than other Western sources. If, as some authorities predict, the microprocessor revolution does lead to machines which can read, transliterate and translate these languages into English the problem of comprehension may be resolved.

If the codes of nomenclature continue to permit the publication of new names in obscure journals and unavailable conference proceedings, I see no solution to the problem of availability unless it be through some abstracting service on the lines of Foscat. Bacteriologists have solved this problem, firstly by instituting the Journal of Systematic Bacteriology in which all descriptions of new taxa must be published to be valid, and secondly by adopting a later starting date for nomenclature of Jan. 1 st 1980 (See Buchanan & Gibbons, 1974; Stanier et al, 1978).

The case for the separation of fossil from living taxa has been argued in Chap.5. I believe that it would be of inestimable value to palaeontology if the ideas of a unified code for the nomenclature of all fossils, a statutory organ of publication for fossil nomenclature, and a later starting date for fossil nomenclature were adopted.

To return to Foscat, the long term object of the exercise is to include all published references to Precambrian fossils no matter how obscure or difficult to get hold of. At present the emphasis is on cryptarch nomenclature and Australian Proterozoic geology, with a range of other publications that happened to be available. Given adequate support, this bias will eventually disappear as more source material and general papers are included. The pilot project has certainly shown that such a development would be well worthwhile.

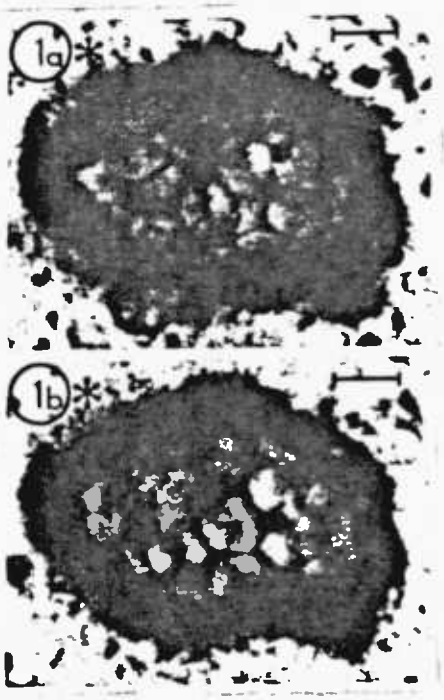
Apart from these general problems there are two specific difficulties with Foscat in its present implementation. The first of these is that the computer cannot distinguish between geological and geographical locality data which means that it cannot compile alphabetical lists of fossiliferous formations or hierarchical tabulations of groups, formations and horizons. The second problem is that the computer cannot easily recognise synonyms because they are input as an integral part of the comment strings. The use of a semi-structured list of synonyms in the form 'Includes 1. Synonym one, 2. Synonym 2, 3. ... etc.' was adopted and should make it possible for the machine to recognise and select this part of the information listing.

In both of these cases, the problem is that of free-format input vs. a rigidly hierarchical data structure. Fossil catalogues rarely provide any new locality information but usually have extensive lists of synonyms. Conversely, when new fossils are reported some papers only mention that fossils were recovered from the 'A' formation near to 'X' while others give detailed localities with several fossiliferous horizons at each. It would be impossible to accommodate these very variable character strings in a conventionally formatted data base without wasting a lot of storage space. Ideally one would also like to be able to plot locality data directly onto base maps to show the distribution of a fossil or biota at a selected scale. This would require some sort of world reference grid and numerically coded locality data for each report. The level of coding - ie all aspects of coding density and the range of scale - would also need to be considered in detail. Also, to be able to search for reports of fossils from a particular map area would require different search programmes, search strategies and fairly sophisticated plotting routines. Such refinements could be developed but were outside the scope of this project and the coding structure adopted. They could be included with other information (Eg. on fossil morphology) in the advanced system projected below.

The way in which Foscat processes character strings is unusual (and possibly unique) in curently available data base systems and has great potential (See Martin, 1975). By using a modified data block structure it has been possible to include the complete text of descriptions of taxa in a data base run in parallel with Foscat. Although it could be used as a data base there is no need

FIGURE 45. TEXT OF A SPECIES DIAGNOSIS RETRIEVED FROM A FOSCAT-TYPE STORAGE SYSTEM

MYXOCOCCOIDES MINOR



TAXON

MYXOCOCCOIDES MINOR SCHOPF 1968.

REFERENCE

SCHOPF J W. 1968. MICROFLORA OF THE BITTER SPRINGS FORMATION, LATE PRECAMBRIAN, CENTRAL AUSTRALIA. JL .PALEONTOLOGY, V. 42, NO. 3, P. 676, TABLE 4-P. 673, PL. 81, F .1A-B.

DIAGNOSIS

CELLS COMMONLY SPHERICAL TO SUBSPHERICAL, OCCASIONALLY ELLIPSOIDAL, FREQUENTLY SOMEWHAT FLATTENED BY COMPRESSION AGAINST ADJACENT CELLS, SOLITARY, OR CLUMPED IN A MORE-OR-LESS ELLIPSOIDAL COLONY COMPOSED OF A FEW TO ABOUT 40 CELLS. SURFACE TEXTURE VARIES FROM PSILATE OR NEARLY PSILATE TO FINELY AND REGULARLY PUNCTATE AND RETICULATE. CELL DIAMETERS VARY BETWEEN ABOUT 8.8 AND 10.5 MU, WITH AN AVERAGE DIAMETER (25 CELLS MEASURED) OF 9.7 MU. CELL WALLS ROBUST, DISTINCT, ABOUT 0.7 MU THICK. CELLS COMMONLY EMBEDDED IN A SOMEWHAT GRANULAR, NON-LAMELLATED ORGANIC MATRIX UP TO 3 MU THICK AT THE PERIPHERY OF THE COLONY. COLONIES VARY IN NUMBER OF COMPONENT CELLS, THE CELLS BEING GEOMETRICALLY UNORDERED IN RELATION TO COLONY SHAPE.

(Illustration is a photocopy).

to interrogate this file at present and the descriptions have been printed out in A4 page format with space for pictures and filed for reference. A page from this file is shown in Figure 45.

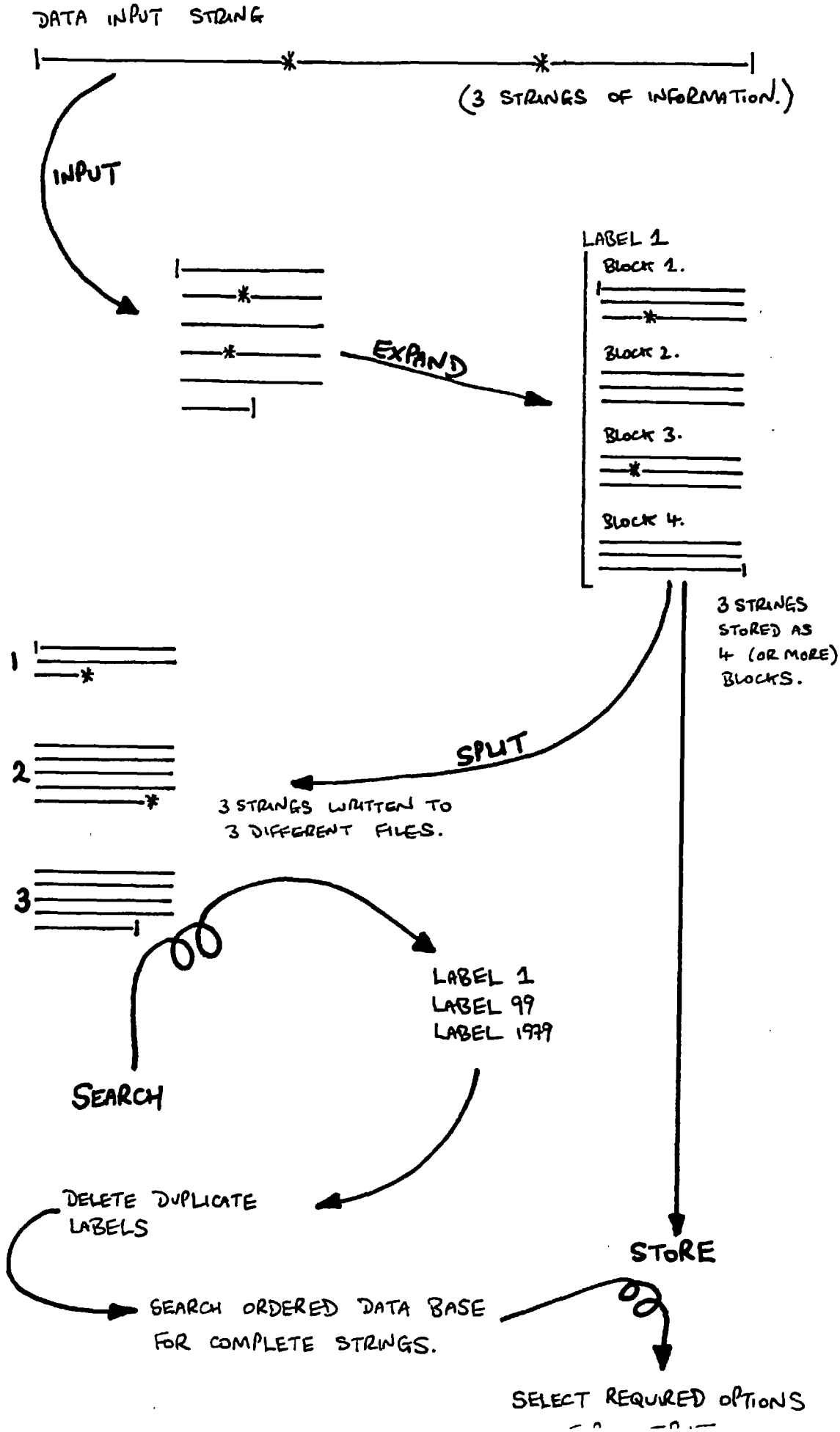
These very long data strings are processed by using the species string as a label and arranging the descriptive text as a series of comment strings that can be resynthesised. The essence of this process is that a data string of any length can be split up into manageable data blocks for searching and computer manipulation, and that selected data blocks can be resynthesised for output.

The logical development of this idea leads to a whole new generation of user-orientated data base systems because practically any number of data strings of any length could be handled. A generalised system to do this has been projected using SORTER as the basic search programme, and may supersede Foscat if developed.

The operation of this system is outlined in Figure 46. The basic steps are as follows:-

1. Data is input as labelled records, each record of 'n' consecutive strings of information (options).
2. The compressed source deck is expanded into a set of 10-card A-T-C blocks. Each block is labelled and numbered in sequence.
3. The expanded source deck is sorted and stored.
4. The expanded source deck is scanned and split into 'n' reference files, each file containing all strings of one option only.
5. The appropriate reference files are searched for keywords and the labels written out.
6. Labels are sorted and duplicate labels deleted.
7. The sorted source file is scanned for the appropriate labels and the complete expanded source deck for each label recovered.
8. Required options are selected from the expanded source blocks and rearranged as labelled and sequentially numbered A-T-C blocks.
9. The blocks are sorted and arranged for output or further processing as required.

FIGURE 46. PROJECTED GENERALISED DATA BASE SYSTEM



This approach is half way between the present implementation of Foscat and a random access memory (RAM) which would require additional computer hardware. The compilation time of the data base would be longer than for Foscat, but searches would be faster and more specific because less information would have to be scanned and only one option would be searched at a time.

The system is more complex than Foscat, but better adapted to big data files and more flexible in the handling and recovery of subsidiary data sets for further processing. This would make it possible to include digitised data sets on fossil morphology and localities, for example, as well as producing a generalised data base system capable of handling almost any kind of information.

Chapter 9

Microfossils from the McMinn Formation

A. General

Geological and geochemical aspects of the preserved organic matter were discussed in Chapter 3 (p.30-37), and techniques for its extraction and observation in Chapter 4 (p.42-60). In vertical thin sections the structured organic matter is only seen as thin streaks (See Pl.7F-G) and recognisable fossils are rare. In horizontal thin sections the fossils are easily seen (See Pl.14J, 18G-H) though often obscured by crystals.

In macerates most of the fossils can be seen to be very thin discs - under the low power binocular microscope used for picking it is impossible to see most of them in end view. When the macerate is gently stirred the fossils flip into sight as they turn over. Vesicles up to 60 microns across have been found preserved in three dimensions in macerates. They were presumably infilled with minerals that were removed by the maceration regime and it is assumed that their walls must have been permeable or broken. Specimens more than about 25 microns across are very brittle and snap if pressed with a mounted needle (See Type 18). Even very thin flat valves (Pl.12) are totally rigid and can be held horizontally by one edge without bending; if squeezed or pressed, they break. Because of this it is unlikely that three dimensionally preserved forms were produced by the inflation of flattened specimens during preparation. It is also very unlikely that any folds were produced during sample preparation.

Even though well preserved material was selected for detailed study, most specimens show surprisingly little damage or visible alteration, especially when compared with other Proterozoic material (Eg. Schopf, 1970; Vidal, 1976). Some filaments have been replaced by pyrite (Pl.31E) and occasional crystals are found within other fossils. Pyrite framboids have not been found. The best preserved assemblages in the McMinn Formation come from a few thin beds of

very fine grained dark siltstone (DDH B7 74'2, DDH M14 150'5, DDH M14 250'8) but patches of finer sediment and unstructured organic material occur in many coarser beds (See Pl.4B). Individual fossils can be well preserved between large grains, and even in fine material between oolites. Macerations concentrate material and avoid wastage, and fossils in a maceration are usually easier to photograph and not obscured. For these reasons most of the Plates show macerated material. Of the fossils described below, only Types 2, 17, 18, 48, 49 and 50 have not been found in thin sections.

In the next section the McMinn Formation microfossils are classified into 55 morphological Types on the basis of the features discussed and evaluated in Chapter 6. Each Type is given a diagnosis, a description and an interpretation, and is compared to similar forms. The fossils are all cryptarchs, and the position of each Type within the Cryptarcha as elaborated in Chapter 7 is given as an abbreviation (Eg. SPH-IX-A).

The diagnosis of each Type is based on features visible in the LM and considered reliable in Chapter 6. This is the basic information on which a fossil form taxon could usefully be defined.

The description of each Type contains other objective information that is not of diagnostic value like colour, or which can only be supplied by SEM or TEM. In this context, colour refers to the appearance of the specimens in the LM as seen by transmitted tungsten light at 5200°K. Some Types (Eg 17 & 18) can only be reliably distinguished by SEM and have essentially identical diagnoses.

The interpretation section deals with the subjective aspects of the Type - what the observed structure represents, and its taxonomic position, assignment and relation to other taxa. The biological affinities of some Types are discussed. Most of the smooth, thin walled sphaeromorph cryptarchs are most likely of algal affinity, though living organisms producing similar structures range from bacteria and cyanobacteria through fungi and protozoa to metazoa and metaphyta. This general ethos (See Downie et al, 1963; Downie, 1973; Diver & Peat, 1979) is not reiterated for each Type.

For most Types a few similar fossils have been listed. Where possible, the type specimens of valid taxa have been given in preference to other material. These names are preceded by a star (*). The interpretation of most relevant taxa is discussed in Table 15 (P.121).

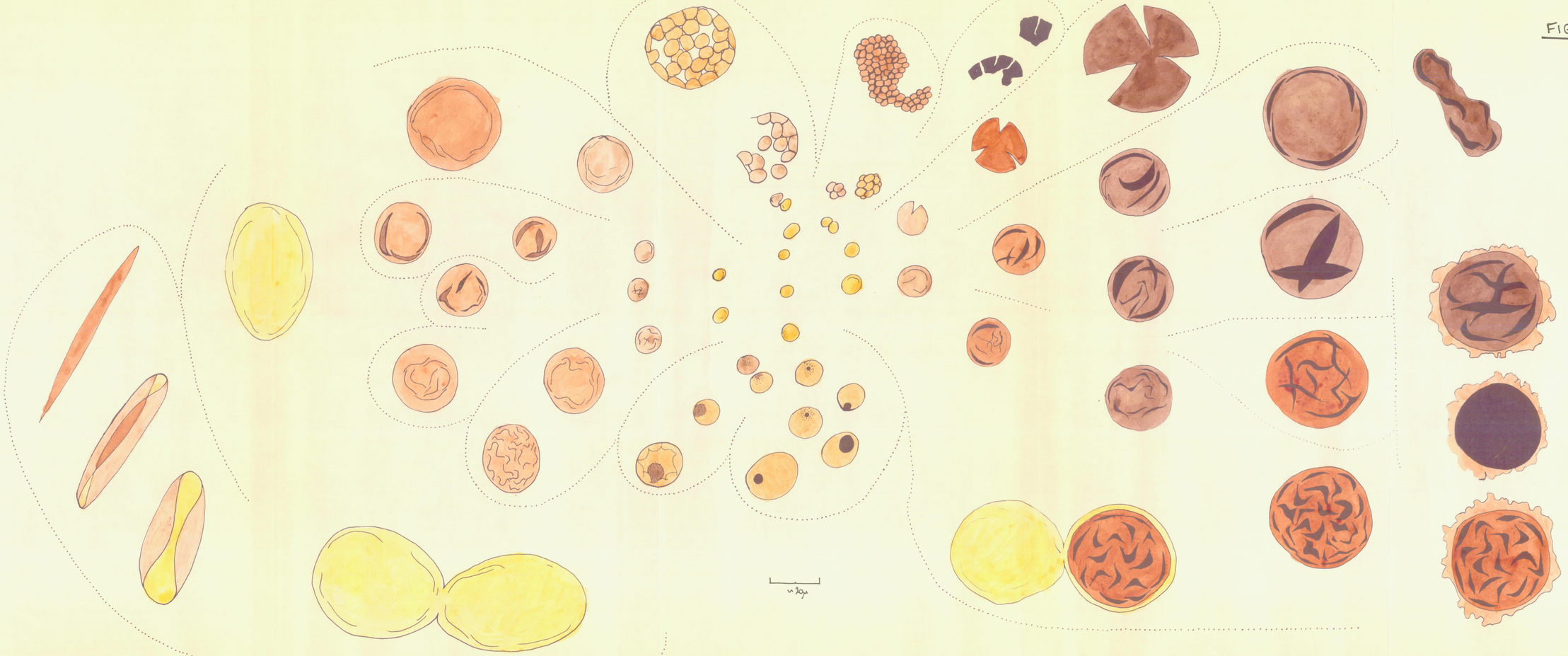
The problems involved in the classification of this kind of material have been discussed in Chapter 6. There is certainly a continuum of structural variation through which arbitrary lines have to be drawn. Some Types from the McMinn Formation microbiota are clearly ontogenetically related. Others are morphologically similar but may not be related at all; within one Type, identical specimens may represent completely different organisms.

Figure 47 attempts to show the range in variation and possible relationships of some of the smooth sphaeromorph cryptarchs. At one extreme most of these fossils could be interpreted as different stages in the life cycle of a single organism; at the other they could be attributed to several hundred different taxa on the basis of minor differences in surface texture, colour and size.

This report is a preliminary one and formal nomenclature has been avoided as far as possible. First, with the advent of Xerox University Microfilms, theses can now be regarded as effectively published under Article 29 of the ICBN. This Article now requires amendment. Under Article 30 of the ICBN the date of effective publication of this thesis will be August 1981, because it will be witheld from circulation for 2 years following acceptance. By that time I hope that some firm retroactive proposals will have been made.

Second, most of the existing and valid cryptarch taxa require immediate and critical study and emendation. As many again are of uncertain validity, and at least twice as many again are invalid beyond redemption and should be dismissed. The problem of invalid names is that when a name is rejected the taxon it represents is often rejected too and valuable information lost. The future development of cryptarch classification and nomenclature will require the construction of detailed synonymies at the specimen level. As a list of specimens the Foscat tabulation is at least one step in the right direction (Appendix 7).

FIGURE 47



B. Classification and affinities

GROUP CRYPTARCHA Diver & Peat 1979

SUBGROUP SPHAEROMORPHITAE Downie et al 1963 emend Diver & Peat 1979

TYPE 1

Plate 8A-J, Figure 48. SPH-VII-F

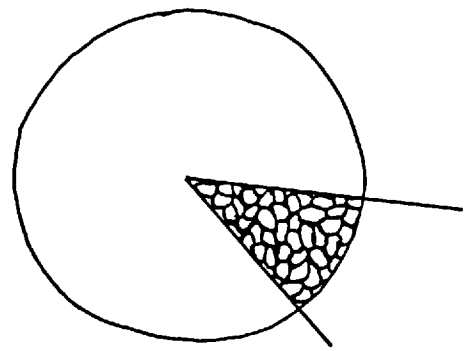


Figure 48. Type 1

Diagnosis

Sphaeromorph cryptarchs with thin walls decorated with a reticulate pattern as shown in the Plate.

Description

These vesicles are usually about 30 microns in diameter and are very dark in colour. Out of the 30 specimens known, 2 show openings (Pl.8C,I) that resemble cyclopyles. The cells of the reticulate decoration are mostly ovate and usually 1-4 microns wide. In distorted specimens (Pl.8F) the reticulation can be stretched in one direction. The ribs of the reticulation are variable in thickness; in poorly preserved specimens (Peat et al, 1978, Fig.3C,D) the ribs can be absent from most of the vesicle wall which then has a granular surface with perforations. SEM has shown that the reticulation of one specimen is not a feature of the outer surface of the vesicle. Two plausible explanations are that the pattern is an elaboration of the inner surface of the vesicle wall, or that the vesicle has a thin membranous cover. The latter suggestion is the most likely since the thickness of the wall at a tear (Pl.8G) could not be resolved in the SEM. Although semi-opaque, one specimen has a darker area within it, suggesting the presence of an inner body (Pl.8H).

Similar fossils

Favososphaeridium favosum, Vidal, 1976, p.19-20, Fig.9.

*F.scandicum Timofeev 1966, p.39, Pl.VIII, Fig.3.

*Huroniospora macroreticulata Barghoorn in Barghoorn & Tyler 1965, p.576, Fig.5 (3).

See also: 'Enigmatic sphaeromorphs' - Vidal, 1976, Fig.23A-H.

Interpretation

These vesicles fall within the generic diagnosis of Favososphaeridium Timofeev 1959, and most closely resemble a specimen attributed to F.scandicum by Timofeev (1966; Pl.LXXIV, Fig.7). The reticulation of this specimen and of the Roper Group specimens is less angular than that of the type specimen of F.scandicum though this could be just because they are smaller (c. 30 microns smaller than 50-60 microns). The reticulation of 2 specimens assigned to F.favosum (Vidal, 1976) is not well preserved. One of these specimens contains a hint of an inner body like that of Pl.8H. The reticulation of Huroniospora macroreticulata is much finer and more irregular than Type 1 and may be an artifact of preservation (See Awramik & Barghoorn, 1977).

The specific biological affinities of these vesicles are not known. The vesicles are unlikely to be the tests of active protozoa because they do not all have openings, and by analogy with living species such decoration is rarely found in active algal cells. The vesicles are also unlikely to be the organic part of agglutinated tests like those of Arcella because the reticulation is not an external feature and too regular. Even with these provisos, Type 1 vesicles could represent almost any extant protistan class.

TYPE 2

Plate 8K-L, Figure 49. SPH-VII-F

Diagnosis

Sphaeromorph cryptarchs with thin walls decorated with a fine reticulate pattern as illustrated.

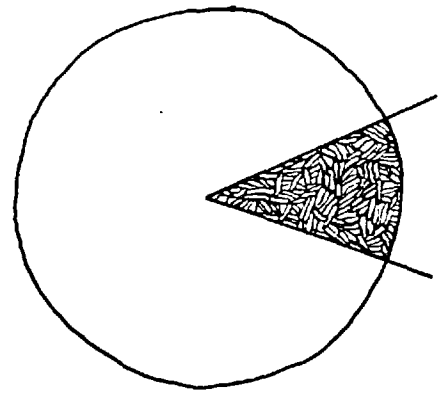


Figure 49. Type 2

Description

Only one specimen of this kind of vesicle has been found, and it is about 60 microns in diameter. The reticulation is very fine and is mostly made up of elongate cells about 1 micron wide and several microns long. Overall, the cells of the reticu reticulation are arranged at random, but because they are elongate they give the impression of being arranged in patches of preferred orientation (Pl.8K).

Similar fossils

*Huroniospora microreticulata Barghoorn in Barghoorn & Tyler 1965, p.576, Fig.5(1).

Interpretation

This pattern of reticulation has not been previously reported in cryptarch genera. Some specimens of Protoleiosphaeridium have been drawn as if they had a finely reticulate surface but this seems to be an artistic rendering of a shagreenate surface (= leathery. See P.acis (Timofeev 1966), P.asaphum (Timofeev 1966)). The reticulation of Huroniospora microreticulata is much finer and less regular, with approximately equidimensional cells.

TYPE 3

Plate 9A-F, Figure 50. SPH-IX-A

Diagnosis

Sphaeromorph cryptarchs with thin walls without folds. The vesicle surface is smooth to finely granular and a few very thin wrinkles may be present.

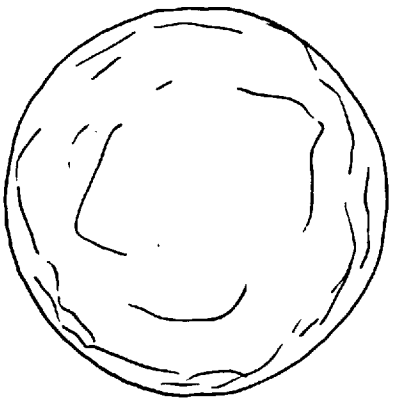


Figure 50. Type 3

Description

These vesicles range between 5 and 50 microns in diameter. The surface texture of the vesicle wall varies from smooth (Pl. 8A) to slightly (Pl.8L) or markedly granulate (Pl.8F). Some specimens show a few fine wrinkles arranged in an angular pattern.

Similar fossils

*Huroniospora psilata Barghoorn in Barghoorn & Tyler, 1965 p.576,fig.5(4).

*Phanerosphaerops capitaneus Schopf & Blacic, 1971, p.951, Table 2, pl.110,figs.14A-D.

*Protoleiosphaeridium acis (Timofeev,1966, p.24, pl.IV, fig.11).

*P.pusillum (Timofeev, 1966, p.23, pl.IV,fig.8).

*P.rigidulum (Timofeev, 1966, p.24, pl.IV, fig.10).

*P.solidum Liu & Sin in Sin & Liu, 1973, p.15,54, pl.VII, fig.4.

*Sinaiicoccus avnimelechi Shimron & Horowitz, 1972, p.340, pl.2,fig.12.

*S.minutus Shimron & Horowitz, 1972, p.340, pl.2,figs.5-6.

*Trachysphaeridium timofeevi Vidal, 1976, p.38, figs.22A-C.

See also Types 29 - 36.

Interpretation

Minor surface features such as the granular textures and wrinkles illustrated here are interpreted as secondary features generated during sedimentation and diagenesis. The small wrinkles look as if they were caused by abrasion against grains in the sediment (Pl.9E), possibly during compaction. Differences

in surface granularity may be original features of the vesicles, but are equally likely to be caused by the crystallisation and lithification of the shale matrix during diagenesis.

Similar vesicles have been described from both stromatolitic chert and shale microbiotas varying in age from Early Proterozoic to Recent. In the absence of other features, size and surface texture are the only characters available for classification. I doubt that these features should really be used to distinguish taxa of generic rank. Type 3 could be attributed to any of the taxa listed above.

If Protoleiosphaeridium and Trachysphaeridium are restricted tc vesicles with folds of type E (Fig.28,p.101), those species listed above would be reassigned to Phanerosphaerops. Sinaiicoccus probably is also a junior heterotypic synonym of Phanerosphaerops. The various species are doubtfully distinguished by size and colour. On this basis Type 3 is attributed to Phanerosphaerops patelliforme (Timofeev).

TYPE 4

Plate 9G - L, Figure 51. SPH-IX-0

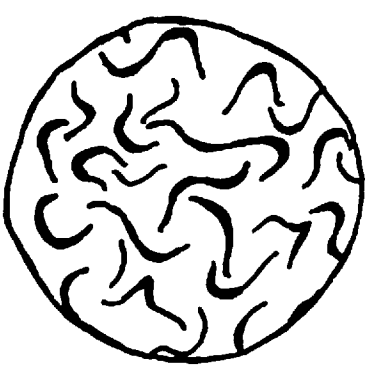


Figure 51. Type 4

Diagnosis

Sphaeromorph cryptarchs with thin walls and a smooth to finely granular or shagreenate surface texture. The vesicle walls have a pattern of short, curved, interdigitating wrinkles, as shown in the illustration.

Description

These vesicles are 15 - 40 microns in diameter and pale orange to orange-brown in colour. The pattern of wrinkles shown in Plate 9I is considered typical, but is part of a continuum of variation from a few longer spaced - out wrinkles (Pl.9G,K)

to a dense, interlocking network of short ones (Pl.9J,L).

Similar fossils

*Podoliella irregulare Timofeev, 1973, p.13, pl.I,fig.5.

P.multangulare - Timofeev, 1959, p.103, pl.X, fig. 16.

Validity uncertain.

*P.vermia (Timofeev, 1969, p.10,pl.I,fig.16).

Protosphaeridium cf P.parvulum - Cloud & Germs, 1971, figs.9,10.

Interpretation

These vesicles are assigned to the genus Podoliella on the basis of the original diagnosis of that taxon and the described type specimen (Timofeev, 1973). Other taxa are here attributed to this genus on the basis of their fold pattern. Type 4 is here synonymised with Protosphaeridium cf P.parvulum Cloud & Germs, and attributed to Podoliella vermia comb.nov.

TYPE 5

Plate 10 A - L, Plate 11 A - H, Figure 52. SPH-IX-0

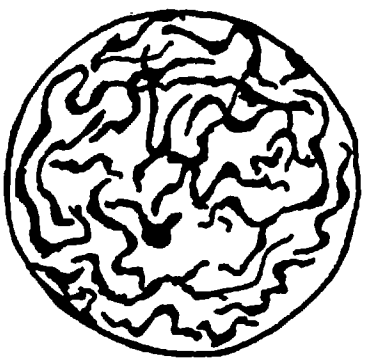


Figure 52. Type 5

Diagnosis

Sphaeromorph cryptarchs with thin walls and a smooth to shagreenate surface texture. The vesicle wall is thrown into numerous medium to wide, interlocking sinuous wrinkles.

Description

These vesicles are 20 - 120 microns in diameter and are usually a dark orange-brown colour. The pattern of long sinuous wrinkles is very distinctive in both the LM (Pl.10A-F) and SEM (Pl.10J-L,11B-D) though it can be difficult to see the wrinkle pattern of dense specimens in the LM. The SEM pictures show that the vesicle surface is not damaged.

Examination of one selected specimen by LM, SEM and TEM

has shown that the total thickness of this vesicle varies between 1.5 and 5.5 microns (Pl.11E,F,H). The TEM micrographs do not show any wall microstructure (Pl.11G,H), nor do they show how the wall was folded or the position of the lumen of the vesicle. A thin line joins the small inclusion shown in Plate 11E,H to the left edge of the section, but does not continue to the right of the inclusion.

Similar fossils

Podoliella serpentinum (Timofeev, 1959, p.102, pl.X, fig.14. validity uncertain).

*P.vesljanica (Timofeev, 1969, p.11-12, pl.II,fig.5).

Protomassulina cozglutinata (Tim) Lop. - Lopukhin, 1966, pl. II, fig.2. validity uncertain.

See also Type 10, Type 28.

Interpretation

The LM, SEM and TEM pictures (Pl.11) do not show any distinctive wall ultrastructure or layering. This could be because the sections were not stained (See Chapter 4) though I would have expected to see some suggestion of ultrastructure if it was there. It is surprising that there is no indication of the lumen of the vesicle.

This vesicle does not appear to have any openings and there is no way of telling whether it was full or empty, spherical or deflated, when deposited. There is no obvious damage to the vesicle surface (Pl.11B-D) so the variation in total wall thickness (Pl.11F) is not likely to be due to the wall material being pushed about by sediment grains or growing crystals. The brittleness of the fossil shows that some chemical alteration has occurred, presumably through the polymerisation and migration of low molecular weight wall components during diagenesis. This process appears to have welded the different wall layers together into a homogeneous structure.

These observations show that the variation in total vesicle thickness is probably due to the superimposition of several layers of the vesicle wall through folding and that these layers were later chemically welded together. The original vesicle wall must therefore have been at least 0.7 microns thick and of unknown, though probably uniform, construction.

Identical vesicles within membranes are described as Type 28. Type 5 is definitely assignable to the genus Podoliella Timofeev 1973, as interpreted here. Although Type 5 is similar to P.serpentinum (Timofeev, 1959) comb.nov. it has more folds which are more sinuous and packed closer together than this species. Type 5 is here regarded as Podoliella sp.nov.

TYPE 6

Plate 12 A - C, Figure 53. SPH-IX-G



Figure 53. Type 6

Diagnosis

Sphaeromorph cryptarchs with thin walls and a smooth outer surface. The wall is thrown into numerous short, thin to medium, sinuous wrinkles. The wrinkles are arranged at random and occur over the whole area of the vesicle as shown in Pl.12A-C.

Description

These vesicles are 20-200 microns in diameter and are almost transparent to very pale yellow in colour with a very fragile appearance. In selected specimens examined by LM and SEM the wall thickness could not be resolved but was certainly less than 0.05 microns.

Similar fossils

*Leiosphaeridia tenuissima Eisenack, 1958, p.391-392, pl.1, fig.2.

Interpretation

Most of these vesicles are probably valves or outer membranes released from vesicles which folded in a similar way (See Types 5 and 28). Single valves such as this cannot always be distinguished from thin but complete flattened vesicles.

TYPE 7

Plate 12 D - F, Figure 54. SPH-IX-H



Figure 54. Type 7

Diagnosis

Sphaeromorph cryptarchs with thin walls and a smooth to shagreenate outer surface. The wall is thrown into numerous long, thin to medium, curved or sinuous folds arranged at random as shown in the illustration.

Description

These vesicles measure about 20-200 microns in diameter and are almost transparent to pale brown in colour. They have a very fragile appearance, and although the thickness of the wall could not be resolved in the SEM it was less than 0.05 microns.

Similar fossils

*Leiosphaeridia tenuissima Eisenack, 1958, p.391-392,pl.1, fig.2.
L.tenuissima - Eisenack, 1958b, pl.2, figs.1-2.

Interpretation

Most of these vesicles are probably single valves or outer membranes. Some of them may have been released from vesicles of Type 28, but most probably originated with Type 27 (See Pl.21 A-B, 20G-L).

TYPE 8

Plate 12 G - I, 18 J - K, Figure 55. SPH-IX-G

Diagnosis

Sphaeromorph cryptarchs with thin walls and a smooth to shagreenate outer surface. The wall has a few straight to curved folds of narrow to medium width arranged at random as illustrated.

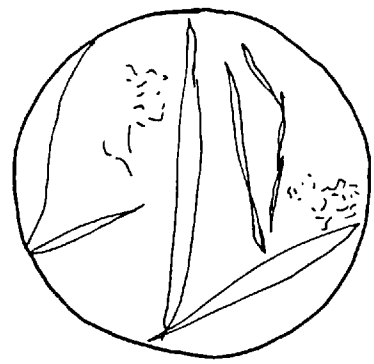


Figure 55. Type 8

Description

The vesicles are about 30-300 microns in diameter, sometimes larger. Some of the largest sphaeromorphs found in the McMinn Formation are of this type (Pl.18J-K) and are up to 600 microns in diameter. They are almost translucent to pale yellow brown in colour with a fragile appearance. The thickness of the wall in three specimens in the 50-80 micron size range could not be resolved in the SEM, and was less than 0.05 microns thick.

Interpretation

Most of these vesicles are probably valves or outer membranes released from other double layered vesicles which fold in a similar way (Type 27, eg). The existence of 600 micron diameter membranes of this type suggests that equally large, thicker walled sphaeromorphs remain to be discovered.

TYPE 9

Plate 12 J - L, Figure 56. SPH-IX-M

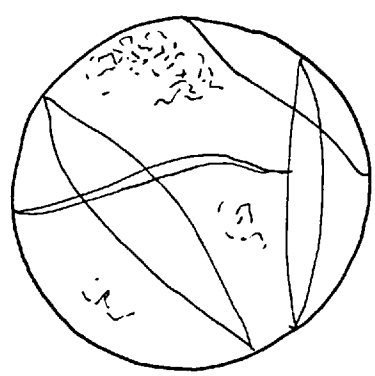


Figure 56. Type 9

Diagnosis

Sphaeromorph cryptarchs with thin walls and a smooth outer surface, often with a pattern of very fine wrinkles. The wall has a few straight to curved, medium or wide folds arranged at random.

Description

These vesicles range from 30 to more than 200 microns in diameter. They are very pale brown in colour and have a fragile appearance. The thickness of the wall could not be resolved in the SEM and is less than 0.05 microns.

Similar fossils

cf. Leiosphaeridia sp - Stockmans & Williere, 1963, pl.III, fig.29.
Indetermine - Stockmans & Williere, 1963, pl.III, fig.30.
*Leiosphaeridia laevigata Stockmans & Williere, 1963, p.474, pl.III, fig.28.
*L.ochroleuca Timofeev, 1966, p.35, pl.VI, fig.3.
Trachypsophosphaera simplex Lop - Lopukhin, 1966, pl.I, fig.1. validity uncertain.

See also Type 16.

Interpretation (Types 9 & 16)

Most of these vesicles are probably single valves or outer membranes released from other vesicles (See Types 10, 27). Some very similar valves have a tendency to become folded in a linear pattern; it is not known whether this folding is controlled by the membrane structure, its source, or the conditions of deposition.

Neither of the taxa listed above belong to Leiosphaeridia as the genus is interpreted here (Table 15, p.128). In the McMinn Formation assemblage, Type 9 is only distinguished from Type 16 by its apparent fragility - not the most reliable of criteria. L.ochroleuca could usefully be regarded as a junior subjective synonym of L.laevigata, and the combined taxon assigned to a new genus. Types 9 and 16 would be attributable to the new genus, Type 16 to 'L'.laevigata and Type 9 to 'L.'laevigata forma tenuissima or a new species.

TYPE 10

Plate 13 A - G, Figure 57. SPH-IX-C or G

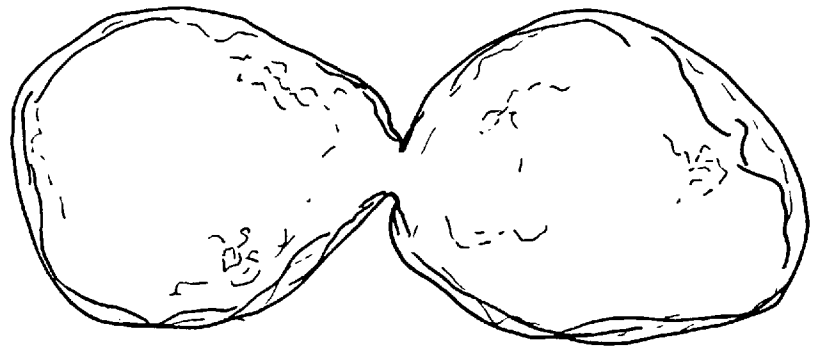


Figure 57. Type 10

Diagnosis

Thin walled sphaeromorph cryptarchs opening by a median split into two equal halves joined by a narrow hinge. The surface of the vesicle is smooth to granular, sometimes with faint linear wrinkles. The wall may have wrinkles and thin folds.

Description

These vesicles are 20 to more than 100 microns in diameter. They are almost transparent to very pale brown in colour and have a very fragile appearance. The thickness of the wall could not be resolved in the SEM, but is less than 0.05 microns.

Similar fossils

*Rugidinium undulatum Pocock & Sarjeant, 1972, p.351, pl.1,figs.6-9.

*Thuledinium groenlandicum Pocock & Sarjeant, 1972, p.352-353, pl. 2, figs.1-9.

See also Timofeev & German, 1974, pl.1, figs.7-9, pl.2, fig.1, pl.3, figs.1-8, where similar fossils are interpreted as dividing cells.

See also Types 5, 11, 12, 28.

Interpretation

These vesicles are interpreted as an intermediate stage between sphaeromorphs within membranes (Types 25-28) and single valves (Types 6-9, 11-12). The single valves of most pairs would be assigned to Types 8 or 9; pairs of Type 6 have not been found. This may reflect a real difference in behaviour between

species in the original living biota or merely a difference in the stage of development at which fossilisation occurred.

TYPE 11

Plate 13 H - I, Figure 58. SPH-IX-L



Figure 58. Type 11

Diagnosis

Sphaeromorph cryptarchs with thin walls and a smooth to granulate or shagreenate surface texture. They have numerous thin to medium folds arranged in a linear pattern, or are rolled up so as to be fusiform in shape.

Description

These vesicles range from about 3 x 15 to 15 x 120 microns. Unfolded areas are very pale brown in colour, but when tightly rolled they can be very dark orange-brown.

Similar fossils

'Eingerollte Leiosphäre' - Eisenack, 1958, pl.1, fig.9, 10-13.

*Lancettopsis lanceolata Madler, 1963, p.353, pl.28, figs.4-8, pl.29, figs.1-3.

Leiosphaeridia sp. - Eisenack, 1958, Taf.1, figs.7-8.

*Podolina angulata Hermann in Timofeev et al, 1976, p.56, pl. XXIII, fig.4.

*P.minuta Hermann in Timofeev et al, 1976, p.57, pl.XXIV, fig.7.

'Spindelformig zusammengerollte Leiosphären' - Eisenack, 1958, pl.2,figs.11-13.

See also Types 10, 12.

Interpretation

Vesicles of Types 11 and 12 are clearly tightly rolled and folded valves related to Type 10 and similar fossils. They could easily be mistaken for poorly preserved leiofusid acritarchs. Remains of this type were recognised by Eisenack (1958a,b) who called them "Zusammengerollte Leiosphären".

Podolina is here regarded as a junior subjective synonym of Lancettopsis. Until detailed comparisons can be made the various species are kept separate. Type 11 is best referred to as Lancettopsis minuta (Herman in Tim.et.al, 1976).

TYPE 12

Plate 14 A - E, Figure 59. SPH-IX-L

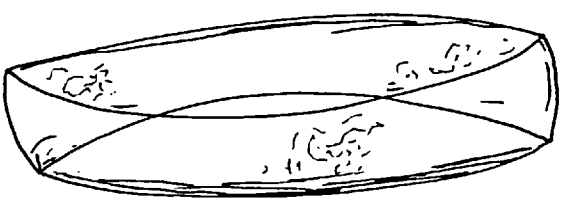


Figure 59. Type 12

Diagnosis

Thin walled sphaeromorph cryptarchs with a smooth to granular or shagreenate surface texture. The wall is folded into a few medium to wide folds, arranged in a linear pattern.

Description

These vesicles range from about 10 x 100 to 40 x 200 microns. Single layers of the wall are a pale yellow-brown colour but multiple layers at folds can be quite dark brown.

Similar fossils

*Lancettopsis lanceolata Madler, 1963, p.353, pl.28, figs.4-8, pl.29, figs.1-3.

*Macroptycha biplicata Timofeev in Timofeev et al, 1976, p.35, pl.XI, fig.10.

*M.multiplicata Timofeev in Timofeev et al, 1976, p.36, pl.XI, fig.12.

*M.triplicata Timofeev in Timofeev et al, 1976, p.35, pl.XI, fig.11.

See also Types 10, 11.

Interpretation

Macroptycha could probably be regarded as a junior subjective synonym of Lancettopsis, but is here maintained as a separate genus pending further studies. The specimens illustrated here are all referrable to M.biplicata. For other comment see Type 11.

TYPE 13

Plate 14 F - K, Figure 60. SPH-IX-D

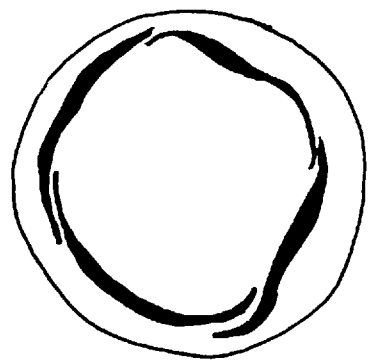


Figure 60. Type 13

Diagnosis

Thin walled sphaeromorph cryptarchs with a smooth to granulate or shagreenate surface texture. They have few to several, medium curved folds, arranged around the edge of the vesicle, but rarely at the margin.

Description

These vesicles are usually 5-60 microns in diameter and orange-yellow to orange-brown in colour with a stout appearance. They are usually solitary, but sometimes occur in clusters of up to about a hundred individuals.

Similar fossils

*Kildinella magna Timofeev, 1969, p.14, pl.VI, fig.5.
*K.nordia Timofeev, 1969, p.12, pl.II, fig.7.
*K.rifeica Timofeev, 1969, p.13, pl.II, fig.9.
K.cf. sinica - Vidal, 1976, fig.10a.

Interpretation

These vesicles are definitely assignable to the genus Kildinella Timofeev in Timofeev & Shepeleva 1963 ex Timofeev 1966 and probably to the species K.nordia. Among other species the

fold pattern is most like that of K.magna which is unfortunately much larger (500-2000 microns in diameter). K.rifeica resembles K.nordia but has a superficial pattern of wrinkles.

TYPE 14

Plate 15 A - C, Figure 61. SPH-IX-C

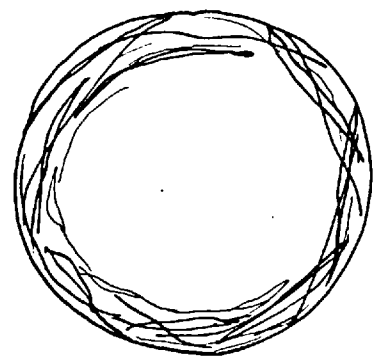


Figure 61. Type 14

Diagnosis

Thin walled sphaeromorph cryptarchs with a smooth to granular surface texture. The vesicle walls have many curved thin folds and wrinkles at their margins but not in the central zones.

Description

These vesicles are 10-80 microns in diameter. They are usually pale brown in colour, but occasionally darker and have a fragile appearance.

Similar fossils

Beltanelloides sorichevae - Sokolov, 1976, p.138-fig.a.

B.sorichevae minor - Sokolov, 1972, p.53 - lower fig.

Chuaria circularis - Ford & Breed, 1973, pl.61,figs.1,6,7, pl. 62, figs.1,2,4.

*Leiosphaeridia wenlockia Downie, 1959, p.65, pl.12,fig.2.

*Pseudozonosphaera verrucosa Sin & Liu, 1973, p.56,19, pl.II,f.6.

See also Type 25.

Interpretation

These vesicles are definitely referable to the genus Pseudozonosphaera. On the basis of the original description and a poor illustration they could probably be referred to

P.verrucosa. Leiosphaeridia wenlockia has very few narrow marginal folds. The similarity of the fold pattern of some very large specimens referred to Beltanelloides and Chuaria is very interesting.

TYPE 15

Plate 15 D - F, Figure 62. SPH-IX-H

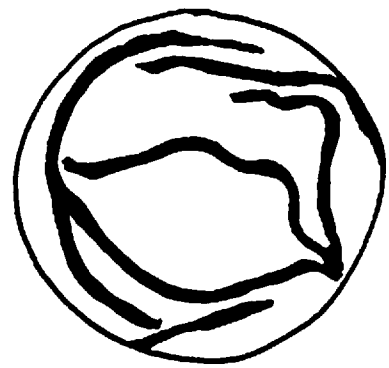


Figure 62. Type 15

Diagnosis

Thin walled sphaeromorph cryptarchs with few to many sinuous folds of medium width arranged at random. The surface texture of the vesicle varies from smooth to granular or shagreenate.

Description

These vesicles are 20-150 or more microns in diameter, and are usually ovoidal to circular in outline. They are usually very dark brown in colour, of robust appearance, and too dense to see well in the LM. The SEM reveals a very distinctive pattern of plump meandering folds. The wall structure and thickness have not yet been studied.

Similar fossils

Kildinella sinica - Timofeev, 1966, pl.XLIV, fig.7.

*Leiopsophosphaera microrugosa Naumova, 1960, p.112, pl.3, fig.7.

L.simplicissima - Naumova, 1960, pl.3, fig.8.

See also Type 27.

Interpretation

Vesicles of Type 15 are tentatively assigned to L.microrugosa on the basis of their fold pattern, though they appear to be much denser and may be thicker. Some specimens that Timofeev

(1966) assigns to Kildinella sinica may be better assigned here too. L.simplicissima has relatively more and broader folds than L.microrugosa.

TYPE 16

Plate 15 G - L, Figure 63. SPH-IX-M

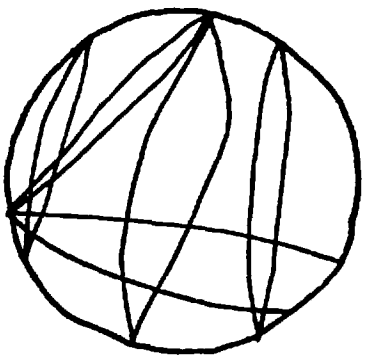


Figure 63. Type 16

Diagnosis

Thin walled sphaeromorph cryptarchs with a smooth to granular or shagreenate surface texture. The wall has a few to several medium to wide, mostly straight folds, arranged at random.

Description

These vesicles are usually somewhat egg-shaped with an angular outline and about 40-200 microns in diameter. SEM examination of one accidentally split specimen revealed that the wall was less than 0.25 microns thick and probably similar to that of Type 17.

Similar fossils

*Leiosphaeridia laevigata Stockmans & Williere, 1963, p.474, pl.3, fig.28.

*L.ochroleuca Timofeev, 1966, p.35, pl.VI, fig.3.

Interpretation

See Type 9.

TYPE 17

Plate 16 A - F, Figure 64. SPH-IX-J

Diagnosis

Sphaeromorph cryptarchs with two thin walls, the outer transparent and membranous, the inner much denser. The surface of the vesicle is smooth to granular or shagreenate. The walls

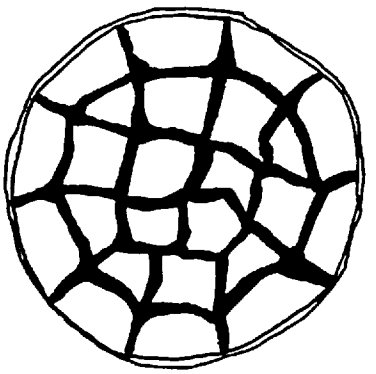


Figure 64. Type 17

are thrown into thick wrinkles which form a polygonal network.

Description, Similar fossils & Interpretation

See Type 18.

TYPE 18

Plate 16 G - L, Figure 65. SPH-IX-J

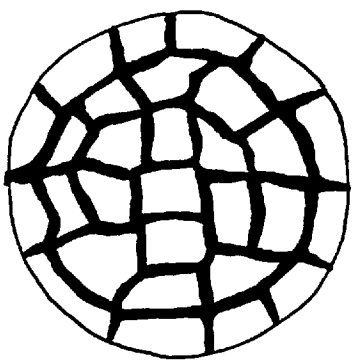


Figure 65. Type 18

Diagnosis

Sphaeromorph cryptarchs with a thin wall and a smooth to granular or shagreenate surface texture. The vesicle wall is thrown into thick wrinkles which form a polygonal network.

Description (Types 17 & 18)

These vesicles are 40-60 microns in diameter. In some specimens the edge of the vesicle has a distinctive pattern of translucent scallops with dark ribs between them, but most specimens are so dense that they cannot be identified by LM. 5 specimens have been examined by LM and SEM, and these show that vesicles of Type 17 have a thin outer membrane (Pl.16A-C,F), while those of Type 18 do not (Pl.16G-L). The presence of an

outer membrane seems to accentuate the polygonal wrinkle pattern. Further work will show whether this feature can be used to distinguish the two types in the SEM without having to deliberately damage every specimen. A fractured specimen is shown in Plate 16 G-L; the wall here is about 1 micron thick and much more substantial than the membrane shown in Plate 16F. When seen in section and side view, the folds of Type 19 (Pl.16 I,J,L) are only about 0.5 microns thick. This is discussed below. This specimen was broken by pressing it with a mounted needle in a droplet of deionised water. Without the water the fragments would have flipped off and been lost, but this has left a slight deposit on some of the fractured surfaces.

The inner wall of Type 17 is similar to that of Type 18; neither Type has yet been examined by TEM. Plate 16 shows that although the vesicle wall of Type 18 is apparently homogeneous throughout its thickness (Pl.16I,J,L), there is a plane of weakness in it where the two halves would be expected to join (Pl.16K).

Similar fossils (Types 17 & 18)

*Archaeofavosina simplex Naumova, 1960, p.113, pl.3, fig.11.

*Cymatiosphaera ovillensis Cramer & Diez, 1972, p.44, pl.2, figs.4,7,10.

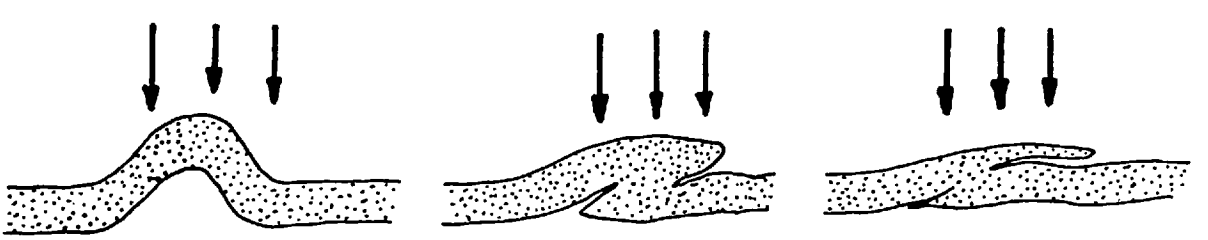
C ? sp - Eisenack, 1965, Taf.24, fig.3a-b.

*Pteinosphaeridium reticulatum Vidal, 1976, p.27-28, fig.14A-E. Spelling error for Peteinosphaeridium.

Interpretation (Types 17 & 18)

The relative thinness of the folds shown along the fracture in Type 18 (Pl.16I,K,L) suggests that they could have been protrusions from the vesicle wall rather than folds involving the whole thickness of the wall. On present evidence it is impossible to tell whether the thin folds were produced during compaction and diagenesis. Those illustrated in Plate 16 could be the thin edges of wrinkles at the start of a fold, generated as sketched below (Fig.66).

Figure 66. Types 17 & 18. Possible origin for thin folds



On the other hand, if the thin protrusions were genuine alae it would make it easier to explain the regularity of the 'folds' and their enhancement in Type 17 by the outer membrane wrapping over the alae and making them stand up more.

Further work is necessary here, if only because acritarchs with alae have not been reported from sediments older than Cambrian. If attributed to the Acritarcha these vesicles could probably be assigned to Cymatiosphaera Wetzel 1933 emend Deflandre 1954 Some fossils of this genus resemble living prasinophycean algae (Downie, 1973).

TYPE 19

Plate 17 A - C, Figure 67. SPH-IX-D

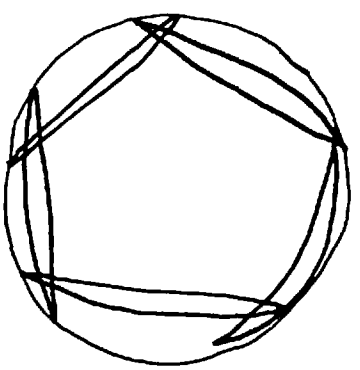


Figure 67. Type 19

Diagnosis

Thin walled sphaeromorph cryptarchs with a smooth to granulate or shagreenate surface texture. The vesicle wall has several to many, straight to curved folds of medium width arranged like the chords of a circle but rarely crossing the central zone of the vesicle.

Description

These vesicles are usually 15-250 microns in diameter and translucent and brown in colour.

Similar fossils

*Kildinella hyperboreica Timofeev in Timofeev & Shepeleva 1963, p.1158, pl.1, fig.11 ex Timofeev, 1966. See Table 15 (p.127) for comment.

Interpretation

These vesicles are definitely assignable to Kildinella and are almost identical to the type species - K.hyperboreica.

TYPE 20

Plate 17 D - F, Figure 68. SPH-IX-D

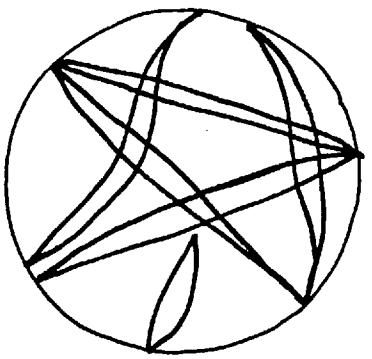


Figure 68. Type 20

Diagnosis

Thin walled sphaeromorph cryptarchs with a smooth to granulate or shagreenate surface texture. The vesicle has several to many, straight to curved folds of medium width arranged at random across it.

Description

These vesicles range from about 15 to more than 200 microns in diameter. They are usually translucent and golden-brown in colour.

Similar fossils

*Kildinella sinica Timofeev, 1966, p.30, pl.V, fig.4.
Trachyoligotriletum alutaceum Timofeev, 1959, pl.X, fig.7.
T.hyalinum - Timofeev, 1959, pl.X, fig.5, pl.XIX, fig.12.
T.perlucidum - Timofeev, 1959, pl.X, fig.6.

Interpretation

These vesicles are not referable to any of the taxa listed in Table 15. They do grade into Type 19, but lack the Kildinellid pattern of mainly marginal, straight to curved folds. On the basis of the illustrated type specimen the attribution of K.sinica to Kildinella is doubtful.

Vesicles with a very similar fold pattern have been illustrated as various species of Trachyoligotriletum. At least some of the trilete marks on these specimens are imaginary (J W Schopf

examined some Riphean and Vendian specimens, pers. comm. 1975). Trachyoligotriletum is apparently invalid (no type species) and an orthographic error for Trachyoligotriletes (Timofeev, 1958). In turn, Trachyoligotriletes seems to be invalid (no type species), and is apparently a junior objective synonym of Trachytriletes (Naumova, 1949). Trachytriletes is invalid as far as its original description is concerned (no type species) but I have not yet checked later references to it .....

In view of this appalling confusion, no reasonable suggestions of affinity or possible name can be made without a great deal of further work. It would probably be more useful to define a new genus based on Type 20.

TYPE 21

Plate 17 G - H, Figure 69. SPH-IX-L

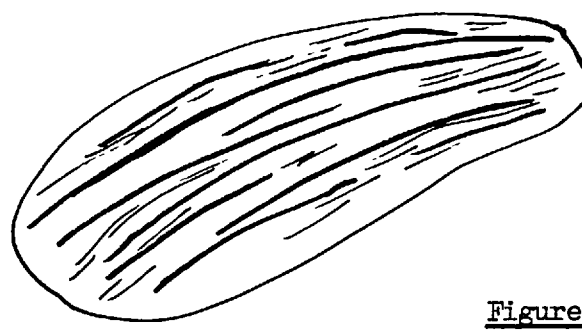


Figure 69. Type 21

Diagnosis

Thin walled sphaeromorph cryptarchs with many straight or slightly curved wrinkles or folds of narrow to medium width arranged in a linear pattern parallel to the longer axis of the vesicle. The surface texture of the vesicle varies from smooth to coarsely granulate or coarsely shagreenate.

Description

These vesicles are rare, with known specimens ranging from 100 x 65 to 600 x 260 microns. They are always dark brown in colour and often corroded or torn. The folds are always very thin relative to the width of the vesicle but can be 20 microns wide in large specimens.

Similar forms are not known, and Type 21 probably represents a new taxon.

TYPE 22

Plate 17 I - K, Figure 70. SPH-IX-?E

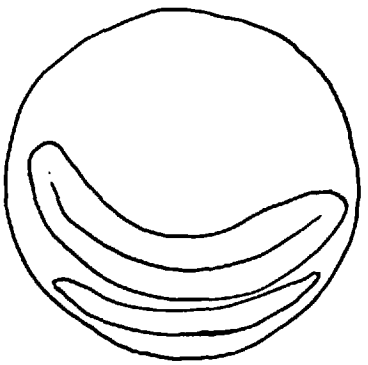


Figure 70. Type 22

Diagnosis

Thin walled sphaeromorph cryptarchs with a few thick, long, curved wrinkles arranged as shown in Plate 17I-K. The surface of the vesicles varies from smooth to granulate or shagreenate.

Description

These vesicles are about 12-45 microns in diameter, and are always pale yellow or brownish in colour.

Interpretation

These vesicles were initially thought to be contaminants because of their pale colour and because the wrinkles of the first specimen encountered resembled a monolete sulcus (Pl.17K). They are rare, but several examples have now been found in both macerates and thin section. Because of their angularity (Pl.17J,K) the wrinkles are thought to have been caused by grains of sediment pushing into the vesicles.

TYPE 23

Plate 18 A - F, Figure 71. SPH-IX-E

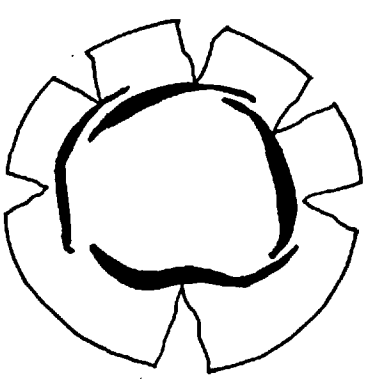


Figure 71. Type 23

Diagnosis

Thin walled sphaeromorph cryptarchs, often with surface wrinkles or short, thin folds. The vesicle is split into segments and has a lobed appearance.

Description

The diameter of these vesicles is about 40-80 microns. They often have a circular fold pattern, and splits commonly run from the edge of the vesicle in to the folded zone (Pl.18D). The vesicle colour varies from yellow-brown to dark orange-brown.

Similar fossils

*Turuchanica ternata Timofeev, 1966, p.45, pl.IX, fig.8.

Interpretation

The splits in these vesicles are secondary features and probably the result of compaction in the sediment. Most of the McMinn Formation vesicles are folded rather than split, which suggests that split vesicles were just more brittle than the others. This brittleness was probably due to the impregnation of the material before final sedimentation rather than to any original structural properties of the vesicle walls. Of course, different wall structures could be expected to be more or less liable to impregnation by humic substances and not all brittle vesicles have been split (Pl.18G-I).

This Type is distinguished here because of uncertainty as to the interpretation of genera like Turuchanica. Split forms may eventually provide useful palaeoenvironmental information, though this is no reason for according them generic status.

TYPE 24

Plate 19 A - H, Figure 72. NEM-XI

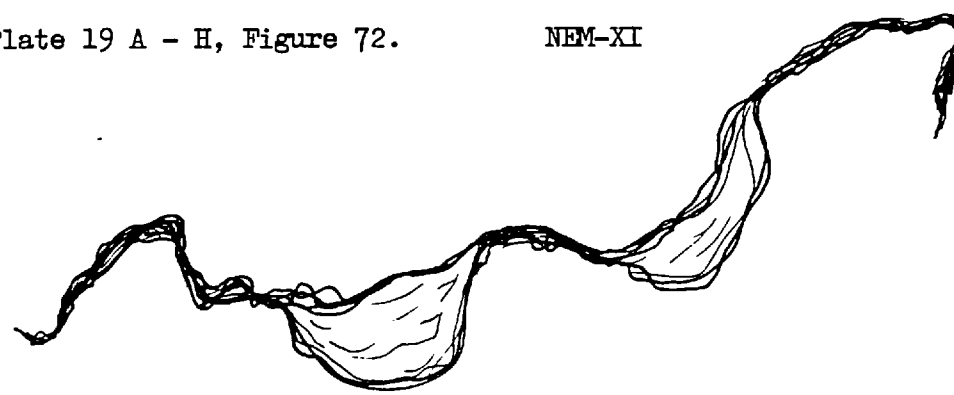


Figure 72. Type 24

Diagnosis

Fibrillar filaments and fibrillar membranes, often highly contorted, rarely branching.

Description

These fossil fragments vary from long thin filaments which sometimes expand into longitudinally striated membranous fronds to large frond-like sheets of organic material.

Similar fossils

Coalesced algal trichome - Oehler, 1977, Fig.14K.

Microtaenia sp- Lopuchin, 1975, p.52,55, Figs. 1C,D, 3E.

See also: 'Phycomycetes' - Timofeev, 1970, p.79-80, pl.I,figs. 1, 3, 5 - 8.

Baltisphaeridium unilateralis - Pykhova, 1973, p.128, figs. 1, 9.

Interpretation

These remains were originally misinterpreted as the remnants of bacterial or algal colonies embedded in mucilage and called 'fronds' (Peat, 1975). They are now interpreted as products of the decay of large sphaeromorph cryptarchs, possibly by bacteria. The sequence Pl.19A - B - D - F shows how these pseudofilaments originate. It seems that folded sphaeromorphs are partially oxidised (chemically or biologically) so that their walls are dissolved but the thicker folds remain as pseudofilaments. Similar threads have been called Microtaenia by Lopuchin (1975, 1976). This validity of this name is uncertain, but it is anyway a junior homonym of Microtaenia Knowlton 1918. Judging by the length of some pseudofilaments seen in thin sections, there are millimetre-sized sphaeromorphs still to be discovered in the McMinn Formation.

Sphaeromorph cryptarchs often become rolled up in these organic sheets and the resulting composite fossils (Pl.19H) then resemble the 'Phycomycetes' described by Timofeev (1970). The interpretation of these 'Phycomycetes' is uncertain - their outer walls and stalks are of irregular width, lack distinct walls and show longitudinal striations like pseudofilaments. On the other hand, the vesicles are at the end of the stalks and not wrapped up like sweets. For comparison, see the specimen of Bacisphaeridium illustrated by Downie (1973, pl.26, fig.7) and

the water moulds described by Howard et al (1970).

TYPE 25

Plate 20 A - C, Figure 73. SPH-VIII-A (Inner vesicle = SPH-IX-C)

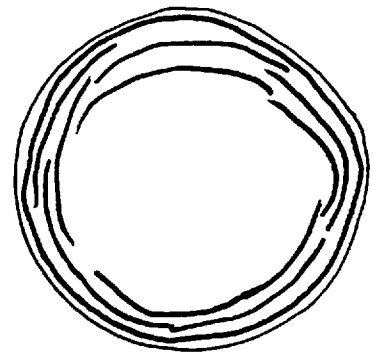


Figure 73. Type 25

Diagnosis

Double walled sphaeromorph cryptarchs with a smooth to granular or shagreenate surface texture. Both walls are thin and the inner vesicle has numerous thin curved folds around its margin as shown in Plate 20A.

Description

The diameter of these vesicles is 40-120 microns. The outer sheath lies very close to the inner vesicle and can only be seen at the edge of the fossil by LM. In the SEM the sheath can only be distinguished in torn or broken specimens.

Similar fossils

Chlamydosphaeridia Eisenack, 1971, p.353.
Divietipellis Wicander, 1974, p.19.
Pterospermopsimorpha Timofeev, 1966, p.33.

See also Type 14.

Interpretation

The inner vesicle bears some resemblance to Type 14, and could be compared with Pseudozonosphaera Sin & Liu, 1973. The complete fossil does not resemble any previously described specimen.

The three genera listed above are all double-layered vesicles in which the diameter of the inner vesicle is more than $\frac{2}{3}$ that of the outer. On the basis of the described type material

they could usefully be restricted as follows - Chlamydosphaeridia to double vesicles with only the outer layer folded, Divietipellis to double vesicles with only the inner layer folded, and Pterospermopsimorpha to vesicles with neither layer folded.

On this basis, Type 25 could be assigned to a new species of Divietipellis.

TYPE 26

Plate 20 D - F, Figure 74. SPH-VIII-A (Inner vesicle = SPH-IX-H)

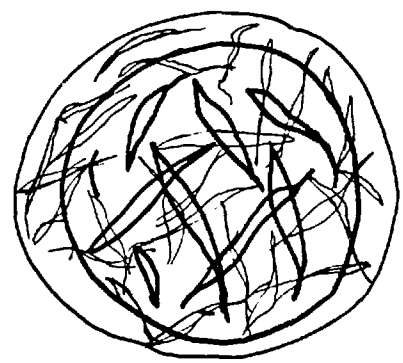


Figure 74. Type 26

Diagnosis

Double walled sphaeromorph cryptarchs consisting of an outer translucent membrane within which lies a thin walled vesicle with thin to medium criss-crossing folds arranged at random.

Description

These vesicles are 50-120 microns in diameter. The outer membrane often overhangs the inner vesicle by as much as 10 microns, forming a translucent marginal flange when seen in the LM. SEM shows the outline of the inner vesicle within the membrane (Pl.20E). SEM also shows that the outer membrane has its own pattern of folds and wrinkles and does not closely follow the fold pattern of the inner vesicle.

Similar fossils

Chlamydosphaeridia Eisenack, 1971, p.353.
Divietipellis Wicander, 1974, p.19.
Pterospermopsimorpha Timofeev, 1966, p.33.

Interpretation

This fossil does not resemble any previously described material. Following the discussion under Type 25 of the three

genera listed above, Type 26 could be referred to a new genus.

TYPE 27

Plate 20 G - L, Figure 75. SPH-VIII-A (Inner vesicle = SPH-IX-H).

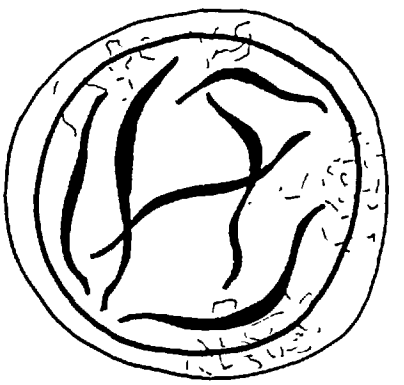


Figure 75. Type 27

Diagnosis

Double walled sphaeromorph cryptarchs consisting of an outer translucent membrane within which is a thin walled vesicle with several sinuous folds of narrow to medium width arranged at random.

Description

These vesicles are 40-120 microns in diameter; the outer membrane often overlaps the inner vesicle with a flange up to 20 microns wide. The outer membrane is always translucent and yellow-brown or paler in colour. The inner vesicle may be opaque but is usually dark and reddish-brown. SEM shows that the outer membrane closely follows the folds of the inner vesicle, sometimes with small additional wrinkles (Pl.20K, right side of vesicle).

Similar fossils

*Divietipellis robusta Wicander, 1974, p.19-20, pl.8, fig.3.

Interpretation

Type 27 is definitely attributable to the genus Divietipellis, but represents a new species. The inner vesicle of Type 27 resembles Type 15.

TYPE 28

Plate 21 A - E, Figure 76. SPH-VIII-A (Inner vesicle = SPH-IX-0)



Figure 76. Type 28

Diagnosis

Thin walled sphaeromorph cryptarchs within a thin membrane. The surface texture of the inner vesicle is smooth to granular or shagreenate and its wall is thrown into many interdigitating sinuous folds, narrow to medium in width, arranged at random.

Description

The total diameter of these vesicles is 30-90 microns; the outer membrane is closely attached to the inner vesicle and rarely overlaps it by more than 8 microns. The outer membrane is translucent and yellow-brown or paler in colour. The inner vesicle may be opaque but is usually dark reddish-brown in colour. These fossils have not yet been studied by SEM.

Similar fossils

*Divietipellis robusta Wicander, 1974, p.19-20, pl.8,f.3.

See also Types 5, 10 - 12.

Interpretation

Similar vesicles have not been reported. Following the discussion under Type 26, Type 28 is referred to Divietipellis as a new species.

TYPE 29

Plate 21 F - K, Figure 77. SPH-VIII-D (Outer vesicle = SPH-IX-C)

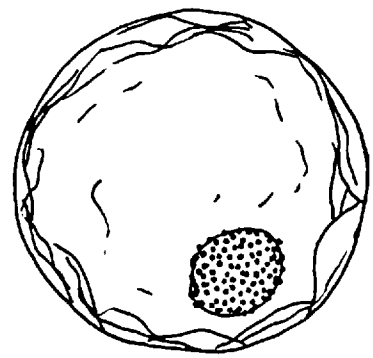


Figure 77. Type 29

Diagnosis

Thin walled sphaeromorph cryptarchs containing one relatively small rounded translucent granular body. The outer wall of the vesicle has a smooth to granular or shagreenate surface texture and is arranged in numerous wrinkles and short, thin folds around its margin.

Description

These vesicles are 15-40 microns in diameter, and the inner bodies are 3-10 microns across. The outer wall of the vesicle is usually translucent and pale yellow-brown in colour, reddish-brown to brown where folded. The inner bodies are coarsely granular and dark reddish-brown in colour. The granularity of the inner bodies is apparently a surface feature of an inner vesicle.

Similar fossils

*Archaeodiscina granulata Naumova, 1960, p.115, pl.3, fig.14.
*Kildinella miroedichia Timofeev 1969, p.13, pl.II, fig.10.

Interpretation

See Type 35 for general discussion.

Type 29 most resembles K.miroedichia (here excluded from Kildinella) and could be referred to as Archaeodiscina miroedichia (Timofeev 1969) comb.nov.

TYPE 30

Plate 22 A - C, Figure 78. SPH-VIII-B

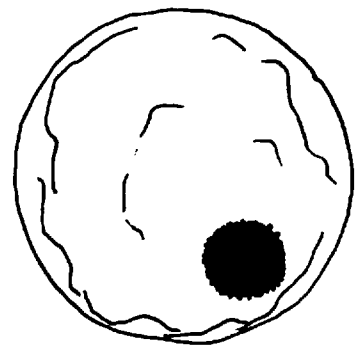


Figure 78. Type 30

Diagnosis

Thin walled sphaeromorph cryptarchs containing one relatively small, rounded, opaque inner body. The surface of the vesicle wall is smooth to shagreenate or granular, usually with a few very fine wrinkles. The inner body has a rough outline.

Description

These vesicles are about 10-60 microns in diameter with inner bodies 5-15 microns across. The outer wall of the vesicle is usually translucent and pale yellow-brown in colour. The inner bodies are opaque, but have a rough outline like those of Type 29.

Similar fossils

*Archaeodiscina granulata Naumova, 1960, p.115, pl.3, fig.14.
*Nucellosphaeridium deunffii Timofeev, 1966, p.42, pl.VIII, fig.10.
*N.medianum Timofeev, 1966, p.42, pl.VIII, fig.9.
*N.minutum Timofeev, 1966, p.41, pl.VIII, fig.8.

Interpretation

For a general discussion see Type 35.

As the outer vesicle lacks folds, Type 30 is best referred to Nucellosphaeridium. The granulate outline of the inner body could be used to distinguish a new species. Otherwise this Type would be split between N.medianum and N.minutum on the basis of size.

TYPE 31

Plate 22 D - F, Figure 79. SPH-VIII-B

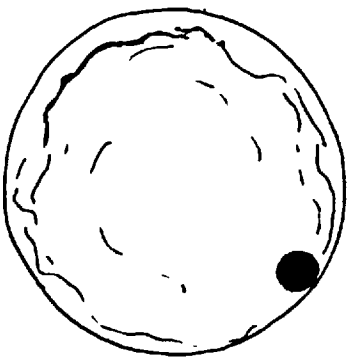


Figure 79. Type 31

Diagnosis

Thin walled sphaeromorph cryptarchs containing one relatively small rounded, opaque inner body. The outer wall of the vesicle has a smooth to granulate or shagreenate surface texture, often with a few very fine wrinkles. The inner body has a smooth outline.

Description

These vesicles are 10-40 microns in diameter with inner bodies 1-5 microns across. The outer wall of the vesicle is usually translucent and pale yellow-brown in colour. The inner bodies are opaque with a smooth outline.

Similar fossils

*Nucellosphaeridium glenos (Schopf 1968). See Table 15.

*N.majorinum (Schopf & Blacic, 1971, p.954-955, Table 3, pl.110, fig.10).

*N.minutum Timofeev 1966, p.41, pl.VIII, fig.8.

See also : Unicells containing intracellular bodies ('spots') - Schopf, 1974, Fig.14.

Interpretation

For a general discussion see Type 35.

Type 31 is definitely referable to Nucellosphaeridium and is assigned to N.majorinum on the basis of the relatively small size of the inner body.

TYPE 32

Plate 22 G, Figure 80. SPH-VIII-D

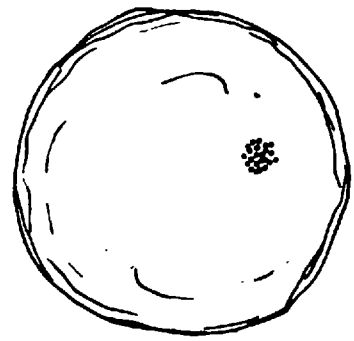


Figure 80. Type 32

Diagnosis

Thin walled sphaeromorph cryptarchs containing a relatively small cluster of granules. The outer wall of the vesicle has a smooth to granular or shagreenate surface texture, often with a few very fine wrinkles.

Description

These vesicles are rare, 20-30 microns across, with a cluster of granules 5 microns across. Individual grains are about 1 micron across, always less than 2 microns. Individual granules are opaque.

Similar fossils

Melasmatosphaera Hofmann, 1976, p.1065.

*M.magna Hofmann, 1976, p.1066, pl.8,f.1A-B.

*M.media Hofmann, 1976, p.1066, pl.8, fig.9A-B.

Unicells containing intracellular bodies ('granulars') - Schopf, 1974, Fig.15.

Interpretation

For a general discussion see Type 35.

These vesicles could be referred to Melasmatosphaera. At present, species of this genus are distinguished by their diameter rather than the arrangement of the inner bodies. If this precept is followed, Type 32 could be refered to M.magna. I would prefer to distinguish species on the arrangement of the inner bodies, in which case Type 32 would be referable to M.media or a new species.

TYPE 33

Plate 22 H, Figure 81. SPH-VIII-C

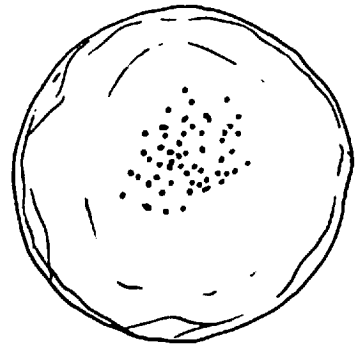


Figure 81. Type 33

Diagnosis

Thin walled sphaeromorph cryptarchs containing a diffuse granular patch. The outer wall of the vesicle is smooth to granular or shagreenate, often with fine wrinkles.

Description

These rare vesicles are about 20-30 microns in diameter. The clusters of granules are up to about 10 microns across; individual granules are less than 2 microns across, often about 1 micron. Individual granules are dark brown or opaque, the vesicle wall is pale yellow-brown.

Similar fossils

*Melasmatosphaera media Hofmann, 1976, p.1066, pl.8, fig.9A-B.
*M.magna Hofmann, 1976, p.1066, pl.8, fig.1A-B.

Interpretation

Type 33 is definitely assignable to Melasmatosphaera and probably to M.magna. For a general discussion see Type 35.

TYPE 34

Plate 22 I, Figure 82. SPH-VIII-?B

Diagnosis

Thin walled sphaeromorph cryptarchs containing a diffuse granular patch within which lies a relatively small, rounded, opaque inner body. The outer wall of the vesicle has a smooth to granulate or shagreenate surface texture, often with fine wrinkles.

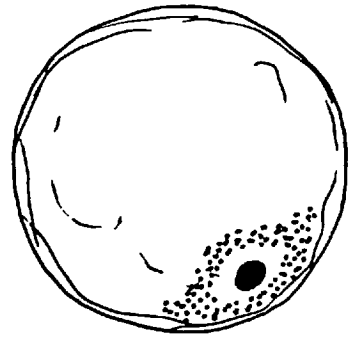


Figure 82. Type 34

Description

These vesicles are uncommon, and about 15-30 microns in diameter. The granular patch is usually 5-12 microns across and the opaque spot about 1-5 microns. The outer wall of the vesicle is usually translucent and pale yellow-brown in colour. The inner body is opaque with a smooth outline and often separated from the surrounding granules by a clear area. Individual granules are very dark to opaque, usually about 1 micron in diameter, but always less than 2 microns.

Similar fossils

*Caryosphaeroides pristina Schopf, 1968, pl.85, figs.1-3, 5-6.

Interpretation

For a general discussion see Type 35.

Identical vesicles have not been previously described as separate taxa. Caryosphaeroides consists of a spot within a membrane.

TYPE 35

Plate 23 A - B, Figure 83. SPH-VIII-B

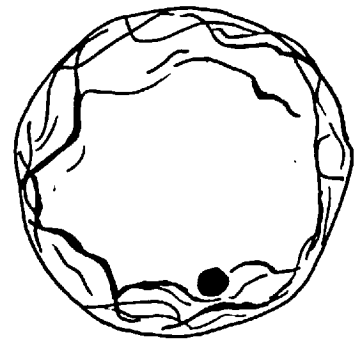


Figure 83. Type 35

Diagnosis

Thin walled sphaeromorph cryptarchs containing one relatively small rounded opaque spot with a smooth outline. The surface texture of the vesicle wall varies from smooth to granular or shagreenate; the wall is thrown into numerous short folds and wrinkles around the margin of the vesicle.

Description

These vesicles are about 15-30 microns in diameter with spots about 1-5 microns across. The outer wall of the vesicle is yellow-brown in colour, reddish-brown to dark brown where folded. One specimen (Pl.23B) has a crinkled surface like that of Type 4.

Interpretation

Similar fossils have not previously been described. For a general discussion see below.

Interpretation (Types 29-35)

These vesicles are interpreted as mucilaginous sheaths or cell walls containing the remnants of plasmolysed cells or their contents. It is significant that only one large inclusion is found in each vesicle. Granules are taken to represent the contents of non-plasmolysed cells.

All these types could have been produced by the partial plasmolysis and variable preservation of a single living species (See Fig.25, p.89). Equally, the 15 specimens illustrated here could represent 15 different living taxa. The most logical policy at the moment is to distinguish the different structures encountered and to suggest possible relationships.

The outer walls of most of the specimens illustrated are very similar to Type 3. The crumpled folds of Plate 21H,I (Type 29) and Plate 23A (Type 35) are unusual, and not found in any other Type.

Inclusions like those of Type 29 have not been described before. They could be hollow, and apparently have a definite wall with the granules as a surface feature.

The inclusions of Type 30 are opaque, but probably much the same as those of Type 29.

Continued plasmolysis or condensation of Type 30 inclusions could give rise to Types 31 and 35. Colonial aggregations of

Type 31 vesicles have been described as Type 36 (See also Types 43 and 45).

Types 32-34 could originate by the coalescence of granules to form a spot, perhaps indistinguishable from Type 31. Because they seem to have a distinct wall, it is unlikely that the granular-textured inclusions of Types 29 and 30 originated in the same way.

TYPE 36

Plate 22 J - L, Figure 84. SYN-X

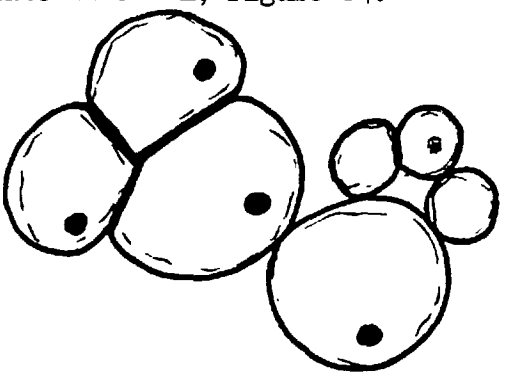


Figure 84. Type 36

Diagnosis

Synaplomorph cryptarchs consisting of several to many associated vesicles. The vesicles are rounded in outline and most of them contain a relatively small opaque spot with a smooth outline. Some of the vesicles of the clusters are connected, but constricted at septa.

Description

The individual vesicles of these clusters are about 6-40 microns in diameter with spots 1-2 or rarely up to 4 microns across. The surface texture of the vesicles varies from smooth to granular or shagreenate. It is common for small vesicles to be closely packed with large ones (Pl.22L). The vesicles are generally brown in colour, and though there may be some unstructured organic material associated with the clusters there is no evidence of mucilage, envelopes or sheaths. Spots are more often found in larger vesicles and are always very dark or opaque.

Similar fossils

*Balbiriniella praestans Oehler, 1978, p.302, fig.5D-G.

*Glenobotrydion aenigmatis Schopf, 1968, p.681, Table 4, pl.84, fig.5. and see pl.83, fig.9.

Myxococcoides reticulata - Schopf & Blacic, 1971, pl.113, fig.1.

*Nucellosphaeridium minutum Timofeev, 1966, p.41, pl.VIII, fig.8.

*N.majorinum (Schopf & Blacic, 1971, p.954-955, Table 3, pl.110, fig.10) See Table 15.

Trachysphaeridium timofeevi - Vidal, 1976, Fig.22G-K.

Interpretation

These fossils are interpreted as clusters of probably algal cells with plasmolysed cell contents.

Glenobotrydion is here restricted to colonies within lamellated mucilage, and solitary vesicles with spots are referred to Nucellosphaeridium. The colonial structure of Balbiriniella praestans is similar to that of Type 36, but its cells are separated within common mucilage and have translucent inclusions. The general arrangement of vesicles in one colony attributed (questionably) to Myxococcoides (Schopf & Blacic, 1971) is very similar to that of Type 36, though the cells of this specimen are of uniform diameter. Another colony of vesicles associated with unstructured organic matter (Schopf, 1968, pl.83, fig.9) is also closely comparable to Type 36.

I would not attribute Type 36 to any of the existing fossil taxa listed in Table 15. It is probably a new genus.

TYPE 37

Plate 23 C - D, Figure 85. SYN-XI

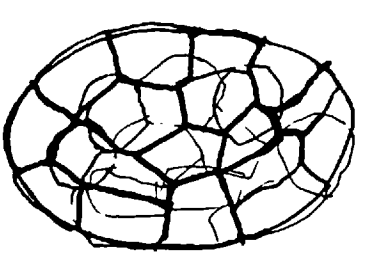


Figure 85. Type 37

Diagnosis

Synaplomorph cryptarchs with vesicles tightly pressed together in colonies with a smooth outline.

Description

These colonies are usually 15-30 microns across, and somewhat ovoidal in shape with dark septa. The cells are not at all constricted at septa, and 3-8 microns in diameter. The smooth outline of the colonies suggests the presence of an outer membrane but none is visible by LM.

Similar fossils

*Clonophycus elegans Oehler, 1977, p.346, fig.11A-C.
*Myxococcoides minor Schopf, 1968, p.676, Table 4, pl.81, fig.1A-B.
*Polyedrosphaeridium bullatum Timofeev, 1966, p.44, pl.V, fig.9.

Interpretation

These colonies are interpreted as vegetative algal cells. The close association of the colony in Plate 23D with a sphaeromorph is taken to be accidental. There is no ostiole in the sphaeromorph like those (doubtfully) reported in Clonophycus (Oehler, 1978). Clonophycus elegans and Myxococcoides minor resemble Type 37 in the arrangement of their cells, but Clonophycus has a very distinctive outer wall and Myxococcoides is embedded in laminated mucilage. Polyedrosphaeridium bullatum (as interpreted here - see Table 15) has fewer and much larger cells, but in a very similar arrangement. Type 37 could be attributed to this genus.

TYPE 38

Plate 23 E, Figure 86. SYN-IX

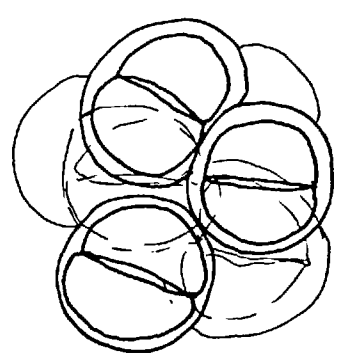


Figure 86. Type 38

Diagnosis

Synaplomorph cryptarchs consisting of closely associated vesicles within individual sheaths or membranes. Up to two vesicles occur within a common sheath. Paired vesicles are constricted at septa, but otherwise vesicles are separate.

Description

This colony is orange-brown in colour and 30-40 microns across. Individual sheaths are about 16 microns in diameter and round in outline with a smooth to finely granular surface texture. There is very little mutual compression, and no overall outer sheath or hierarchy of sheaths. Individual vesicles are about 12 microns in diameter - there is a space of 1-3 microns between the sheath and vesicle. Paired vesicles measure about 12 x 6 microns.

Interpretation

The vesicles are interpreted as dividing cells within sheaths, probably of algal affinity. There are 8 sheaths in this cluster, but no evidence in the form of overall membranes as to whether this number has any sexual significance. I am not aware of any closely comparable microfossils.

TYPE 39

Plate 23 F, Figure 87. SYN-IX

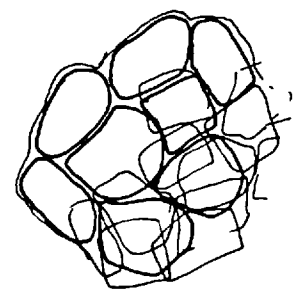


Figure 87. Type 39

Diagnosis

Synaplomorph cryptarchs consisting of numerous vesicles closely packed but separate within a common organic matrix.

Description

The whole colony of which Plate 23F is a detail is about 100 microns across and very dense. Details of the constituent vesicles can only be seen at the edges. Individual vesicles are 4-10 microns in diameter and pressed closely together, though separated by a narrow space (1 micron or less). Vesicle surfaces and walls are often indistinct or granular.

Similar fossils

Myxococcoides kingii - Muir, 1976, p.151,153, fig.6H.
M.minor - Schopf & Blacic, 1971, pl.113, fig.11.

Interpretation

These colonies are interpreted as vegetative and are probably of algal or cyanobacterial affinity. The 2 synaplomorphs listed above have cells separated within common mucilage, but individual vesicles are much less closely packed than in Type 39 and the colonies are much smaller overall. Type 39 cannot be attributed to any of the taxa listed in Table 15.

TYPE 40

Plate 23 G - J, Figure 88. SYN-IX

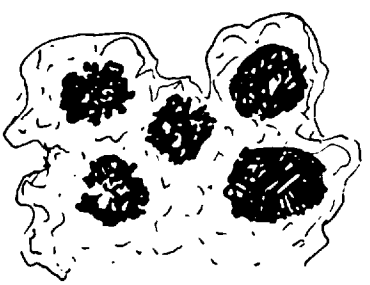


Figure 88. Type 40

Diagnosis

Synaplomorph cryptarchs consisting of numerous, separated, rounded dark inclusions embedded in an unstructured organic matrix.

Description & Interpretation

The dark blobs are interpreted as poorly preserved cells and the pale, unstructured organic material as common mucilage. The mucilage occurs in sheets or ribbons a few cells thick and many cells long. The colony in Pl.23G is more than 250 microns across; if uncoiled, its constituent ribbon would be more than 1000 microns long. One ovoidal colony 200 microns across has been recognised in thin section (TS DDH B8 143'0/1017-071). Judging by the density of cells in this specimen it was probably originally a thin sheet or perhaps a hollow ball. Individual cells are between 6 and 12 microns in diameter, but are preserved as granular carbon.

Among living genera these fossils resemble Microcystis or Tetraspora; the size of the fossil cells suggests an algal rather than a cyanobacterial analogue. The fossils are definitely assignable to the genus Ostiana and possibly to O.microcystis. This genus was previously only known from the Upper Riphean

Miroedikhinskaya and Lakhandinskaya suites of the USSR (Timofeev et al, 1976).

Similar fossils

*Ostiana microcystis Hermann in Timofeev et al, 1976, p.43, pl.12, figs. 5-6.

TYPE 41

Plate 24 A - L, Figure 89. SYN-IX

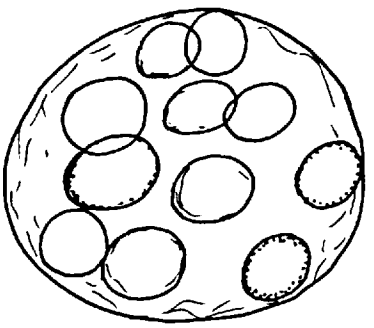


Figure 89. Type 41

Diagnosis

Synaplomorph cryptarchs in the form of rounded envelopes containing rounded vesicles. The inner vesicles are separate, not packed together.

Similar fossils

Unusual accumulations of single celled algae surrounded by a separate membrane ('Krome togo naideny svoeobraznye skopleniya odnokletochnykh vodoroslei, zaklyuchennykh v osobuyu obolochku') - Timofeev & German, 1974, p.172, pl.IV, figs. 7, 8.

See also *Eovolvox silesiensis Kazmierczak, 1975, p.77, pl.18, fig.1.
E.silesiensis - Kazmierczak, 1975, pl.18, figs.2-4, pl.19.figs.1,3-4, pl.20.figs.1-6.

Description & Interpretation

These colonies are all rounded, and are interpreted as originally spherical envelopes containing cells. Their overall diameter is 30-80 microns while the cells are about 4-10 microns across. Envelopes contain between about 12 and 40 cells. The cells are variably preserved as rounded dark inclusions like those

of Type 40 (Pl.24A-F,H; p.220) or as convincing vesicles (Pl.24G,I-L). These differences are inferred to be partly due to preservation and partly to the original condition of the fossils. It is difficult to be sure whether these fossils represent one or more living species. Those with poorly preserved cells look as if the cells were embedded in common mucilage while those with more convincing cells look as if they might have been membrane-bound. Some of the well preserved cells (Pl.24K,L; edges) are in the form of folded discs, and look as if they were originally flat and pressed against the inner wall of a hollow sphere. In other specimens the outer membrane or mucilage seems to have split up into patches around individual cells (Pl.24B, G, H, I) or is absent (Pl.24K, L).

These fossils could represent either the germination or production of a resting stage, vegetative growth of an organism, or both. The simplest interpretation is to assume that the differences between the cells of different specimens are due to preservation and that the original organism resembles Coelosphaerium or Aphanocapsa and reproduced by colony fragmentation.

I prefer to interpret these fossils as part of a more complex life cycle in which the protoplasm of a large cell becomes segregated and eventually develops into new solitary vesicles which are released by the lysis of the outer membrane. The only observations which support this speculation are the regular shape of the colonies and the apparent breakup of the colonies to release large (c.10 microns) solitary cells. This habit is not a typical feature of living cyanobacteria.

The only similar taxon I know is Eovolvox silesiensis, which is not as well preserved as Type 41 and consists of a spherical colony with peripheral cells. Type 41 undoubtedly represents a new taxon unless Timofeev & German have recently proposed one based on their material. Poorly preserved fossils that are referable to Type 41 have also been found in late Precambrian shales from the Tanafjord area of E.Finnmark (G.M.Bliss, pers.comm, 1978. For geology see Johnson et al, 1978).

TYPE 42

Plate 25 A - F, Figure 90. SYN-XI

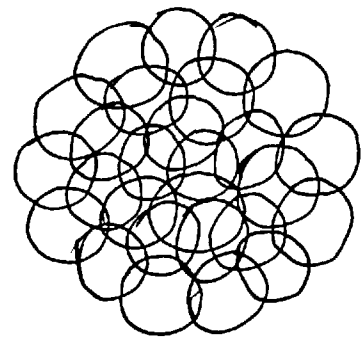


Figure 90. Type 42

Diagnosis

Synaplomorph cryptarchs consisting of 3 or more vesicles closely associated in colonies. Septa are constricted only at the edge of larger colonies.

Description

These colonies are 15-60 microns across and individual cells are 4-12 microns in diameter. Vesicles at the edge of the colonies are usually pale yellow-brown in colour; the central region of large colonies is usually opaque. Cell walls at septa are dark and usually less than 1 micron wide. Individual vesicles have a delicate appearance and resemble clusters of soap bubbles.

Similar fossils

Myxococcoides minor - Schopf, 1968, pl.83, fig.10.
*Pyritella polygonalis - Love, 1957, p.434, pl.33, fig.6.
*Symplassosphaeridium Timofeev 1959 ex Timofeev 1966.
S.incrustatum - Timofeev, 1959, p.27, pl.I, fig.10 (invalid).

Interpretation

See Type 45.

TYPE 43

Plate 25 G - L, Figure 91. SYN-XI

Diagnosis

Synaplomorph cryptarchs consisting of 3 or more vesicles closely associated in colonies. Many vesicles contain a relatively small opaque spot or granular patch. Septa are constricted only at the edge of larger colonies.

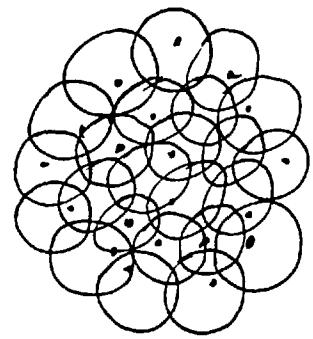


Figure 91. Type 43

Description

These colonies are about 15-60 microns across with individual cells about 4-12 microns in diameter. Small spots are usually 1-2 microns, rarely 4 microns across. Vesicles at the edge of the colonies are usually pale yellow-brown in colour; the central region of large colonies is usually opaque. Cell walls at septa are dark but usually less than 1 micron wide. Individual vesicles have a delicate appearance, resembling clusters of soap bubbles.

Similar fossils

Thick walled spheroidal bodies - Barghoorn & Schopf, 1965, Fig.7.

Interpretations

See Type 45.

TYPE 44

Plate 26 A - F, Figure 92. SYN-XI

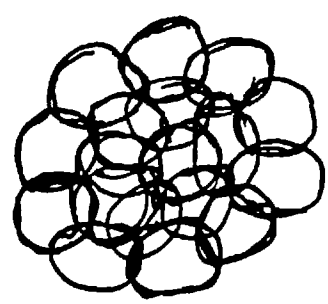


Figure 92. Type 44

Diagnosis

Synaplomorph cryptarchs consisting of 3 or more vesicles closely associated in colonies. Septa are constricted only at the edge of larger colonies.

Description

These colonies are about 15-60 microns across with cells 4-12 microns in diameter. One specimen (Pl.26A) measures 60 x 130 microns. Vesicles at the edge of the colonies are usually brown in colour; the central region of colonies is usually opaque. Cell walls at septa are dark and usually between 1 and 5 microns wide. Individual vesicles have a robust granular appearance; in general the colonies look very ragged and granular.

Similar fossils

Myxococcoides reticulata - Schopf & Blacic, 1971, pl.113, fig.1.

*Symplassosphaeridium tumidulum Timofeev, 1959, p.27, pl.I, fig. 11 ex Timofeev 1966.

Interpretation

See Type 45.

TYPE 45

Plate 26 G - L, Figure 93. SYN-XI

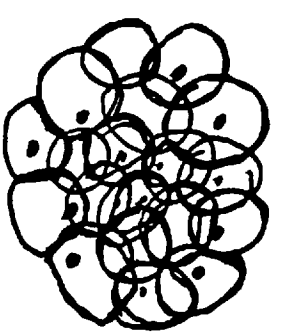


Figure 93. Type 45

Diagnosis

Synaplomorph cryptarchs consisting of 3 or more vesicles closely associated in colonies. Many vesicles contain a relatively small dense spot or granular body. Septa are constricted only at the edge of larger colonies.

Description

These colonies are about 15-60 microns across with cells about 4-12 microns in diameter. Inner spots are usually about 1-2, rarely up to 4 microns in diameter. Vesicles at the edge of the colonies are usually brown in colour while the central region is usually opaque. Cell walls at septa are dark and

usually 1-5 microns wide. Individual vesicles have a robust granular appearance; the colonies look very grainy and ragged.

SEM observation of one specimen has shown that the apparent thickness of the cell wall is due to the folding of the ruptured wall. When complete, the cell walls are densely granular (Pl.26J,K). The small granular inclusion can be seen to be a three-dimensional lump attached to the inner cell wall (Pl.26L).

Similar fossils

See Myxococcoides minor - Schopf & Blacic, 1971, pl.113, fig.3.

Compare the wall of Melasmatosphaera media Hofmann, 1976, pl.8, fig.9A.

Interpretation of Types 42-45

These fossils are all interpreted as vegetative algal colonies. The apparently thick walls of Type 45 have been shown to be produced by the folding of corroded cells. Because of their similarity the walls of Type 44 are also interpreted as a secondary feature of corroded and folded or flattened material. This suggests that Types 44 and 45 are preservational variants of Types 42 and 43.

Small spots and inner bodies have little or no biological significance, though they could provide useful palaeontological information (See Chap.6). Certainly, Types 42, 43 and 44,45 respectively could also be regarded as preservational variants. In the McMinn Formation material there is a continuum of forms from Plate 25A&C to Plate 26E&J. The question is whether it is palaeontologically useful to separate these Types, even though they could have a monospecific biological origin. I have decided to split this 'biological' taxon for three reasons. Firstly current usage sanctions such splitting. Secondly, spots and inner bodies may indicate special conditions at the time of fossilisation. Thirdly, stained and corroded specimens indicate sediment reworking and recycling and the partial degradation of material before fossilisation.

Detailed studies of the distribution of these Types in the McMinn Formation have not yet been made, but could clearly provide much useful palaeoenvironmental information.

With the suggested emendation of Myxococcoides (Table 15) some specimens and taxa previously attributed to it will have to

be reassigned. Both Pyritella and Symplassosphaeridium represent more or less spherical colonies of rounded vesicles without inclusions. On the basis of described type material, Pyritella could be restricted to thin walled vesicles (Type 42), and Symplassosphaeridium to colonial vesicles with thick or folded walls (Type 44).

TYPE 46

Plate 27 A - G, K, 29 A - B, D, Figure 94. NEM-XI



Figure 94. Type 46

Diagnosis

Nematomorph cryptarchs in the form of solitary, unbranched, granular threads.

Description

These filaments are 5-15 microns wide and vary in colour from yellow-brown to black and opaque. The texture of the granulation varies from coarse and almost solid to very fine (Pl.27B, G). Some specimens are straight or slightly sinuous, but many are twisted (Pl.27D), wound together (Pl.27F) or folded over each other (Pl.27E). They are often disrupted by crystallisation or grains of sediment (Pl.27A,C).

Similar fossils

*Archaeonema longicellularis Schopf, 1968, p.678, Table 3, pl.80, fig.11.

A.longicellularis - Schopf & Barghoorn, 1969, pl.21,figs.1-4, pl.22, figs.2-4

*Eomycetopsis rugosa Maithy, 1975, p.140, pl.4, fig.26.

Gunflintia grandis,Barghoorn & Tyler, 1965, Fig4 (4).

See also Type E pseudofossils - Pflug, 1967, p.22, pl.III, figs.19-20.

Types 47, 52.

Interpretation

These filaments are generally poorly preserved as granular, presumably graphitic compressions. Their attitudes in the sediment suggest transportation or at least rolling about before final deposition. They are rarely found in macerates, probably because they fall apart. The frequent suggestions of cells are interpreted as disruption by crystal growth or grains of sediment; other authors have given more imaginative interpretations of similar material (Eg. Schopf & Barghoorn, 1969).

These filaments closely resemble Eomycetopsis rugosa Maithy 1975, which is too poorly preserved to be assigned to that genus. In their preservation these threads also resemble many other poorly preserved filaments attributed to Gunflintia. On the basis of described type material, the genus Gunflintia could usefully be restricted to granular filaments of this type, with Type 46 attributed to G.rugosa (Maithy) emend. G.grandis, G.barghoornii, G.kanshiensis and G.oehlerae show much better preservation with details of cell structure and could be attributed elsewhere (See Table 15). Poorly preserved granular threads previously (wrongly) attributed to G.grandis would merit a new specific designation or could probably be synonymised with Beckspringia as Gunflintia communis (Licari).

Type 46 filaments could represent poorly preserved cellular filaments of algae or cyanobacteria, but are most likely sheaths. Threads of this Type have previously been largely interpreted as poorly preserved specimens of cellular genera and unjustifiably attributed to them. Gunflintia is a suitable genus for poorly preserved material.

TYPE 47

Plate 28 B, Figure 95. NEM-XI

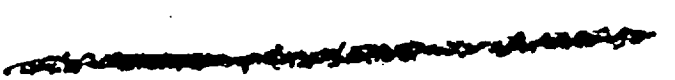


Figure 95. Type 47

Diagnosis

Nematomorph cryptarchs in the form of solitary, unbranched granular filaments.

Description

These granular organic threads are dark brown or black in colour and 1-3 microns wide. Most specimens are straight, but some are twisted, recurved or bent.

Similar fossils

*Beckspringia communis Licari, 1978, p.779, Table 2, pl.1, fig.6.
Cyanophycean filaments type a - Cloud et al, 1969, figs.3-5.
Filaments - Cloud & Hagen, 1965, Figs.1,3-4.
Filaments - Licari & Cloud, 1972, fig.1,c-e.
*Gunflintia minuta - Barghoorn in Barghoorn & Tyler, 1965, p.576, fig.4 (8).
Iron bacteria resembling Chlamydothrix - Gruner, 1922, pl.VIID.
'Niti slabo izognutye' - Shenfil, 1978, p.1217, pl.1i.
Non-septate unbranched filament - Diver, 1974, fig.1F-H.

See also: *Tenuofilum septatum Schopf, 1968, p.679, table 3, pl.86, fig.11.

Interpretation

The granularity of these filaments sometimes suggests cells, but this is considered to be an artifact of preservation. The threads could represent sheaths or cellular filaments of bacterial, algal or fungal affinity.

The interpretation of Tenuofilum and Beckspringia as cellular is questionable and these taxa may be junior subjective synonyms of Gunflintia minuta. Type 47 is attributed to G.minuta Barghoorn in Barghoorn & Tyler, 1965.

TYPE 48

Plate 27 H, Figure 96. NEM-II

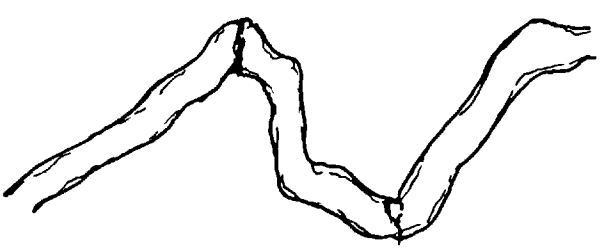


Figure 96. Type 48

Diagnosis

Nematomorph cryptarchs consisting of aseptate, unbranched, hollow tubes.

Description

These filaments are 4-6 microns wide and pale yellow-brown in colour. The tubes are always twisted and folded, sometimes giving the appearance of septa. All of the specimens found so far appear to be broken fragments with open ends.

Similar fossils

*Archaeothrix contexta Kidston & Lang, 1921, p.874-876, pl.VIII, figs.87-88.

*Siphonophycus kestron Schopf, 1968, p.671, Table 5, pl.80, figs.1-2.

*Taeniatum crassum Sin & Liu, 1973, p.28,63, pl.V, fig.5.

Taeniatum sp. - Hofmann & Aitken, 1979, fig.9A,B.

*Tortunema eniseica Hermann in Timofeev et al, 1976, p.40, pl.XII, fig.4.

*Tortunema sibirica Hermann in Timofeev et al, 1976, p.40, pl. XII, fig.2.

*Trematosphaeridium arbustus Aseeva, 1971, p.206, pl.1, V, figs. 9 - 11.

Interpretation

These fossils could represent aseptate fungal hyphae or well preserved algal or bacterial sheaths. They are almost identical to Taeniatum sp. as illustrated by Hofmann & Aitken (1979), and closely comparable with the two species of Tortunema listed above. Among other genera, Archaeothrix is narrower and Siphonophycus wider.

The assignment of Type 48 is a problem because the validity of Taeniatum is uncertain and the original description is in Chinese. I do not know whether Taeniatum can be distinguished from Tortunema (T.eniseica is coiled; both species have tapering closed ends). Although poorly illustrated, Trematosphaeridium arbustus apparently represents a coiled filament rather than a sphaeromorph.

Septa described in the type specimen of Eomycetopsis Schopf, 1968 are not convincing, and this genus may therefore be a junior subjective synonym of Taeniatum. Other nematomorphs with convincing septa and distinctive surface textures assigned to Eomycetopsis warrant new genera.

Filaments closely similar to Type 48 have been attributed to Eomycetopsis (Hofmann, 1976) and are known from late Aphebian and several younger fossil assemblages (See Foscat).

TYPE 49

Plate 27 I, Figure 97. NEM-VIII-A



Figure 97. Type 49

Diagnosis

Nematomorph cryptarchs consisting of an unbranched, uniseriate chain of vesicles with a length/width ratio of less than 0.5 and not constricted at septa.

Description

This filament is 6-8 microns wide and orange-brown in colour. The individual cells are wider than long, usually 2-4 microns long. There is no obvious sheath or mucilage, nor does the filament taper at the ends.

Similar fossils

*Palaeolyngbya barghoorniana Schopf, 1968, p.665, Table 3, pl. 77, figs. 1A-C.

*P.minor Schopf & Blacic, 1971, p.942-943, Table 2, pl.105, fig.4.

Interpretation

This fragment may be from the interstitial region of a filament and is probably of algal or cyanobacterial affinity. The 2 species listed above are the nearest to Type 49 but show differences in the septa and the roundness of the sides of the cells. Type 49 is not attributable to any known fossil taxon.

TYPE 50

Plate 27 J, Figure 98. NEM-IX-A

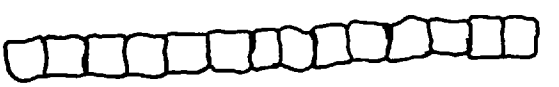


Figure 98. Type 50

Diagnosis

Nematomorph cryptarchs consisting of unbranched uniseriate chains of approximately equidimensional vesicles, not constricted at septa.

Description

These filaments are 1.5-5 microns wide and yellow brown in colour. Individual cells are more or less equidimensional within the above limits. There is no obvious mucilage or sheath, nor does the filament taper at the ends.

Similar fossils

*Cephalophytarion grande Schopf, 1968, pl.78, fig.2 emend Schopf and Blacic, 1971, p.956.

*Contortothrix vermiformis Schopf, 1968, p.671, Table 3, pl. 79, figs.7A-B.

Interpretation

This fragment may have been an interstitial part of a longer filament; it is probably of algal or cyanobacterial affinity. Contortothrix vermiformis is strongly coiled, so Type 50 is assigned to Cephalophytarion grande.

TYPE 51

Plate 28 A, C, Figure 99. NEM-XI



Figure 99. Type 51

Diagnosis

Nematomorph cryptarchs consisting of sinuous, granular unbranched filaments twisted together. The filaments are sometimes associated with unstructured organic material.

Description

These filaments are 0.5-1 microns wide and irregularly preserved. In some places along the filaments there is a suggestion of septation.

Similar fossils

*Archaeotrichion contortum Schopf, 1968, p.686, pl.86,fig.1.
*Biocatenoides incrustata Oehler, 1977, p.330, fig.5A.
*Biocatenoides pertenuis Oehler 1977, p.332, fig.7 O.
*Spirillenema bentori Shimron & Horowitz, 1972, p.338, pl.1, figs. 1-4.

Interpretation

These fossils are interpreted as poorly preserved cellular filaments or possibly sheaths. The original filaments may have been wider and shrunk during fossilisation. Their size and habit suggest bacteria rather than fungi or algae. Their occasional association with unstructured organic matter may be fortuitous but also suggests polytrichous cyanobacteria as a living source.

Among similar described filaments, those of Biocatenoides are narrower, while Spirillenema consists of a pair of threads that are closely and regularly intertwined.

Filaments of Type 51 fall within the bounds of Archaeotrichion contortum and are assigned to this species.

TYPE 52

Plate 28 D - E, Figure 100. NEM-VII



Figure 100. Type 52

Diagnosis

Nematomorph cryptarchs consisting of branching granular filaments, each with a single denser strand running down the centre.

Description

The overall width of these nematomorphs is about 8-12 microns, while the denser inner strands are 0.5-1 micron wide. The inner strand is not visible along the whole length of the filaments. In places, and at high magnification, the inner strand can be seen to be segmented like a string of beads. Some specimens branch more freely than others, though genuine branching can be difficult to distinguish from closely tangled specimens.

Similar fossils

*Palaeogeminella folkii Fairchild et al, 1973, p.951, pl.1, figs.1-9.

See also Types 46, 47.

Interpretation

These fossils are interpreted as a filament of small, perhaps shrunken cells, embedded in a relatively thick sheath. The preservation of these specimens is very variable, as can be seen from Plate 28D,E. 28E shows the indifferent preservation of the presumed sheath and the irregular appearance of the central strand. This specimen also shows how filaments can be disrupted by diagenesis and crystal growth. The marked expansion of the filament near the top is regarded as an artifact of preservation. It does not show any structural detail.

The occurrence of a filament of cells within a sheath strongly suggests living algae or cyanobacteria as a source. The fossils could be interpreted as complete and well preserved examples of Types 46, 47 and ?51, but there is no way of proving such affinity.

Among described microfossils, Type 52 most resembles P Palaeogeminella folkii from the Devonian, though P.folkii is 5 or 6 times wider and does not branch. Type 52 represents a new taxon.

TYPE 53

Plate 29 C, E - K, 30 A - I, 31 A - D, Figure 101. NEM-II

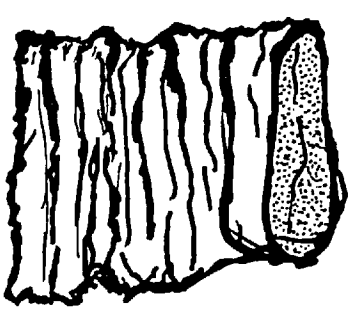


Figure 101. Type 53

Diagnosis

Nematomorph cryptarchs consisting of unbranched, thin-walled hollow tubes with transverse striations. The surface texture of the tubes varies from granular to very rough and flaky.

Description

The diameter of these tubes varies from about 35 to 120 microns, and their walls are less than 1 micron thick. The tubes vary in colour and preservation from opaque, black and three-dimensionally preserved (Pl.29F,G) to corroded, partly translucent flattened fragments (Pl.29H,J-K, 30C). The 30 known fragments are lumped together here because they are all big hollow tubes with transverse striations. There are important differences between specimens that may be of taxonomic importance, and these are discussed below.

Similar fossils

Narrow, transversely striated filaments:

*Oscillatorites wernadskii Shepeleva, 1960, p.170-1, fig.1. 13.2 - 16.5 microns wide.

Oceilatorites wernadskii error for Oscillatorites in Timofeev, 1966, pl.72, figs.3-4. 10-30 microns wide.

Oscilatorites sp. error for Oscillatorites in Timofeev, 1966, pl.II, fig.5, pl.86. fig.9. 10-30 microns wide.

Oscilatorites wernadskii error for Oscillatorites in Timofeev, 1966, pl.2,fig.4, pl.46, fig.7. 10-30 microns wide.

Wide, transversely striated filaments

Calyptrina partita Sokolov 1965 - Sokolov, 1967, p.203-204. pl.2, fig.2. 1500-2000 microns wide.

C.striata - Sokolov, 1967, p.204, pl.2, fig.3. Up to 6000 microns wide.

Laminarites antiquissimus Eichwald - Timofeev, 1966, p.16-17, pl.I, fig.1, pl.II,fig.1a. 1500-2000 microns wide.

*Paleolina evenkiana Sokolov, 1967, p.203, pl.1, fig.3. 500-1000 microns wide.

*Parasabellidites yanichevskyi Sokolov, 1967, p.203, pl.1, figs.2A-B. About 1200 microns wide.

*Saarina tenera Sokolov, 1965 - Sokolov, 1967, pl.2, figs.1A-B.. 3500-5000 microns wide.

Sabellidites cambriensis Yanichevsky 1926 - Sokolov, 1967, p.202, pl.1, fig.1. 200 - 3000 microns wide.

*Tyrasotaenia podolica Gnilovskaya, 1971, p.377, pl.XI. figs.1-5. About 500 microns wide.

*Vendotaenia antiqua Gnilovskaya, 1971, p.376, pl.XI,figs.6-8. 1500 to 2000 microns wide.

See also: Vermiforma antiqua Cloud in Cloud et al, 1976, p.405, figs.3,6-11.

See also the various tubes described by Pratt et al, 1978.

Interpretation

7 fragments are interpreted as terminal and either taper slightly and end with an abrupt cut off (Pl.30A,B,D,G, 31A,C,D) or are bluntly rounded (Pl.30C). One possible example of 2 linked terminal fragments (ie a septum) is known (Pl.29E). The single bluntly-rounded specimen is also the widest (120 microns) fragment found so far and may only look different because it is wider. All of the terminal fragments taper over a length of 30-40 microns.

The remaining fragments (22, some poorly preserved) are interpreted as interstitial, and 3 types can be distinguished. Type A tubes have marked annular or transverse ridges spaced out along them (Pl.29C,F,G). Type B tubes have a finer transverse striation, and could be corroded Type A (Pl.29G,H,J,K, 30C,E, 31A-D). Type C tubes have a solid cellular appearance because the striations are so closely packed (Pl.29I, 30D).

Some of these fragments probably have different biological origins, though they could conceivably form a single degradational series. Unequivocal evidence for cells is lacking, and this and the state of preservation suggest an origin as mucilaginous or chitinous tubes or sheaths of various kinds. Among living taxa Pl.29I resembles Lyngbya majuscula Desikachary 1959, though the fossil is about 10 wider. L.majuscula has been used for experiments in simulated fossilisation (Oehler, 1976) and the similarity between this material and Type 53 in both the LM and SEM is striking. Some species of Enteromorpha form similar tubes. The possible septum (Pl.29E) could perhaps be of cyanobacterial origin but suggests a filamentous alga, for example Ulothrix, or even a constricted tube like Scytosiphon.

It is possible, but doubtful, that some of the fragments (not pl.29F,G) could be parts of large leiofusid acritarchs or of other elongate tubular fossils such as Tawuia (Hofmann & Aitken, 1979).

Among described filamentous microfossils, Type 53 most resembles the wide transversely striated filaments listed above. However, the widest known specimen of Type 53 is only just over half as wide as the narrowest species of these fossils (Sabellidites cambriensis). On the other hand, the narrowest specimens of

Type 53 are just over twice as wide as Oscillatorites.

As far as I am aware, Type 53 does not fall within the bounds of any described fossil taxon. The possible affinities of these fossils range from cyanobacterial sheaths through eukaryotic algae and protozoan dwelling tubes to metaphytes and metazoans (See Sokolov, 1967; Cloud et al, 1976).

The McMinn Formation forms are fragmented and do not narrow the range of possible affinities. However, they do fill a gap in the known size range of this kind of fossil, and demonstrate a probable continuum from about 10 to 6000 microns in width. The stratigraphic occurrence of these fossils is too patchy to attach much significance to the relative age and size of these forms, except that they are another Riphean record of possible metazoa or metaphyta (See Sokolova, 1976).

TYPE 54

Plate 31 F, Figure 102. NEM-XI



Figure 102. Type 54

Diagnosis

Branching granular filaments arising from a central organic mass.

Description

The filaments are granular, dark and about 3 microns wide. They taper gradually towards their ends where they are only about 1 micron wide. There is no evidence of cells except for a faint and dubious suggestion of a thread within one filament (lower arm, N.E. of Pl.31F).

Similar fossils

*Eoastrion bifurcatum Barghoorn in Barghoorn & Tyler, 1965, p.576-577, fig.6(7).

See also: Metallogenium - like budding bacteria, Cloud, 1976, pl.4.

Interpretation

This fossil resembles Metallogenium (See Cloud, 1976) which is well known from iron-rich environments. Type 54 may be a colonial arrangement of threads of Types 47 or 51. It is attributable to E.bifurcatum. (The genus Eoastrion is currently being reassessed- see Awramik & Barghoorn, 1977).

TYPE 55

Plate 31 G, Figure 103. NEM-XI



Figure 103. Type 55

Diagnosis

Numerous opaque filaments radiating from an opaque central body. Some of the filaments branch.

Description

The filaments are 8-10 microns wide, black and opaque. No detail is visible. The central body is an opaque mass, either a solid substrate or a dense aggregation of filaments.

Interpretation

The filaments may be carbonised organic material or encrusted with iron or other minerals. They are massive, and not chains of closely connected crystals. The colony is very three-dimensional and so was either living in the sediment at the time of fossilisation or in a rigid condition before it was deposited. The former interpretation is preferred and is supported by the similarity of this fossil to heavily encrusted living bacteria like Metallogenium. Type 55 is referred to Eoastrion bifurcatum (See Type 54).

C. Palaeontological interpretations

The microfossils described above represent the richest and best preserved assemblage yet reported from the Precambrian. The most striking features of this biota are the wide size range of the fossils (Fig.104) and the variety of forms encountered (Fig.105).

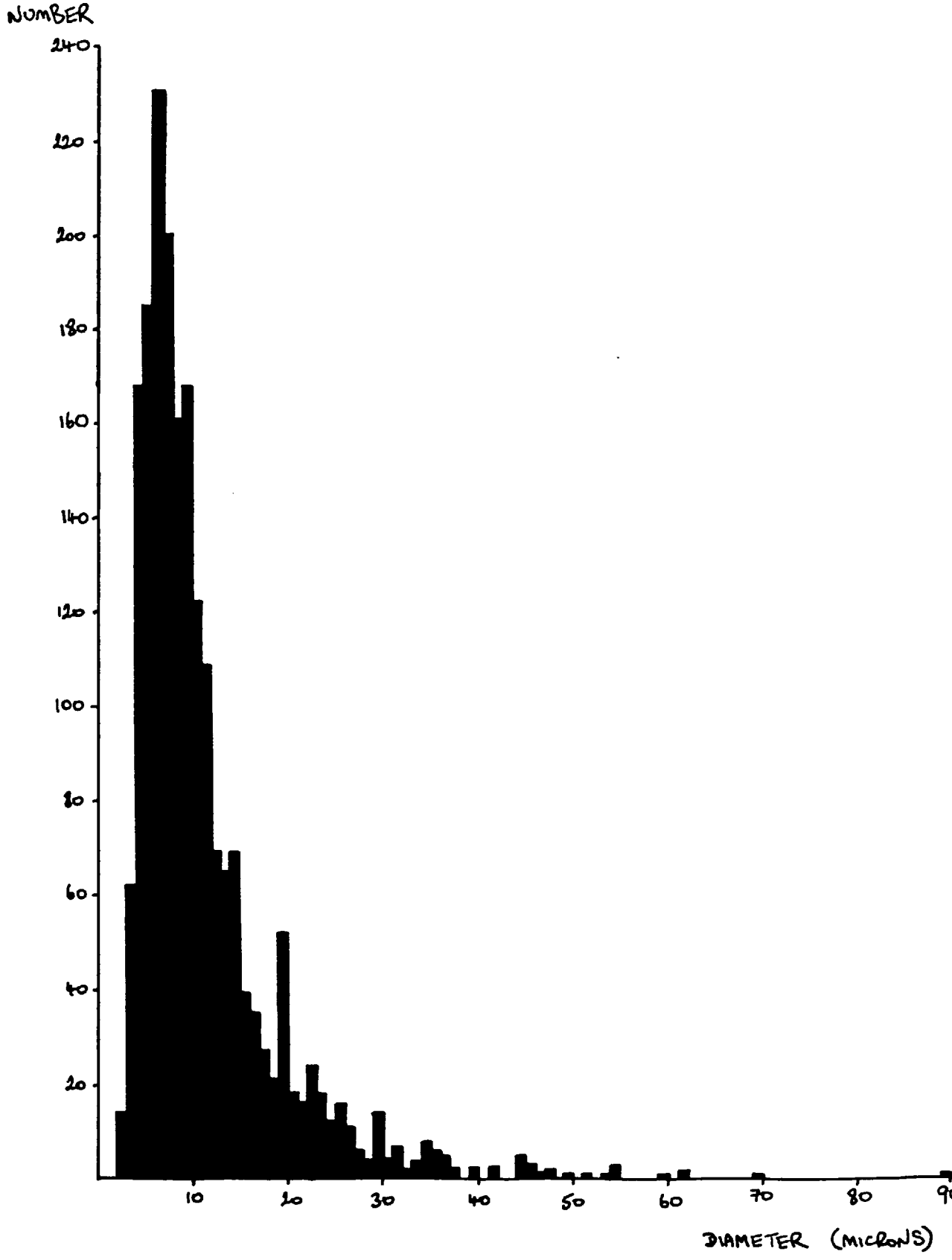
In diameter the sphaeromorph cryptarchs range from 3-600 microns. Fig.104 shows the diameter of solitary, smooth sphaeromorphs measured in a series of traverses across one thin section. Most of the vesicles are 5-15 microns in diameter and of Types 3, 4 or 13. Those more than 30 microns across make up less than 5% of the assemblage by number.

Fig.105 is an attempt to show the enormous variation in size between some of the different fossil types. Although the relative size of these vesicles is obviously an important feature of the assemblage, it is difficult to see how it can be used in a non-arbitrary way in classification. Detailed studies of the variation in fold pattern with vesicle diameter and wall structure may provide answers for some of the smooth sphaeromorphs.

Some distinctive cryptarchs are most abundant in certain samples; for example, granular filaments (Types 46, 47) are most common in DDHs A, B, and C while Type 41 is most common in the DDH M series. Types 1-3 are only known from DDH B7 74'2, and Type 5 from DDH M14 250'8. Detailed analyses of the distribution of the microfossils relative to each other and to other features of the sediment have not yet been made. To be useful, such a study would have to be on a bed-by-bed basis at the millimetre level. (See Awramik & Semikhatov, 1979 for a similar approach to the Gunflint stromatolites). Vidal (1976) attempted a stratigraphic approach to the Visingso Formation, but took widely spaced samples and was clearly hindered by poor preservation.

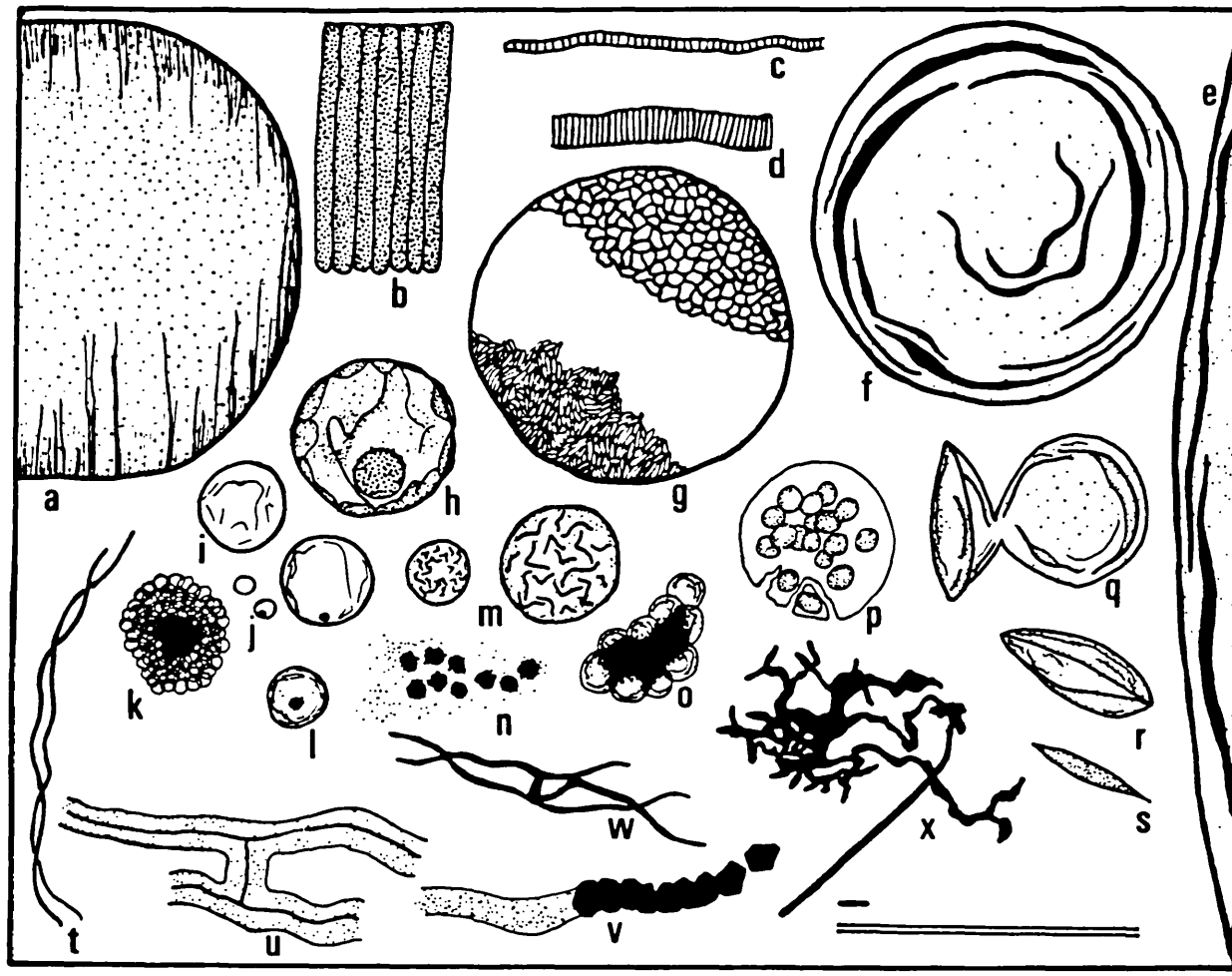
Sphaeromorph cryptarchs are generally assumed to have been planktonic in the Palaeozoic, but their distribution in Proterozoic sediments is patchier than might have been expected. They are apparently less resistant to oxidation than pollen and spores. Staplin (1961) reported that in the Devonian sphaeromorphs were found closer to reefs than spiny acritarchs, but were more numerous towards the open sea. The environmental and sedimentological

FIGURE 104. DIAMETER OF SPHAEROMORPH CRYPTARCHS



$\Sigma N = 2000$. ALL MEASUREMENTS $\pm 1\mu$.
DATA FROM 8 NON-INTERSECTING LINEAR TRAVERSES OF TS-DDH-M15-173'5-1

FIGURE 105. RELATIVE SIZE OF McMINN FMN. CRYPTARCHS



Scale : single bar = 10 microns, double bar = 100 microns.

a. Type 53
b. Type 53
c. Type 50
d. Type 49
e. Biggest found
f. Type 13
g. Types 1, 2
h. Type 29
i. Type 3
j. Type 31
k. Type 42
l. Type 32
m. Type 4
n. Type 40
o. Type 13
p. Type 41
q. Type 10
r. Type 12
s. Type 11
t. Type 51
u. Type 52
v. Type 46
w. Type 54
x. Type 55

factors governing the broad distribution of Precambrian cryptarchs have not been studied though opportunities exist in many well exposed sequences.

In the McMinn Formation, Types 54 and 55 are the only fossils that look as if they were benthonic. Most of the filaments are corroded, fragmentary and twisted or broken as if transported before deposition. Types 48-50 are the only well-preserved filaments, and are rare. Some of the sphaeromorphs are corroded and were probably transported and recycled too, though most are very well preserved. A planktonic origin for most of the assemblage seems likely - many living planktonic algae produce cysts that rest in the sediment (Anderson & Morel, 1979 eg).

Although ultrastructural studies have only just begun, it is clear that it is not possible to work out the structure of many cryptarchs by LM alone. The discovery of thin outer membranes by SEM that were unsuspected after LM makes the presence of membranes an even less reliable character than was originally suggested. Taking the ranking of characters developed in Chapter 6 (p.96) I would now suggest that folds be ranked higher than the presence of inclusions, membranes or sheaths, and that Tables 9 and 12 be modified accordingly. It is most concise and informative, for example, to regard Type 28 as 'Type 5 in a membrane' but it is a moot point whether the two types should be united within the same taxon (See below).

The preliminary structural observations made here have shown two types of wall - the 1 micron thick wall of the dark vesicles and the much thinner (0.1 microns or less) of the outer membranes and cells. Of the few walls examined by LM and SEM the thin specimens were almost transparent in the LM while the thicker ones were relatively opaque. When examining macerates by LM there is a continuum of vesicle colour from pale translucent yellow to completely opaque. It is not known whether there are two wall types - 0.1 microns and translucent and 1 micron thick and darker - or whether there is a continuum from 0.1 microns to 1 micron or more. The thinner walls could represent either an original cell wall or mucilage on present evidence (See Kessel & Eloff, 1975; Schopf, 1970). All the walls are apparently unstructured and resemble the much thicker walls of Leiosphaeridia. Again, it is not known whether the 2 micron cut-off point for wall thickness adopted here is real or arbitrary. There could easily be a biological continuum of wall development from 0.1

microns to 10 or more.

Mucilage and sheaths have been distinguished by their appearance in the LM - mucilage looks lumpy and unstructured; membranes are thin sheets. Colonial mucilage could fragment in the way shown here (Type 41); colonial sheaths usually open by median splits to release cells or baeocytes. Even cyanobacterial sheaths can be more than 200 microns across and up to 1 micron thick and bear a remarkable resemblance to some thin-walled sphaeromorph cryptarchs (See Kessel & Eloff, 1975; Waterbury & Stanier, 1978). It is not known how sheaths and mucilage would react to fossilisation in a silty matrix, or whether their fossils could be distinguished.

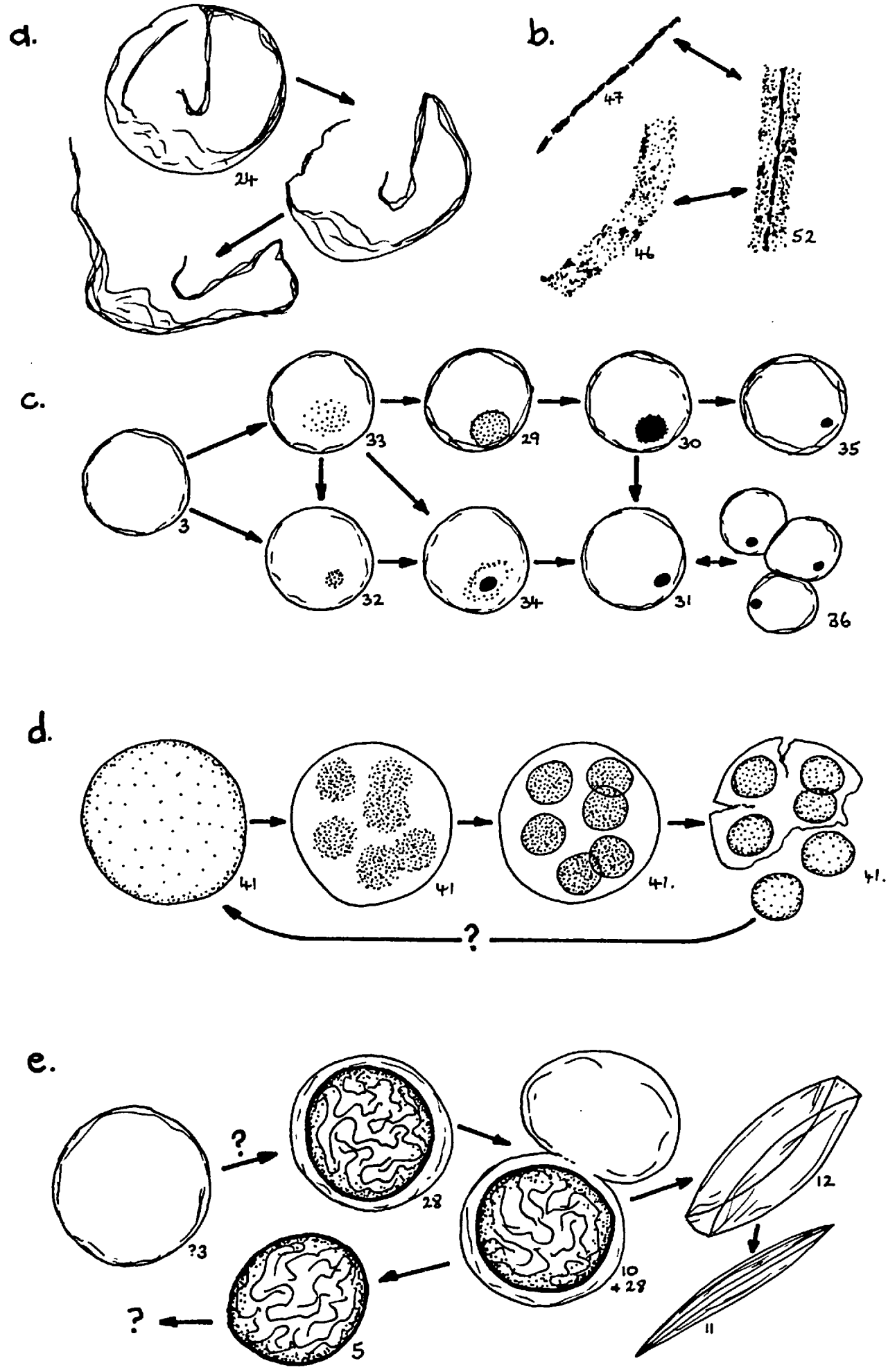
Possible relationships between some types from the McMinn Formation assemblage are shown in Fig. 106 a-e. The production of pseudofilaments from decaying sphaeromorphs is well documented and although a Type 20 vesicle is shown as the source in the example illustrated, other vesicle types could decay in the same way (Type 24, Fig.106a, Pl.19A-H).

Intravesicular bodies were discussed in Chapter 6 (p.88-90). It is possible that all the varieties described here could have been produced by the partial plasmolysis and variable preservation of a single biological species as shown (Fig.106c).

Type 41 (Fig.106d, p.221-222) can be interpreted as part of the life cycle of an endosporulating alga. My implication is clearly that this represents a eukaryotic organism, and a superficial comparison with living algae supports this. Although some living cyanobacteria have similar vegetative cycles and can reproduce by colony fragmentation, their cells are usually smaller than those of Type 41 (Waterbury & Stanier, 1978).

This general line of argument presupposes that Type 41 can be referred to the currently living biota. Although living organisms must be at the basis of any interpretations, Type 41 could represent an extinct line, possibly one of many proto-eukaryotic stocks (See Bonen & Doolittle, 1976). It could also be suggested that some of the broad filamentous fossils (Type 53) represent cyanobacterial sheaths or trichomes, and therefore that ancient cyanobacteria grew much bigger than their living representatives. In this connection

FIGURE 106. POSSIBLE RELATIONSHIPS BETWEEN CRYPTARCHS



NOT TO SCALE.

SUBSCRIPTS REFER TO TYPES.

it is worth pointing out that some living cyanobacteria produce akinetes with a laminar wall and a spiny or granular surface. Those of Cylindrospermum can measure 12 x 40 microns (Fogg et al, 1973, Fig.11:34; Rippka et al, 1979,Fig.36).

Some of the darker vesicles open by median splits but paired dark valves are very rare. Some of the more translucent sphaeromorphs could be single valves produced by the darker vesicles (See Types 19 & 20, Pl.17A-F, and Types 15 & 16, Pl.15D-L). The relationship of Types 10 and 28 is reasonably certain, and the pathway Type 10 - 12 - 11 is well established. It is reasonable to assume that at least some of the other membrane-vesicle pairs also opened via a median split. There is evidence that the fold patterns of some membranes reflect those of their inner vesicles but further study is essential (See Types 6-12, Pl.12A-L, 13A-I, 14A-E, and Types 17, 25 - 27, Pl. 16A-F, 20A-L). It is possible that only some membrane types eventually roll up to form Types 11 and 12. It follows that the presence of Type 12 or even Type 5 cannot be used to infer the presence of Type 28. For this reason I believe that these Types should be assigned to different morphological taxa, even though they may be biologically related.

By analogy with living microorganisms, Type 28 is interpreted as an endocyst of some kind, and the outer membrane is taken to be a cell wall. Some inner vesicles are in close contact with their membranes while others are a looser fit. The way in which the inner wall originated is not known - it could be formed de novo within a cell, or be the original cell wall thickened up within a protective sheath. No convincing proto-cysts have been found, though Type 29 could provide material for speculation.

From these arguments it is clear that there is no way of proving conclusively that the McMinn Formation microfossils represent prokaryotic or eukaryotic types. However, living prokaryotes are not known to produce regularly sculptured cysts like Types 1 and 2, or endocysts like Types 25 - 28 and 41. The balance of the evidence favours the eukarotes - certainly these are the most convincing Precambrian eukaryotes yet discovered.

D. Biostratigraphic interpretation

It is difficult to put this microbiota in evolutionary perspective, partly because of the difficulty of interpreting many reports of microfossils and partly because of the patchiness of the fossil record. Uncertainties of radiometric age are another hazard in this and many other assemblages.

There are many other uncertainties: the influence of facies on the distribution and preservation of OWMs has not been studied, Phanerozoic cryptarchs are hardly known, and the preservation and diagenesis of living microorganisms (except perhaps in algal mats) is not understood. The more detailed subdivision of the sphaeromorphs suggested here will hopefully lead to a greater understanding of their development and stratigraphic potential. These microfossils are the easiest subgroup to assess because of the valuable groundwork of Downie (1967; 1973).

Processes do not develop until at or near the base of the Cambrian, though very short spines have been reported from the Upper Riphean (Yankauskas, 1978; Vidal, 1976). Tubercular decoration is well developed in the Lower Ordovician (Lophosphaeridium rarum) and may reach back to the Lower Proterozoic (Protosphaeridium tuberculiferum) (Timofeev, 1959; 1969).

The earliest pores are Upper Riphean (Yankauskas, 1978) and are found in thin walled sphaeromorphs (Punctosphaeridium rifejicus (Yank.)) while thick-walled porate sphaeromorphs (Tasmanites) are uncommon before the beginning of the Ordovician though doubtfully recorded from the Lower Cambrian and Vendian (Timofeev, 1966). If my interpretation of Zonosphaeridium is correct (See Table 15, p.139), thick walled sphaeromorphs are known from the Upper Riphean (Timofeev, 1969).

Surface decoration in the form of meandering ridges (Stictosphaeridium) or reticulation (Favososphaeridium) is known from the Lower Proterozoic (Timofeev, 1966; 1969) though some material is open to reinterpretation.

Small sphaeromorphs with small inclusions are common from the Aphebian (Hofmann, 1976), but relatively large vesicles with large inclusions (Pterospermopsimorpha) are only common in the Riphean (Timofeev, 1966; 1969).

Nematomorphs are known from the Aphebian (Barghoorn & Tyler, 1965; Hofmann, 1976) though well preserved cellular trichomes are rare before the Upper Riphean (Oehler, 1977; Schopf, 1968; Schopf & Blacic, 1971). Narrow striated filaments (Oscillatorites) are known from the Upper Riphean (Shepeleva, 1960; Timofeev, 1966) and very broad ones from the Vendian (Gnilovskaya, 1971). One filament with large, thin walled cells has been reported from the Aphebian (the type specimen of Gunflintia magna) but others are only known from the Upper Riphean (Maithy, 1975; Timofeev et al, 1976). Branching filaments have not been found before the Lower Riphean (Licari, 1978; Schopf et al, 1977).

Small synaplomorphs are common in stromatolitic carbonates from the Aphebian on, but seem to grow larger at the base of the Riphean (Schopf & Oehler, 1976). These observations are restricted to benthonic stromatolitic microbiotas; large solitary sphaeromorphs are common in much older sediments. Membrane bound colonies are also known from the Aphebian (Hofmann, 1976; see also Oehler, 1978) though colonies of larger vesicles (Symplassosphaeridium) are only common in the Riphean (Timofeev, 1966; 1969). Colonies similar to Type 41 were previously only known from the Upper Riphean (Timofeev & German, 1974). Cellular differentiation has been doubtfully recorded from the basal Riphean (Myxomorpha, Muir, 1976) but is otherwise (Majaphyton) only known from the Upper Riphean (Timofeev et al, 1976).

It is very difficult to estimate the stratigraphic ranges of cryptarch taxa because of the present confusion in nomenclature and classification. Some of the Types described above can be referred to Archaean genera, others to Cretaceous ones. In terms of the general level of morphological complexity and overall similarity, the McMinn Formation assemblage most resembles microbiotas from Eastern Europe and the Baltic, and suggests a Riphean age, most likely Upper Riphean (950-680 Ma). This estimate differs from the radiometric age estimate of 1400 Ma (Lower Riphean) but this may only be because there are no other contemporaneous and well preserved shale assemblages.

Chapter 10

Summary

The Roper Group is a sequence of sandstones, siltstones and shales with minor carbonates and oolitic ironstones. It unconformably overlies the McArthur Group and its equivalents, and is unconformably overlain by Lower Cambrian and/or Cretaceous sediments. The Roper Group sediments were probably deposited as a large (400 x 600 km) epicontinental shelf in a slowly subsiding basin. Sedimentary structures typical of shallow water environments are abundant, but earlier reports of trace fossils have not been confirmed.

The lower part of the McMinn Formation at the top of the Group has been studied in more detail and is interpreted as two facies - the Moroak and Kyalla Members. The change in depositional environment from relatively low to higher energy is marked by the deposition of ironstones in a series of lenses and by rapid dewatering of the lower Moroak shales. The different facies of iron formation are interpreted as the result of varying conditions of sedimentation and differential diagenesis.

The radiometric age of the Roper Group has been estimated as 1400 Ma, but this figure should be treated with caution. On present palaeontological evidence the McMinn Formation is likely to be of Upper Riphean age (950-650 Ma). An age of about 1000 Ma is plausible, considering the present level of information on the Proterozoic fossil record.

Several techniques have been described in detail and their potential assessed. Translucency measurements on individual fossils require abundant material, take longer to make and are less precise and less sensitive indicators of kerogen rank than organic geochemical indicators such as H/C ratio. The measurement of the absorption spectra of dispersed kerogens could be a useful technique.

For most purposes the SEM is best used for the detailed examination of selected and carefully prepared specimens. A simple technique for the examination of the same specimen by LM and SEM

has been invaluable in working out the structure of some cryptarchs and has shown that several different fossils could not be distinguished by LM alone. A more complex technique has been developed for the examination of the same specimen by LM, SEM and TEM, and has given very promising results in the study of cryptarch walls.

Current approaches to the classification of OWMs have been reviewed and it is clear that OWMs cannot be classified in the same system as living microorganisms because they do not show the necessary characters. For practical purposes it has been suggested that the diagnosis of genera should be based on reliable characters visible by LM.

Morphological characters useful for the classification of OWMs have been evaluated and ranked. These characters have been used in the development of keys, and a new system of classification conceptually based on the Acritarcha. The group Acritarcha has been redefined and the new group Cryptarcha proposed and described. Because of the relative unreliability of inclusions, membranes and sheaths as diagnostic characters, the subgroup Disphaeromorphitae has been abandoned and taxa from it have been assigned to the Sphaeromorphitae. The diagnosis of the Sphaeromorphitae has been emended. Two new subgroups, the Nematomorphitae and Synaplomorphitae have been defined and attributed with the Sphaeromorphitae to the Cryptarcha. Many existing OWM taxa have been critically evaluated and classified in this new system.

A computerised data base system (Foscat) has been developed to deal with information on the occurrence, distribution, classification and nomenclature of fossils. This system provides an objective synthesis of the literature and has been invaluable in sorting out the nomenclature and status of many taxa. Two useful selections from the Foscat data base are tabulated in microfiche form as Appendices 6 and 7. Some other ways in which the system can be used have been described. Foscat is unique among existing data base packages and could be generalised to form a very flexible and efficient system for all kinds of data handling, storage and retrieval.

Fifty five different cryptarchs from the McMinn Formation have been described and illustrated. The commonest fossils are smooth sphaeromorphs and it is impossible to distinguish between hemispheres (valves) and flattened but complete spheres. It is also impossible to make out all the relevant features of some fossils without a combination of LM and SEM.

Some of the fossils described are probably degradational or preservational variants while others represent life cycles. Some sphaeromorph cryptarchs occur within thin membranes and are released from them via median splits. One synaplomorph type consists of separate vesicles within a membrane or common mucilage which are released by autolysis and fragmentation. Together with decorated sphaeromorphs, these fossils probably represent eukaryotic organisms; they are certainly the most convincing eukaryotic microfossils yet described from the Proterozoic.

Another type consists of broad filaments which could be of cyanobacterial affinity but probably represent either metaphytes or metazoan living tubes. Other sphaeromorph and synaplomorph cryptarchs show various inner bodies which are of uncertain significance. The fold patterns of the smooth sphaeromorph cryptarchs will probably provide a more useful basis for classification than other features such as vesicle surface texture or the presence of membranes or inclusions.

Micropalaeontologists studying Phanerozoic sediments have neglected the cryptarchs, and many of those studying Precambrian sediments have neglected various lithologies. I hope that this report will encourage further studies of shales and a unified and objective approach to the classification of OWMs from all facies. Together, these developments are a vital preliminary to the dating of significant evolutionary events and the future development of Precambrian biostratigraphy.

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Appendix 1

Stratigraphic columns, McMinn Formation, from diamond drill cores.

Compiled by K. A. Plumb, 1959.

Inside map pocket.

Appendix 2

Contents of core shed at Sherwin Creek.

Tray number	Hole	Contents
1	DDH C1	0'-22'0"
2		22'0"-41'8"
3		41'8"-72'10"
4		72'10"-95'5"
5		95'5"-99'6"
6		99'6"-132'10"
7		132'10"-164'7"
8		164'7"-191'6"
9	DDH C2A	0'-16'2"
10		16'2"-35'5"
11		35'5"-42'10"
12	DDH C2	0'-36'0"
13		36'0"-54'6"
14		54'6"-72'5"
15		72'5"-84'8"
16		84'8"-114'0"
17		114'0"-141'3"
18		141'3"-174'4"
19		174'4"-203'2"
20		203'2"-230'10"
21		230'10"-257'9"
22		257'9"-261'10"
23	DDH C3A	40'2"-58'9"
24		58'9"-77'0"
25		77'0"-94'2"
26	DDH C3	0'-24'2"
27		24'2"-42'3"
26A		42'3"-74'3"
27A		74'3"-109'1"
28		109'1"-143'6"
29		143'6"-161'0"
30	DDH C4	0'-18'11"

Tray number	Hole	Contents
31	DDH C4	18'11"-38'6"
32		38'6"-57'7"
33		57'7"-76'11"
34		76'11"-90'8"
35		90'8"-121'8"
36		121'8"-152'8"
37		152'8"-179'1"
38	DDH C5	0'-19'9"
39		19'9"-38'11"
40		38'11"-40'3"
41		40'3"-71'9"
42		71'9"-102'6"
43		102'6"-133'2"
44		133'2"-160'8"
45	DDH C6	0'-19'10"
46		19'10"-36'0"
47		36'0"-54'8"
48		54'8"-72'7"
49		72'7"-79'0"
50		79'0"-110'2"
51		110'2"-142'2"
52		142'2"-169'0"
53	DDH B7	0'-22'9"
54		22'9"-30'3"
55		30'3"-60'6"
56		60'6"-91'2"
57		91'2"-118'2"
58		118'2"-148'4"
59		148'4"-178'8"
60		178'8"-208'0"
61		208'0"-239'10"
62		239'10"-271'2"
63		271'2"-302'5"
64		302'5"-333'5"
65		333'5"-364'8"

/Appendix 2 continued

Tray number	Hole	Contents
66	DDH B7	364'8"-395'0"
67		395'0"-426'5"
68		426'5"-460'8"
69		460'8"-491'10"
70	DDH B8	0'-18'10"
71		18'10"-37'4"
72		37'4"-56'10"
73		56'10"-75'10"
74		75'10"-80'7"
75		80'7"-112'0"
76		112'0"-143'0"
77		143'0"-174'4"
78		174'4"-205'0"
79		205'0"-230'0"
80	DDH A9	0'-19'11"
81		19'11"-50'5"
82		50'5"-80'10"
83		80'10"-112'0"
84		112'0"-140'2"
85	DDH A10	0'-19'9"
86		19'9"-30'3"
87		30'3"-60'7"
88		60'7"-90'8"
89		90'8"-121'5"
90		121'5"-129'0"
91	DDH C11	0'-19'7"
92		19'7"-39'6"
93		39'6"-70'10"
94		70'10"-101'3"
95	DDH C12	0'-15'6"
96		15'6"-35'0"
97		35'0"-73'6"
98		73'6"-84'9"
99	DDH M13	0'-
100		-58'10"
101		58'10"-89'5"

Tray number	Hole	Contents
102	DDH M13	89'5"-120'11"
103		120'11"-151'0"
104		151'0"-184'0"
105		184'0"-216'0"
106		216'0"-247'6"
107		247'6"-
108		-
109	DDH M14	0'-24'5"
110		24'5"-34'5"
111		34'5"-64'5"
112		64'5"-94'3"
113		94'3"-123'9"
114		123'9"-155'0"
115		155'0"-186'4"
116		186'4"-217'3"
117		217'3"-248'4"
118		248'4"-268'2"
119	DDH M15	2'0"-26'5"
120		26'5"-45'2"
121		45'2"-76'0"
122		76'0"-106'7"
123		106'7"-137'3"
124		137'3"-168'0"
125		168'0"-200'0"
126		200'0"-216'0"
127	DDH U16	0'-19'2"
128		19'2"-49'0"
129		49'0"-79'0"
130		79'0"-109'8"
131		109'8"-142'0"
132		142'0"-172'3"
133	DDH M17	0'-44'10"
134		44'10"-80'0"
135		80'0"-94'0"
136	DDH U18	0'-20'0"
137		20'0"-50'3"

/ Appendix 2 continued

Tray number	Hole	Contents
138	DDH U18	50'3"-81'3"
139		81'3"-112'6"
140		112'6"-143'6"
141		143'6"-175'1"
142		175'1"-201'0"
143	DDH T19	0'-21'8"
144		21'8"-51'10"
145		51'10"-82'0"
146		82'0"-122'10"
147		122'10"-151'11"
148		151'11"-167'8"
149	DDH W20	0'-24'3"
150		24'3"-41'2"
151		41'2"-71'0"
152		71'0"-103'0"
153		103'0"-130'0"
154		130'0"-165'0"
155		165'0"-200'0"
156		200'0"-230'0"
157		230'0"-250'6"
158	DDH W21	0'-29'2"
159		29'2"-30'4"
160		30'4"-61'6"
161		61'6"-92'0"
162		92'0"-123'3"
163		123'3"-152'2"
164		152'2"-157'10"
165	DDH W22	0'-20'0"
166		20'0"-35'2"
167		35'2"-83'0"
168		83'0"-107'0"
169		107'0"-138'0"
170	DDH W23	0'-19'1"
171		19'1"-20'0"
172		20'0"-50'7"
173		50'7"-81'7"

/ Appendix 2 continued

Tray number	Hole	Contents
174	DDH W23	81'7"-118'9"
175		118'9"-148'9"
176		148'9"-171'0"
177	DDH W24	0'-16'3"
178		16'3"-35'8"
179		35'8"-65'6"
180		65'6"-83'2"
181	DDH W25	0'-21'8"
182		21'8"-28'10"
183		28'10"-60'0"
184		60'0"-92'1"
185		92'1"-123'4"
186		123'4"-146'10"
187		146'10"-170'4"
188		170'4"-194'0"
189		194'0"-217'3"
190		217'3"-222'3"
191	DDH W26	0'6"-16'3"
192		16'3"-47'1"
193		47'1"-c.79'
194		c.79'-89'0"
195	DDH W27	0'-19'2"
196		19'2"-41'3"
197		41'3"-84'8"
198		84'8"-102'4"
199		102'4"-132'0"
200		132'0"-162'9"
201		162'9"-193'2"
202		193'2"-222'0"
203		222'0"-230'7"
204	DDH X28	0'-17'10"
205		17'10"-40'11"
206		40'11"-64'3"
207		64'3"-87'8"
208		87'8"-111'3"

/ Appendix 2 continued

Tray number	Hole	Contents
209	DDH X28	111'3"-134'10"
210		134'10"-167'9"
211		167'9"-189'10"
212		189'10"-202'0"
213		202'0"-236'0"
214		236'0"-258'5"
215		258'5"-273'5"
216	DDH X30	0'-21'2"
217		21'2"-43'2"
218		43'2"-65'9"
219		65'9"-88'2"
220		88'2"-110'3"
221		110'3"-133'2"
222		133'2"-156'3"
223		156'3"-179'2"
224		179'2"-203'8"
225		203'8"-225'10"
226		225'10"-244'11"
227		244'11"-261'11"
228	DDH X31	0'-21'6"
229		21'6"-43'8"
230		43'8"-66'0"
231		66'0"-88'7"
232		88'7"-110'8"
233		110'8"-129'0"
234		129'0"-137'6"
A	DDH X38	280'5"-370'11"
B		154'0"-185'0"
C		258'0"-280'5"
D		213'0"-258'0"
E		185'0"-213'0"
F		123'0"-154'0"
G		90'3"-123'0"
H		60'1"-90'3"

/ Appendix 2 continued

Tray number	Hole	Contents
A	DDH W23	514'0"-519'0"
B		482'3"-514'0"
C		450'8"-482'3"
D		420'4"-450'8"
E		385'0"-420'4"
F		358'2"-385'0"
G		327'0"-358'2"
H		295'8"-327'0"
I		264'5"-295'8"
J		232'0"-264'5"
K		202'0"-232'0"
L		171'4"-202'0"
A	DDH U33	352'7"-373'9"
B		326'0"-352'7"
C		297'0"-326'0"
D		266'0"-297'0"
E		234'8"-266'0"
F		205'0"-234'8"
G		174'0"-205'0"
H		143'6"-174'0"
I		112'0"-143'6"
J		82'0"-112'0"
K		50'7"-82'0"
L		33'0"-50'7"
M		0'-33'0"
A	DDH W27	510'0"-518'9"
B		478'6"-510'0"
C		447'3"-478'6"
D		417'0"-447'3"
E		386'0"-417'0"
F		354'4"-386'0"
G		323'3"-354'4"
H		292'0"-323'3"
I		261'0"-292'0"
J		230'8"-261'0"

Tray number	Hole	Contents
A	DDH U34	476'0"-505'6"
B		446'0"-476'0"
C		409'0"-446'0"
D		378'0"-409'0"
E		348'-378'
F		322'-348'
G		290'-322'
H		256'-290'
I		226'-256'
J		194'-226'
K		162'-194'
A	DDH U32	197'-231'
B		169'4"-197'
C		138'-169'4"
D		107'-138'
E		76'-107'
F		45'-76'
G		32'-45'
H		Fragments
A	DDH U37	179'0"-191'0"
B		153'-179'
C		110'-153'
D		84'7"-110'0"
E		53'2"-84'7"
A	DDH U36	222'6"-232'8"
B		187'-222'6"
C		161'0"-187'
A	DDH U35	318'0"-333'6"
B		286'3"-318'0"
C		254'0"-286'3"
D		223'6"-254'0"
E		192'0"-223'6"
F		162'5"-192'0"

Appendix 3

Samples taken from the core shed

A. Original samples. K. A. Plumb to M. D. Muir, 1972

Now in the collection of C. J. Peat.

DDH A9 71'11"-72'1"
DDH A9 137'6"-137'8"
DDH A10 121'6"-121'8"
DDH B8 143'4"-143'5"
DDH C3 101'0"-101'2"
DDH C5 155'11"-156'1"
DDH C6 94'11"-95'2"
DDH A9 73'8"-73'10"
DDH A10 65'0"-65'3"
DDH B7 167'0"-167'2"
DDH B8 173'3"-173'5"
DDH C5 81'11"-82'1"
DDH C6 80'2"-80'4"
DDH C6 154'2"-154'4"

Sample A/320/2, studied by Norvick (1970) came from DDH U37 120'-166' (D. M. McKirdy, pers.comm. 1973).

B. Original samples. K. A. Plumb to D. M. McKirdy, 1972

DDH A9 72'1"-72'2"
DDH A10 65'3"-65'6"
DDH B7 167'2"-167'3"
DDH B8 173'1"-173'3"
DDH C5 82'1"-82'3"
DDH C6 80'0"-80'2"
DDH C6 154'4"-154'6"
DDH A9 73'6"-73'8"
DDH A10 121'8"-121'10"
DDH B8 143'0"-143'1"
DDH C3 101'2"-101'3"
DDH C5 155'10"-155'11"
DDH C6 85'6"-85'9"

C. Samples of T. C. Hoering, 1967

Probably from the interval DDH U33 234'8"-326'0" judging by gaps in trays C, D and E of this hole.

D. Samples collected in 1975

In the collection of C. J. Peat.

* indicates that the sample was split and that half of it is either in another collection or still in the core shed.

DDH A10 38'1"-38'2"
39'6½"-39'8"
58'5½"-58'6½"
64'1¼"-64'2"
39'2½"-39'3"
40'1½"-40'2"
61'10½"-62'0"
66'4"-66'5"

DDH A10	68'5½"-68'7"	83'10"-84'0"
	103'2"-103'6½"	109'9"-109'10"
	119'9"-119'11"	120'9"-120'10"
	122'8½"-123'1"	128'10"-128'11"
DDH A9	16'4"-16'6"	33'7"-33'10"
	39'9"-40'3"	41'1"-41'2"
	41'9"-41'10"	44'10"-44'11"
	48'6"-48'7"	56'1"-56'2"
	76'3"-76'4½"	79'1"-79'2"
	97'11"-98'0"	104'9"-104'10"
	107'10"-107'11"	111'0"-111'1"
	125'0"-125'1½"	
DDH B8	47'5"-47'6"	55'6"-55'9½"
	58'8"-58'9"	67'5"-67'5½"
	77'10"-77'11"	86'2½"-86'3"
	95'9"-95'10½"	93'9"-94'0"
	95'5"-95'5½"	104'0"-104'1"
	110'10½"-111'0"	113'10"-113'11"
	125'5"-125'7"	126'7"-126'9"
	131'3"-131'4"	149'0"-149'1"
	155'7"-155'9"	162'5"-162'7"
	166'4½"-166'6½"	170'2"-170'6½"
	167'0"-167'1½"	174'1"-174'6"
	179'3"-179'4½"	195'10"-196'0"
	206'11"-207'1"	210'1½"-210'2½"
	228'8½"-228'10"	
DDH B7	33'1"-33'2"	56'5"-56'6"*
	74'2"-74'3"	102'2"-102'2½"
	105'2"-105'5½"	123'2"-123'7"
	134'10½"-134'11"	136'5"-136'6"
	146'7½"-146'9"	149'10"-149'11"
	184'3"-184'4"	199'8"-199'9"
	209'1½"-209'2½"	215'7"-215'8"
	217'5"-217'5½"	377'8"-378'1"
	378'9"-378'9¼"	379'1½"-379'2"
	380'8"-380'8½"	381'6½"-381'7"
	381'3"-381'3½"	384'0"-384'0½"
	385'0"-385'0½"	386'8½"-386'9"

DDH B7	388'10"-388'10½"*	389'6"-389'7"*
	391'2"-391'2½"	392'5"-392'6"*
	393'11½"-394'1½"*	403'7"-403'7½"
	416'4"-416'5½"	422'0½"-422'1½"
	431'6"-431'7"	451'8"-451'10"
	466'8"-466'9"	474'3"-474'5"
	491'5½"-491'6"	
DDH C2	53'2½"-53'3"	100'1"-100'2"
	197'10½"-197'11½"	
DDH C6	59'3"-59'4"	104'5"-104'6"
	138'5"-138'6"	155'4"-155'5"
DDH C5	29'8"-29'9"	41'1"-41'2"
	76'1½"-76'2½"	120'1"-120'2"
	134'7"-134'8"	
DDH C3	126'6"-126'7"	130'6"-130'7½"
	157'6"-157'7"	
DDH C4	43'5"-43'6"	66'0½"-66'4½"
	80'1½"-80'2"	154'11"-155'1"
	168'11"-169'0"	
DDH C11	29'0"-29'1"	42'11"-43'1"
	45'5"-45'6"	78'0"-78'1"
	90'10"-91'0"	
DDH C12	36'9"-36'10"	65'1½"-65'2½"
	76'5½"-76'7"	
DDH M14	72'9"-72'11"	73'4"-73'8"
	98'5"-98'6½"	150'5"-150'6½"
	161'1"-161'2"	207'10"-207'11"
	233'10"-233'11"	245'0"-245'6"
	250'6½"-250'8"	258'0"-258'4"
	263'11"-264'3½"	

/ Appendix 3 continued

DDH M15	39'4½"-39'5"	58'2½"-58'4"
	70'5½"-70'6½"	90'9½"-90'10"
	155'4"-155'5½"	173'5"-173'7"
	213'10"-214'6"	
DDH M17	72'8½"-72'10"	79'9"-79'11"
DDH X30	70'6"-70'8"	
DDH C1	145'2"-145'4"	160'4½"-160'6"
	189'3½"-189'4½"	
DDH X31	132'5"-132'7"	
DDH X28	79'6"-79'7½"	79'9½"-79'11"
	80'3"-80'4"	105'3½"-105'5"
	113'3"-113'4½"	149'2"-149'4½"
	94'6"-94'8"	
DDH W27	169'0"-169'2"	71'6½"-71'8"
	88'1"-88'2½"	98'0½"-98'3"
	72'1"-72'2"	
DDH W25	65'8½"-65'10"	102'0"-102'2"
	162'10"-163'0"	184'2"-184'4"
DDH W23	45'0"-45'1½"	110'8"-110'9"
	50'9"-50'11"	127'9"-127'11"
	150'1½"-150'3"	153'0"-153'1½"
	49'1"-49'4"	
DDH W21	107'3"-107'6"	119'3½"-119'5"
DDH W22	24'4"-24'6"	83'9"-83'10"
	93'6"-93'8"	115'3"-115'4"
	120'3"-120'7"	

DDH M13	76'5½"-76'6½"	87'10"-87'11"
	89'9"-89'10½"	252'6"-252'8"*
	269'6½"-269'7½"	284'4"-284'10½"
DDH T19	59'10½"-60'0"	61'5"-61'8"
	133'0½"-133'2½'	142'4½"-142'6"
	133'10"-134'0½"	137'5"-137'7"
	154'8"-154'10"	
DDH U16	48'3"-48'5"	73'4"-73'6"
	132'2"-132'5"	149'9"-149'10"
	157'4"-157'6"	
DDH U18	34'9"-34'10"	58'8"-58'9"
	73'6"-73'8"	97'10"-98'0"
	101'10"-102'0"	120'0"-120'1"
	144'6"-144'7½"	196'3"-196'5"
DDH U32	82'6"-82'9"	145'0"-145'2"
	191'9"-192'0"	184'3"-184'5"
DDH U33	63'6"-63'8½"	90'1"-90'4"
	109'2"-109'4"	140'7"-140'10½"
	257'0"-257'1"	289'9"-289'10"
	288'10"-288'11"	305'5"-305'6"
	317'7"-317'9"	350'1"-350'2"
	364'11"-365'2"	367'7"-367'8½"
	c. 304'6"	
DDH U34	225'10"-226'0"	239'1"-239'2"
	291'10"-291'11"	324'1"-324'3"
	429'1"-429'3"	434'2"-434'4"
	451'8"-451'10"	
DDH U35	218'4"-218'6"	241'5"-241'6"
	234'5"-234'6"	257'5½"-257'7"
	324'8"-324'10"	

/ Appendix 3 continued

DDH U36	184'8"-184'10"	224'9"-224'11"
DDH U37	62'5"-62'7"	142'2½"-142'3½"
DDH W20	138'11"-139'1"	92'8½"-92'10½"
	181'6"-181'7"	231'8"-231'11"
	236'7"-236'9"	
DDH W23	214'5"-214'6"	245'6"-245'7½"
	292'8"-292'10"	358'9"-358'11"
	371'0"-371'2"	387'2"-387'5"
	394'9½"-394'11"	469'11"-469'12"
	499'5"-499'6"	
	518'4"-518'6"	
DDH W27	276'2"-276'4"	285'10"-286'1"
	294'3"-294'5"	315'9"-315'10"
	323'10"-323'11½"	341'5"-341'7"
	360'8½"-361'0"	402'2"-402'4"
	429'5"-429'6½"	441'2"-441'5"
	456'5"-456'7"	504'4"-504'6"
	516'0"-516'1"	

E. Samples collected in 1975

In the collection of D. M. McKirdy.

* indicates that the sample was split and that half of it is either in another collection or still in the core shed.

DDH A10	39'3"-39'3½"	64'1"-64'1¼"
DDH B7	102'2½"-102'3"	123'1"-123'2"
	134'11"-134'11½"	209'2½"-209'3½"
	215'8"-215'9"	217'5½"-217'6"
	378'9¼"-378'10"	379'1"-379'1½"
	380'8½"-380'9"	381'6"-381'6½"
	381'2½"-381'3"	383'11"-383'11½"
	385'0½"-385'1"	386'8"-386'8½"
	388'10"-388'10½"*	389'6"-389'7"*
	391'1½"-391'2"	392'5"-392'6"*
	393'11½"-394'1½"*	403'6½"-403'7"

/ Appendix 3 continued

DDH B7	416'3"-416'4"	422'0"-422'0½"
	431'7"-431'8"	451'10"-452'1"
	475'6"-475'9"	491'5"-491'5½"
	56'5"-56'6"*	74'3"-74'4"
DDH C1	189'2"-189'3½"	
DDH C2	53'2"-53'2½"	100'0"-100'1"
DDH C3	157'7"-157'8"	
DDH C4	43'3"-43'5"	80'1"-80'1½"
	168'10"-168'11"	
DDH C5	29'5"-29'8"	76'0"-76'1½"
DDH C6	155'3"-155'4"	
DDH C11	28'10"-29'0"	41'0"-41'2½"
	90'8"-90'10"	
DDH C12	36'8"-36'9"	
DDH M13	76'3"-76'5½"	87'9"-87'10"
	89'10½"-90'1"	252'6"-252'8"*
	269'5"-269'6½"	
DDH M14	72'8"-72'9"	150'6½"-150'9½"
	160'10"-161'1"	207'11"-208'1"
	233'8½"-233'10"	250'5"-250'6½"
DDH M15	39'3"-39'4½"	70'4"-70'5½"
	90'10"-91'0½"	155'2"-155'4"
	173'3"-173'5"	
DDH U18	73'5"-73'6"	
DDH U32	184'5"-184'6"	

DDH U33	289'8"-289'9"	364'9"-364'11"
	367'6"-367'7"	
DDH W20	231'6"-231'8"	
DDH W22	83'10"-84'0"	
DDH W23	45'1½"-45'3"	150'0½"-150'1½"
	214'3"-214'5"	358'11"-359'0"
	371'2"-371'3"	387'5"-387'6"
	394'11"-395'0"	518'3"-518'4"
DDH W25	65'7"-65'8½"	184'0"-184'2"
DDH W27	97'10½"-98'0½"	169'2"-169'3½"
	285'8"-285'10"	341'7"-341'9"
	360'6"-360'8½"	429'6½"-429'8"
	441'0"-441'2"	456'3"-456'5"
	504'6"-504'8"	516'1"-516'2"
DDH T19	61'8"-61'9"	132'11"-133'0½"
	133'8"-133'10"	
DDH X28	79'8"-79'9½"	

F. Samples collected in 1975

In the collection of T. Donnelly (BMR). Collected for sulphur isotope studies.

* indicates that the sample was split and that half of it is either in another collection or still in the core shed.

DDH A9	67'9"-67'11"	
DDH A10	119'11"-120'0½"	
DDH B8	77'10"-77'11"*	
DDH C2	197'10"-197'10½"	250'0"-250'1"
DDH C4	97'5"-97'6"	154'9"-154'11"
DDH W27	263'5"-263'7"	

Appendix 4

Logs of diamond drill holes in the McMinn Formation

This list excludes holes logged by K. A. Plumb (Appendix 1). Unless otherwise stated the core logged here is stored in the core shed at Sherwin Creek and the logs were compiled with M. D. Muir in 1975.

DDH C1

0'-8'	Chamositic oolitic sandstone
8'-21'8"	Weathered red shale
21'8"-41'8"	Haematitic pisolitic ore, some chamosite
41'8"-54'	Chamositic silt and shale
54'-58'6"	Chamositic, haematitic silt and shale
58'6"-62'	Weathered shale
62'-73'6"	Pisolitic haematite
73'6"-75'	Weathered shale
75'-76'	Chamositic oolite
76'-77'3"	Weathered shale
77'3"-97'	Pisolitic oolitic haematite
97'-99'6"	Chamositic sandstone
99'6"-148'10"	Grey, green and black shale
148'10"-150'10"	Chamositic sandstone
150'10"-163'6"	Siltstone with some oolites and shale partings
163'6"-166'	Haematitic oolite
166'-191'6"	Variegated black, green and grey shales with silts, clasts etc.

DDH MV29A

Location of core unknown, probably NTDM. Information kindly supplied by P. W. Crohn, NTDM from core logs submitted by BHP (Pers.comm to M. D. Muir, 17.6.1975).

0'-24'	Alluvium
24'-37'	Gravel and alluvium
37'-52'	Alluvium
52'-57'	Weathered limestone
57'-65'	Silicified limestone

/ Appendix 4 continued

65'-66'	Weathered limestone
66'-158'	Silicified limestone
158'-166'	Interbedded sandstone and shale

DDH T19

0'-35'6"	Soil and very weathered green and purple shales
35'6"-40'10"	Green and purple shales. Some fine sandstone laminations and mud cracks
40'10"-83'6"	Green and black shales. Some thin (15 cm) cross bedded sandstones
83'6"-84'6"	Coarse grained oolitic sandstone with clasts
84'6"-98'	Black, green and grey shales
98'-120'6"	Quartzite. Current bedded with some shale partings and clasts.
120'6"-136'	Black, green and grey shales. Some thin (less than 15 cm) sandstone partings
136'-138'	Chamositic oolites
138'-149'8"	Haematitic oolites, some shale partings
149'8"-156'	Chamositic sandstone and siltstone
156'-157'10"	Shale and siltstone. Some chamositic oolites
157'10"-159'10"	Coarse sandstone
159'10"-167'8"	Siltstone and sandstone with Moroak-type mud cracks

DDH U16

0'-5'	Soil
5'-37'7"	Variegated purple and green shales
37'7"-151'	Variegated grey, green and black shales with thin (less than 15 cm) sandstone partings
151'-166'	Ore zone. Chamositic oolitic haematite
166'-172'3"	Black shales with thin quartzites and Moroak-type structures.

/ Appendix 4 continued

DDH U18

0'-8'	Earth
8'-27'11"	Weathered purple and green shales
27'11"-182'6"	Green, grey and black shales with minor (less than 15 cm) sandstone partings
182'6"-192'	Chamositic oolitic sandstone grading in 15 cm to haematitic oolitic iron ore
192'-194'	Chamositic with shale partings
194'-196'	Haematitic oolitic ore
196'-197'8"	Chamositic ore
197'8"-201'	Black shales.

DDH U32

32'-40'	Green and purple shales
40'-122'	Grey, green, black and variegated shales with some mud cracks
122'-126'	Sandstone parting
126'-185'	Shale with thin sandstone partings
185'-203'6"	Ore zone. Haematitic, pisolitic oolites
203'6"-231'	Quartzites with shale partings and mud cracks.

DDH U33

0'-14'	Earth
14'-43'7"	Weathered red and green shales
43'7"-345'	Grey, green and black shales
345'-362'	Haematitic, chamositic oolitic iron formation
362'-366'	Grey and black shales
366'-373'9"	Sandstone with shale partings and mud cracks.

DDH U34

162'-482'	Variegated grey, green and black shales with sandstone partings up to 30 cm.
482'-498'	Ore zone. Haematitic, oolitic, chamositic ore
498'-502'	Black shale
502'-503'6"	Quartzite.

/ Appendix 4 continued

DDH U35

162'5"-287'	Variegated grey, green and black shales with minor sandstone partings (less than 15 cm.)
287'-312'	Green and grey shales with mud cracks
312'-325'5"	Sandstone with haematitic, chamositic oolitic ore
325'5"-333'6"	Fine sandstone with siltstone partings

DDH U36

161'-211'	Green, grey, black and variegated shales with some sandstone partings.
211'-223'	Haematitic, oolitic and chamositic ore zone
223'-232'8"	Fine sandstone with siltstone partings.

DDH U37

53'2"-148'	Greenish grey variegated sandstones and shales with some black shales.
148'-148'9"	Sandstone parting
148'9"-162'4"	Ore zone with haematitic, oolitic chamositic ironstone
162'4"-191'	Variegated greenish-grey siltstones.

DDH W20

0'-6"	Soil
6"-33'	Grey and green shales
33'-232'5"	Grey, green and black shales with ferruginous flecks.
232'5"-241'	Chamositic oolitic ore with shale partings
241'-250'6"	Quartzite, cross bedded, with some ooliths and shale partings with mud cracks.

/ Appendix 4 continued

DDH W21

0'-2'	Soil
2'-33'4"	Weathered red and green clays
33'4"-37'4"	Pink quartzite
37'4"-96'	Purple, green and black shales. Some sandstone bands, cross-bedded, upward fining
96'-102'	Ferruginous sandstone with some clay partings
102'-130'	Purple and green shales, some mud cracks and sandstone partings
130'-143'3"	Haematitic oolitic ore
143'3"-145'9"	Shale parting
145'9"-157'10	Ferruginous sandstone. Some shale partings

DDH W22

0'-27'	Weathered purple, red and green shales
27'-102'6"	Green and black shales and sandstone partings, cross bedding and slump structures
102'6"-112'	Haematitic oolitic ore
112'-118'	Chamositic oolitic ore with shale partings
118'-120'	Haematitic oolitic ore
120'-138'	Ferruginous sandstone and shale partings. Mud cracked shale to base.

DDH W23

0'-8'	Soil
8'-34'6"	Weathered green and purple shales
34'6"-154'9"	Black, green and grey shales, some sedimentary structures at bottom
154'9"-161'9"	Ore zone. Chamositic oolitic ore
161'9"-165'9"	Grey shale with 5 cm sandstone bands
165'9"-171'	Quartzite, some shale partings
171'-239'	Fine sandstone, some current bedded. Some shales with mud cracks
239'-519'	Fine green, grey, black and purple shales, mudstones, thin micaceous laminae

/ Appendix 4 continued

DDH W24

0'-10'	Soil
10'-49'	Red and green shales with clay partings. Green, grey and black shales at bottom.
49'-59'	Fine white sandstone with some shale partings, some chamositic and haematitic horizons
59'-83'2"	Quartzite.

DDH W25

0'-5'	Soil
5'-23'	Weathered shale
23'-31'10"	Grey and red shales. Probably weathered
31'10"-153'	Grey green and black shales with some 15 cm sandstone partings
153'-157'4"	Medium grained chamositic sandstone
157'4"-190'	Black, green and grey shales without any sandstone partings
190'-196'	Quartzite
196'-199'	Black and green shales
199'-210'	Green chamositic sandstone with some ooliths and partings of disturbed silt
210'-222'3"	Quartzite

DDH W26

0'-8'	Soil
8'-24'	Weathered red, green and grey clay
24'-62'1"	Fine sandstone with clay and siltstone partings; some black shale near bottom
62'1"-76'1"	Haematitic oolitic ore zone
76'1"-89'	Coarse chamositic sandstone with clay partings to base. 19" length of dolerite loose in core tray.

DDH W27

0'-19'2"	Soil
19'2"-24'	Weathered red shales
24'-211'	Green, grey and black shales and mudstones with some sandstone lenses near bottom. Lenses less than 30 cm thick.
211'-230'8"	Mudcracked shales and sandstones
230'8"-272'	White sandstones and shales with mud cracks and coarse sandstone (50 cm) at top
272'-286'	Black shale
286'-323'	Alternating current bedded white sandstone and black shale
323'-518'9"	Black shale, some greenish grey silt partings.

DDH X28

0'-8'2"	Soil
8'2"-20'2"	Weathered red and green shale
20'2"-177'9"	Black and green shale, sedimentary structures and some silty bands
177'9"-180'9"	Fine grained quartzite
180'9"-187'	Black and green shales
187'-189'4"	Oolitic sandstone with some shale partings
189'4"-201'	Black and green shales
201'-217'8"	Pisolitic, haematitic, chamositic sandstone
217'8"-219'5"	Black and green shales
219'5"-237'3"	Coarse quartzite with shale partings
237'3"-241'8"	Siltstone with sedimentary structures
241'8"-273'5"	Fine sandstone with chamositic oolites, some silty partings and sedimentary structures.

DDH X30

0'-12'10"	Lateritic soil
12'10"-24'1"	Light grey, rather uniform, weathered shale
24'1"-49'2"	Green and purple micaceous shales and silts with some bedded sandstones
49'2"-88'2"	Green and black interlaminated shales

/ Appendix 4 continued

88'2"-114'	Greenish silt with mud cracks and fine partings
114'-114'4"	Sandy greenish grey siltstones.
114'4"-144'	Greenish silts with mud cracks and fine partings
144'-148'	Purple and green shales
148'-183'2"	Green, black and light brown silts
183'2"-208'	Green and purple shales, some sandstone partings and oolites
208'-224'	Chamositic sandstone
224'-244'	Greenish and purplish shales
244'-247'8"	Haematitic oolitic ore
247'8"-251'8"	Green and grey shales
251'8"-257'10	Oolitic, chamositic sandstone
257'10"-261'11"	Silts with abundant mud cracks.

DDH X31

0'-19'6"	Soil
19'6"-32'7"	Weathered red and green shales
32'7"-36'	Sandstone.
36'-89'5"	Green, grey and black shales
89'5"-94'2"	Fine white quartz sandstone
94'2"-98'7"	Grey shales, ferruginous at base
98'7"-104'	Fine silt and greenish, greyish shale with some slump structures
104'-122'	Green, grey and black shales
122'-124'	Chamositic oolitic ore
124'-130'	Pisolitic, oolitic, haematitic ore
130'-139'6"	Fine white carbonate-banded sandstone, pinkish with some black shale partings.

DDH X38

60'1"-248'	Black, green and grey shales with some sandstone partings
248'-264'	Quartzite
264'-291'	Green and grey shales with brown partings
291'-296'	Chamositic, oolitic ore zone
296'-370'	Quartzite coarsening downwards.

Appendix 5

Co-ordinates of 'x' on front left corner of microscope slides

MAC DDH B7 74'2-1 1450-032
MAC DDH B7 74'2-2 1432-029
MAC DDH B7 74'2-3 1434-027
MAC DDH B7 74'2-4 1422-028
MAC DDH B7 74'2-5 1407-023
MAC DDH B7 74'2-6 1437-025
MAC DDH B7 74'2-7 1426-033
MAC DDH B7 74'2-8 1417-048
MAC DDH B7 74'2-9 1406-049
MAC DDH B7 74'2-10 1405-042
MAC DDH B7 74'2-11 1410-036

MAC DDH M14 73'8-10 1404-031
MAC DDH M14 150'5-1 1406-037
MAC DDH M14 245'6-2 1407-044
MAC DDH M14 250'8-1 1400-039
MAC DDH M14 250'8-3 1278-054
MAC DDH M14 250'8-8 1312-060
MAC DDH M14 250'8-12 1212-090
MAC DDH M14 250'8-15 1396-054
MAC DDH M14 250'8-18 1393-061
MAC DDH M14 250'8-20 1409-040
MAC DDH M14 258'0-1 1336-040
MAC DDH M14 258'0-2 1357-053

MAC DDH M15 173'5-1 1408-036

TS DDH A9 73'9-12 1267-025
TS DDH A9 73'9-19 1367-050

TS DDH B7 74'2-9 1417-033

TS DDH B8 143'0-7 1356-046
TS DDH B8 143'0-9 1348-026

TS DDH M14 250'8-1 1396-047

TS DDH M15 173'5-1 1390-046

Appendix 6

Foscat - fossil catalogue - bibliography

Microfiche - inside back cover.

Appendix 7

Foscat - fossil catalogue - species list

Microfiche - inside back cover.

Plates 1 - 31

Slides are referred to in the standard format used throughout this report (See p.1).
Locations on slides are given by microscope stage co-ordinates. Each slide has a reference cross on the front left corner. The co-ordinates of these marks are given in Appendix 5 (p.296).

In this convention

MAC DDH M14 250'8-15/1000-200

means slide number 15 prepared from a macerate of a sample from the 250'8 level of diamond drill hole number M14. The prefix TS denotes a thin section. Co-ordinates are not given for specimens prepared for SEM. In each sample, picked specimens are numbered for reference F1, F2 etc. meaning fossil 1 ...

All slides are in the working collection of C J Peat at the Royal School of Mines, London. They will eventually be deposited at the CPC, Bureau of Mineral Resources, Canberra, Australia.

Plate 1

Scale bar E - H = 5.0 cm.

A. Mount McMinn from the East. Locality 1 is on the right shoulder (arrowed).

B. Hells Gate ridge from near locality 2.

C. Mountain Valley Limestone at 14°7'S 133°50'E.

D. Hodgson Sandstone at Hells Gate ridge, near locality 2.

E. Selection of mud cracks and contorted sandstone dykes from locality 1. The shale weathers away, leaving the sandstone dykes in relief. The central round marking is probably the mould of a gas pit (cf Conybeare & Crook, 1968,pl.75c).

F. Sun cracks or mud cracks in Kyalla Shale at 14°56'S 133°48'E.

G. Mud cracks in Munyi Member at Hells Gate, near locality 2.

H. Sinuous, multi-filled mud cracks in Kyalla Shale. Sample 32*.

* See tables 2 and 3 for more information.

PLATE 1.



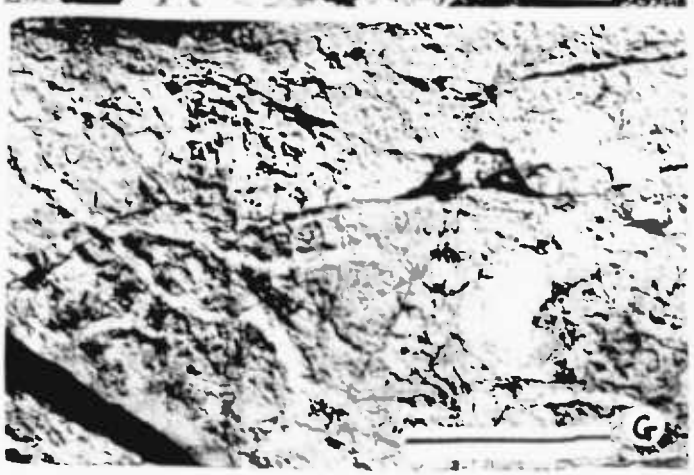












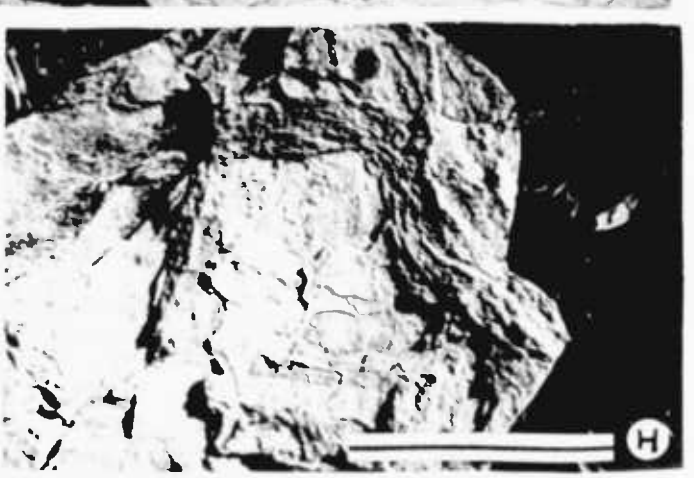


Plate 2

Scale bar A - H = 5.0 cm.

A. Small mud cracks on ripple-marked slab. Moroak Sandstone Member, locality 1.

B. Ripple-marked slab with mud-crack casts. Sample 1*.

C. Sandstone dykes, grade in size from left to right. Sample 5*.

D. Contorted sandstone dykes with some shale still between them. Sample 12*.

E. Ripple and rill marks in the Moroak Sandstone Member at locality 1.

F. Samples 23-25*. Mud cracks casts and clay pellet casts.

G. Sample 18*. Braided channel casts.

H. Ripple marks with transverse drag marks. The ripple marks have an amplitude of 0.8 cm and the drag marks cut up to 4.0 mm into the crests of the ripples. Moroak Sandstone at locality 1. This slab was left in the Core Shed at Gum (Sherwin) Creek.

* See tables 2 and 3 for more information.

PLATE 2.

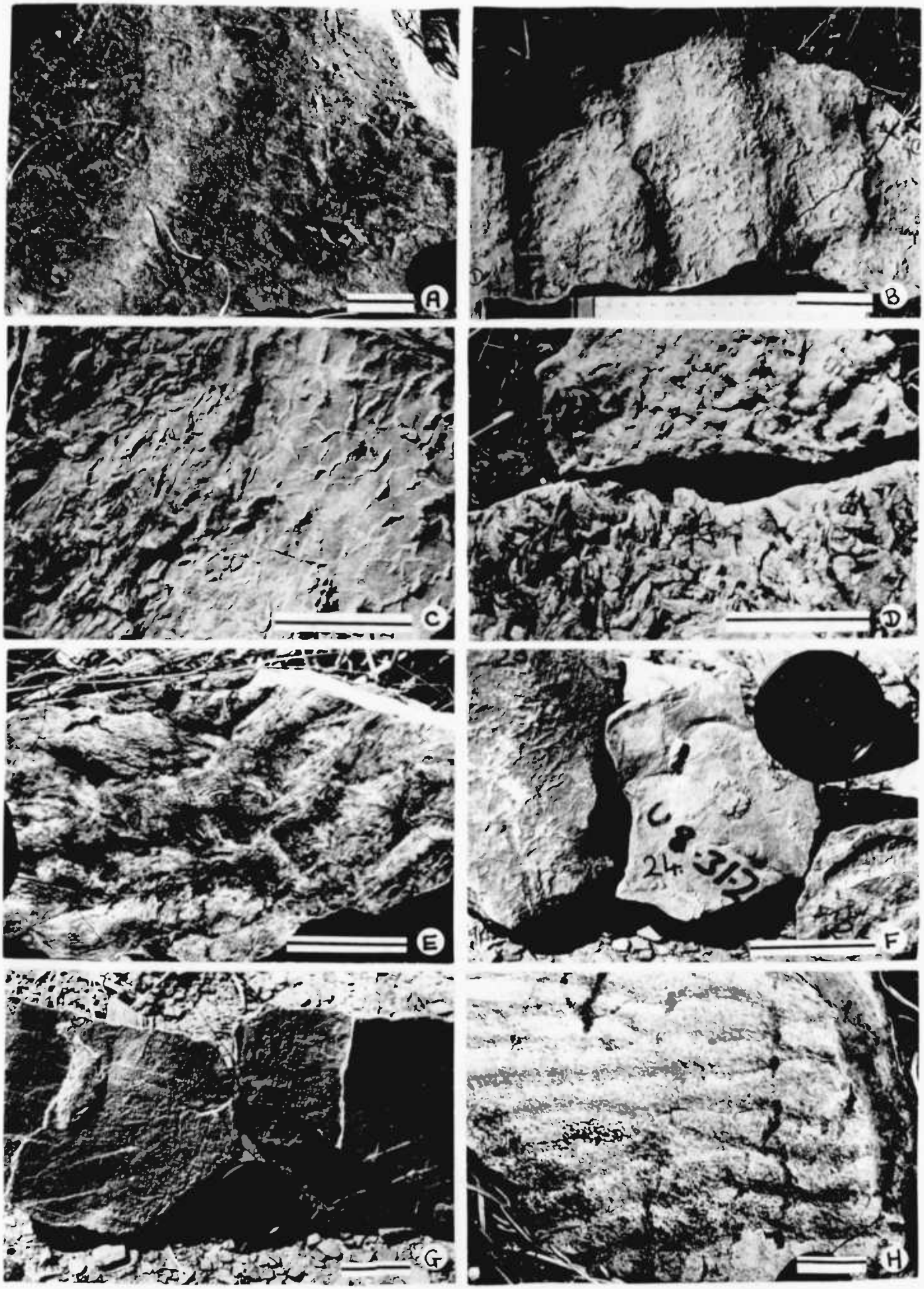


Plate 3

Scale bar A - H = 5.0 cm.

A. Interference ripple marks. Sample 27*.

B. Interference ripple marks and/or compaction structures. Scree material at $15^{\circ}7\frac{1}{2}'S$ $133^{\circ}59\frac{1}{2}'E$.

C. Large clay gall marks in fine sandstone. Part of this slab was collected as sample 21*.

D. Strand-line casts. Sample 20*.

E. Sub-parallel rill marks on a rippled surface. Sample 26*.

F. Bubble impression with drag mark or strand-line cast. Sample 17*.

G. Samples 28-30*. Clay gall casts and brush markings.

H. Brush marks. Sample 31*.

* See tables 2 and 3 for further information.

PLATE 3.

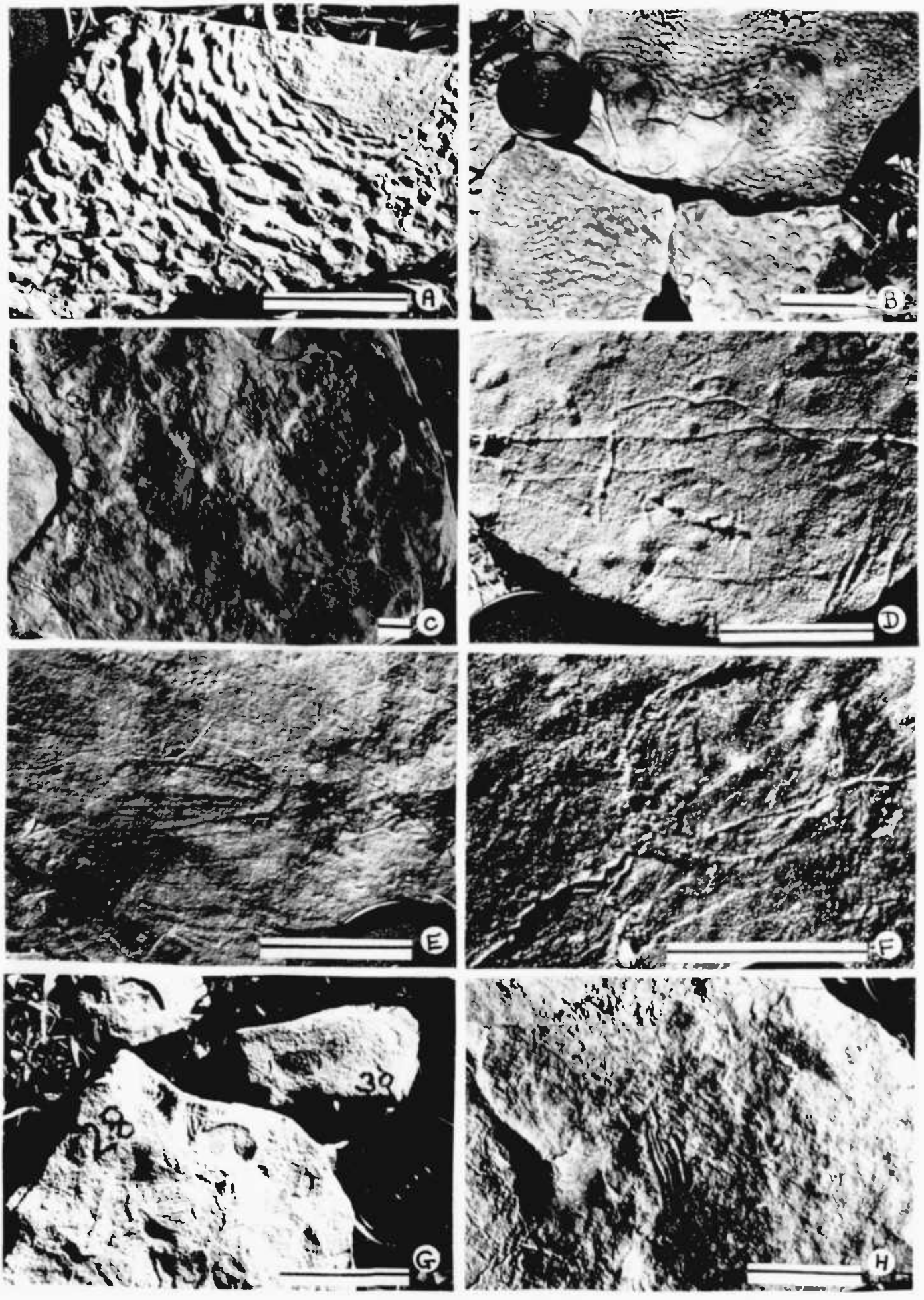


Plate 4

Scale bar A - B = 100 microns.
Scale bar C - H = 5 mm.

A. General view. Organic matter and quartz grains in a siltstone matrix. TS-DDH-M14-250'7-1/1121-137.

B. Sphaeromorph acritarch in a patch of finer grained sediment. TS-DDH-M14-250'8-1/1118-134.

C. Horizontal section of siltstone with narrow dewatering channels. TS-DDH-M15-173'5-]

D. Vertical section showing part of a deformed shale bed, or possibly part of a large clast. TS-DDH-X31-132'5-1.

E. Vertical section of shale clasts in quartz sandstone. TS-DDH-U33-304'6-3.

F. Shale/sandstone interbedding. TS-DDH-B7-209'1½-1.

G. Finely laminated and cross-bedded sediment with a microfault. TS-DDH-A10-126'0-7.

H. Interbedding of coarse sands and fine shales. TS-DDH-B7-431'6-1.

PLATE 4.

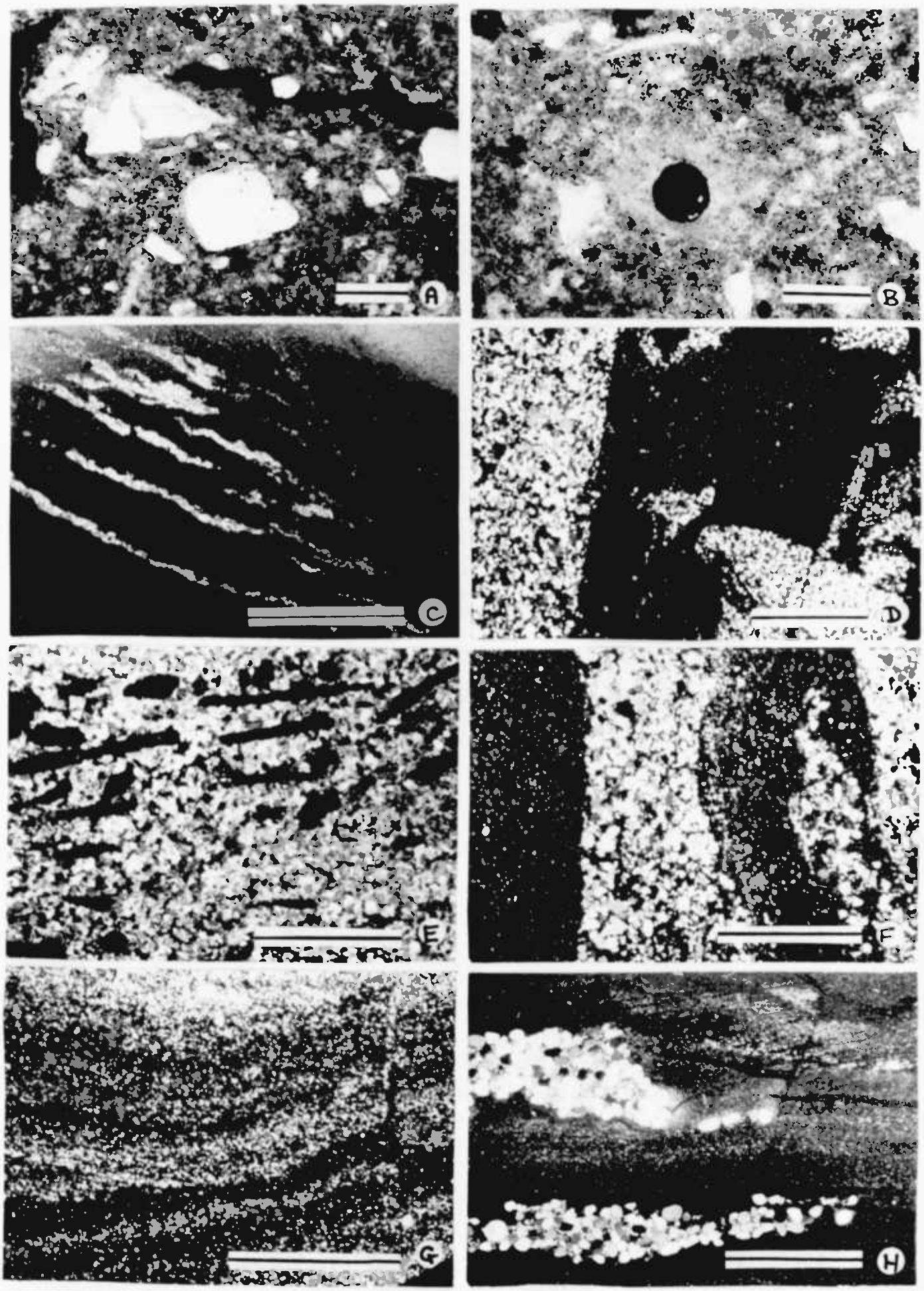


Plate 5

Scale bar A = 5 mm.
Scale bar B - H = 100 microns.

A. Lensing of fine shale beds. The iron-rich matrix contains mainly quartz grains but there are occasional solitary oolites. A detail of one oolite (arrowed) is shown in Pl.5G. TS-DDH-B7-474'3-5.

B. Abrupt transition from sand to shale. The quartz grain shows internal sub-grains. TS-DDH-B7-431'6-1/1106-086.

C. Quartz sandstone showing overgrowths. TS-DDH-B7-209'1½-1/1073-040.

D. Well rounded quartz grains in a matrix of shale. TS-DDH-B7-431'6-1/1191-145.

E. Sub-angular quartz grains in a matrix of iron. TS-DDH-B7-474'3-5/1080-087.

F. Various iron-encrusted sedimentary grains in a matrix of shale and poorly sorted quartz. TS-DDH-B7-474'3-4/0968-133.

G. Detail of the solitary arrowed oolite in Pl.5A. TS-DDH-B7-474'3-5/1113-071.

H. OOlite ghost showing quartz centre, mobilised iron and organic rim. TS-DDH-U33-350'1-3/1041-081.

PLATE 5.

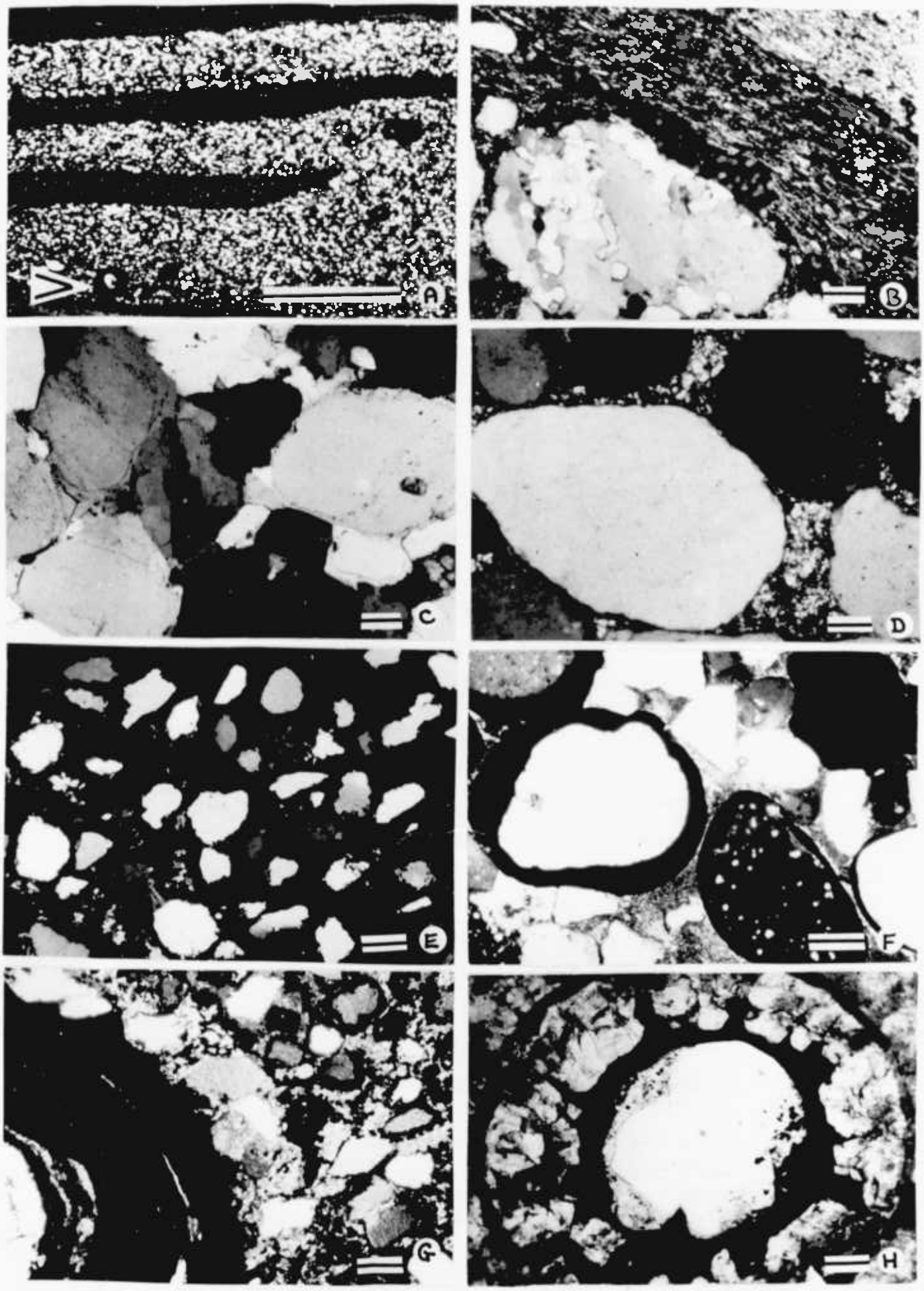


Plate 6

Scale bar A - F, H = 100 microns.
Scale bar G = 5 mm.

A.) Ghost oolite transected by a stylolite. Crossed polars.
B.) TS-DDH-A10-58'6-1/1191-147.

C. Ghost oolites with chert rims. Crossed polars.
TS-DDH-B8-126'7-1/1175-103.

D. Granules of iron. TS-DDH-B7-146'9-2/1140-081.

E. Simple (top) and elongate (bottom) oolites. TS-DDH-B7-474'3-4
TS-DDH-B7-474'3-4/1169-125.

F. Compound oolite. Vertical section. TS-DDH-B7-474'3-3/1116-135.

G. Dewatering has caused only a minor disturbance of bedding. Water flowed upwards, from right to left of the picture.
TS-DDH-B8-170'2-1.

H. Detail of Pl.6G showing disruption of a shale lamina at the edge of the disturbance. Water flowed upwards, from right to left of the picture. TS-DDH-B8-170'2-1/1126-074.

PLATE 6.

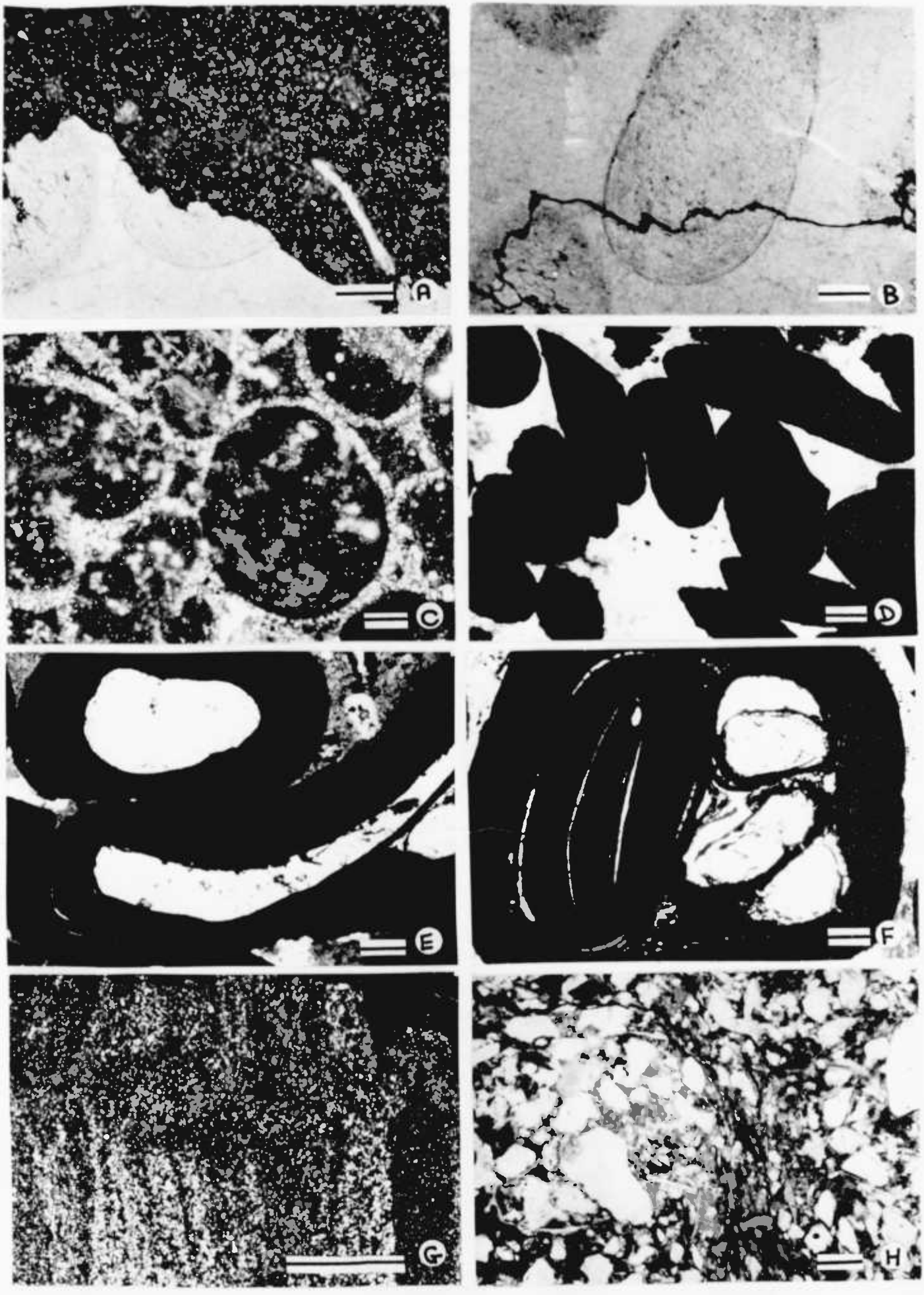


Plate 7

Scale bar A - D = 5 mm.
Scale bar E - G = 100 microns.

A. Vertical section of a small sandstone dyke. TS-DDH-M14-73'8-2.

B. Vertical section of convoluted sandstone dykes.
TS-DDH-M13-284'4-3. Details of this thin section are shown in Pl.6E-G.

C. Sandstone dykes in core. In horizontal section the dykes are linear. 'Upwards' is to the right of the picture.
Sample DDH-M15-213'10-214'6.

D. Horizontal section of sandstone dykes. TS-DDH-B7-105'2-1.

E.) Deformed shale beds near to sandstone dykes. These three
F.) details are from the vertical section shown in Pl.7B.
G.) Co-ordinates - E=1093-107; F=1133-154; G=1090-072.

PLATE 7.

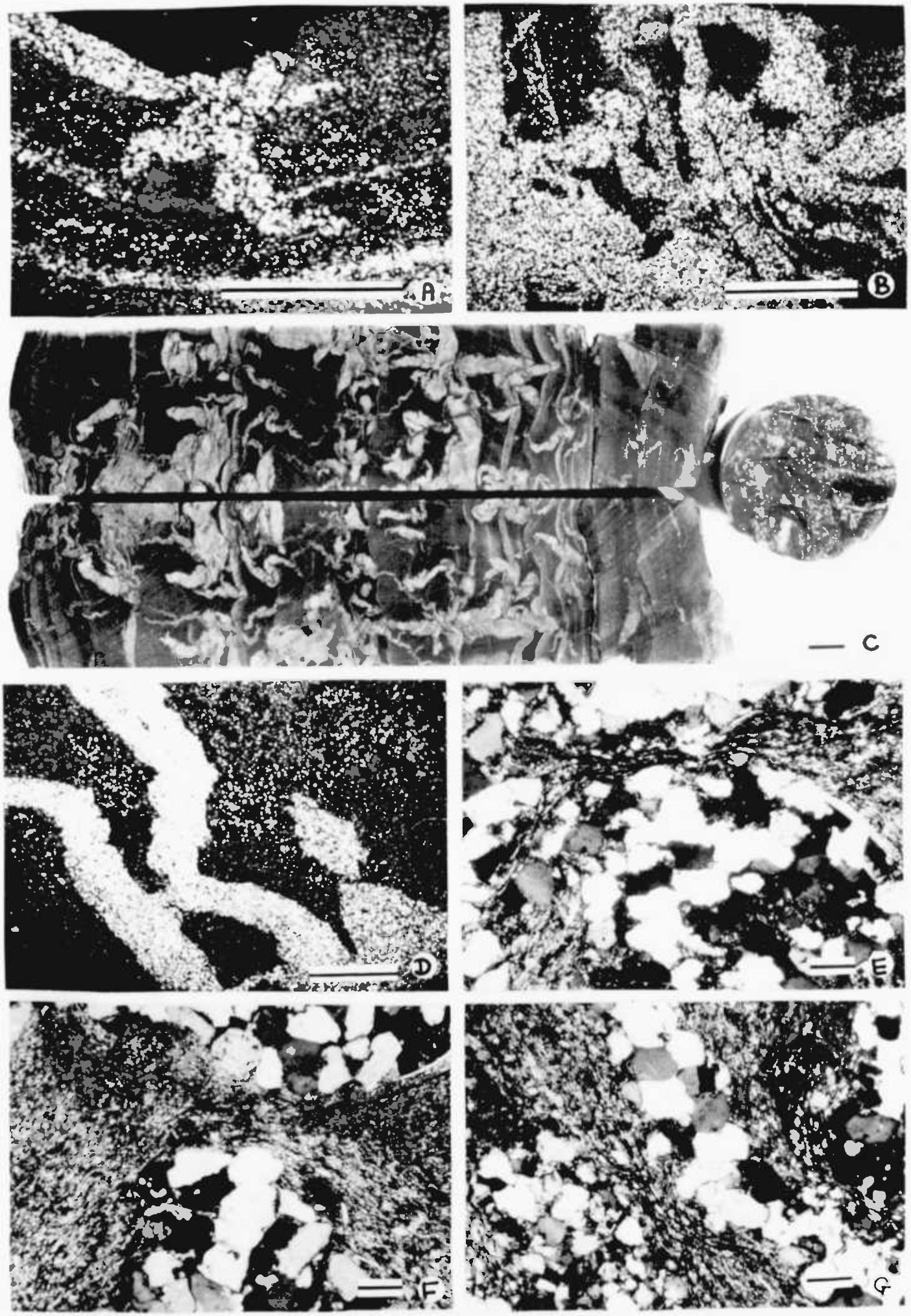


Plate 8

Scale bars A - I, K - L = 10 microns.
J = 5 microns.

A - J. Type 1. Sphaeromorph cryptarchs with thin walls decorated with a reticulate pattern as shown.
G & J are SEM pictures of the fossil in D.
C & I are the same specimen at different focal planes.

K - L. Type 2. Sphaeromorph cryptarchs with thin walls decorated with a fine reticulate pattern as shown.
K & L are the same specimen at different focal planes.

A. MAC DDH B7 74'2-8/1264-215.
B. MAC DDH B7 74'2-8/1216-171.
C. MAC DDH B7 74'2-1/1129-010.
D. MAC DDH B7 74'2-F28 LM.
E. MAC DDH B7 74'2-4/1021-090.
F. MAC DDH B7 74'2-9/1244-029.
G. MAC DDH B7 74'2-F28 SEM.
H. MAC DDH B7 74'2-9/1132-055.
I. MAC DDH B7 74'2-1/1129-010.
J. MAC DDH B7 74'2-F28 SEM.
K. MAC DDH B7 74'2-9/1257-067.
L. MAC DDH B7 74'2-9/1257-067.

PLATE 8

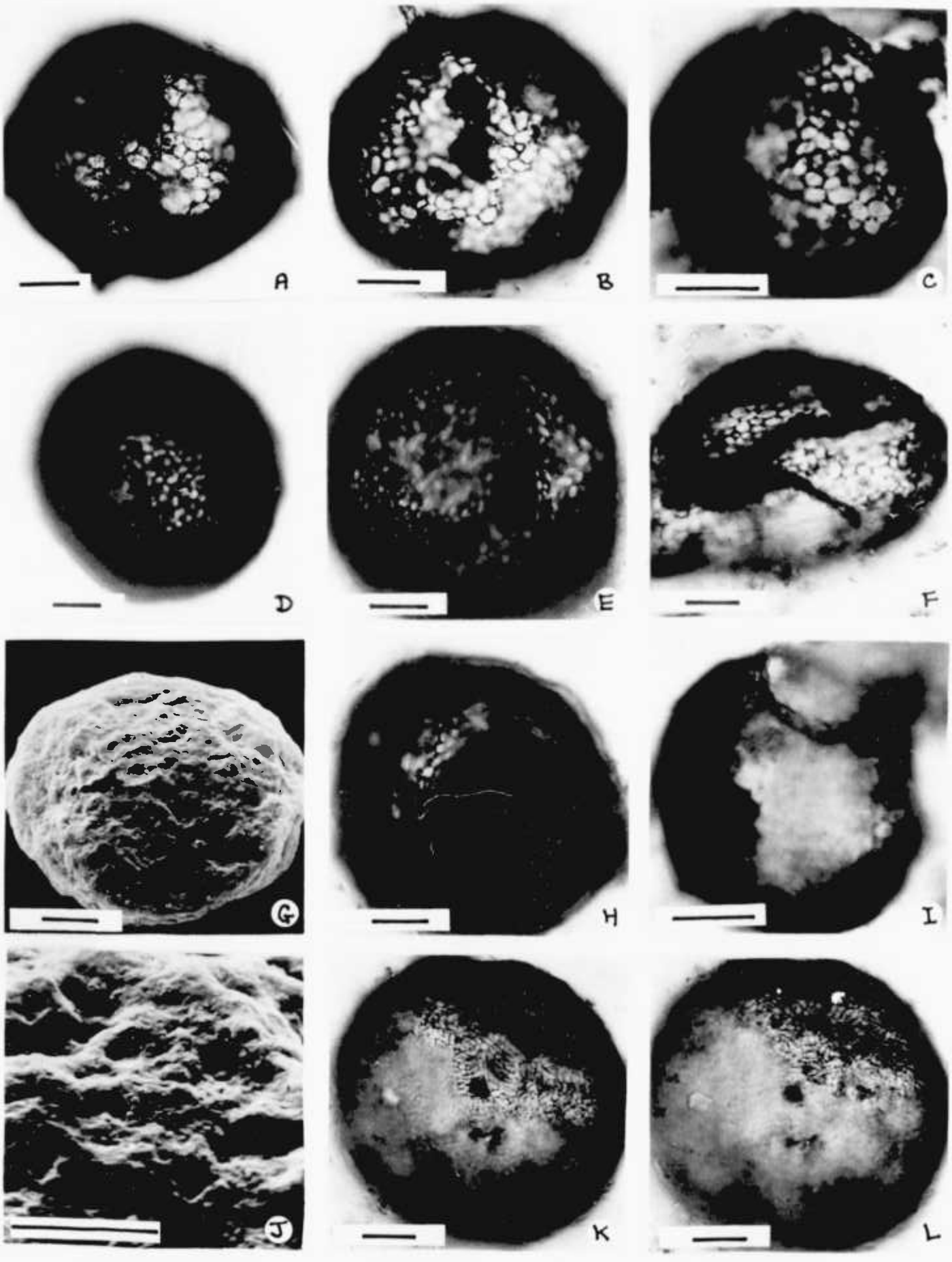


Plate 9

Scale bars A - L = 10 microns.

A - F. Type 3. Sphaeromorph cryptarchs with thin walls without folds. The vesicle surface is smooth to granular and a few very thin wrinkles may be present.

G - L. Type 4. Sphaeromorph cryptarchs with thin walls and a smooth to finely granular surface. The vesicle walls have a pattern of short, curved, interdigitating wrinkles, as shown in the illustration.

A. MAC DDH B7 74'2-10/1194-156.
B. MAC DDH B7 74'2-4/1003-092.
C. MAC DDH B7 74'2-9/1096-083.
D. MAC DDH B7 74'2-10/1248-178.
E. MAC DDH B7 74'2-4/950-132.
F. MAC DDH B7 74'2-4/1193-158.
G. MAC DDH B7 74'2-9/1250-034.
H. MAC DDH B7 74'2-1/992-164.
I. MAC DDH B7 74'2-4/0945-042.
J. MAC DDH B7 74'2-9/0972-035.
K. MAC DDH B7 74'2-1/1064-157.
L. MAC DDH B7 74'2-1/1402-102.

PLATE 9

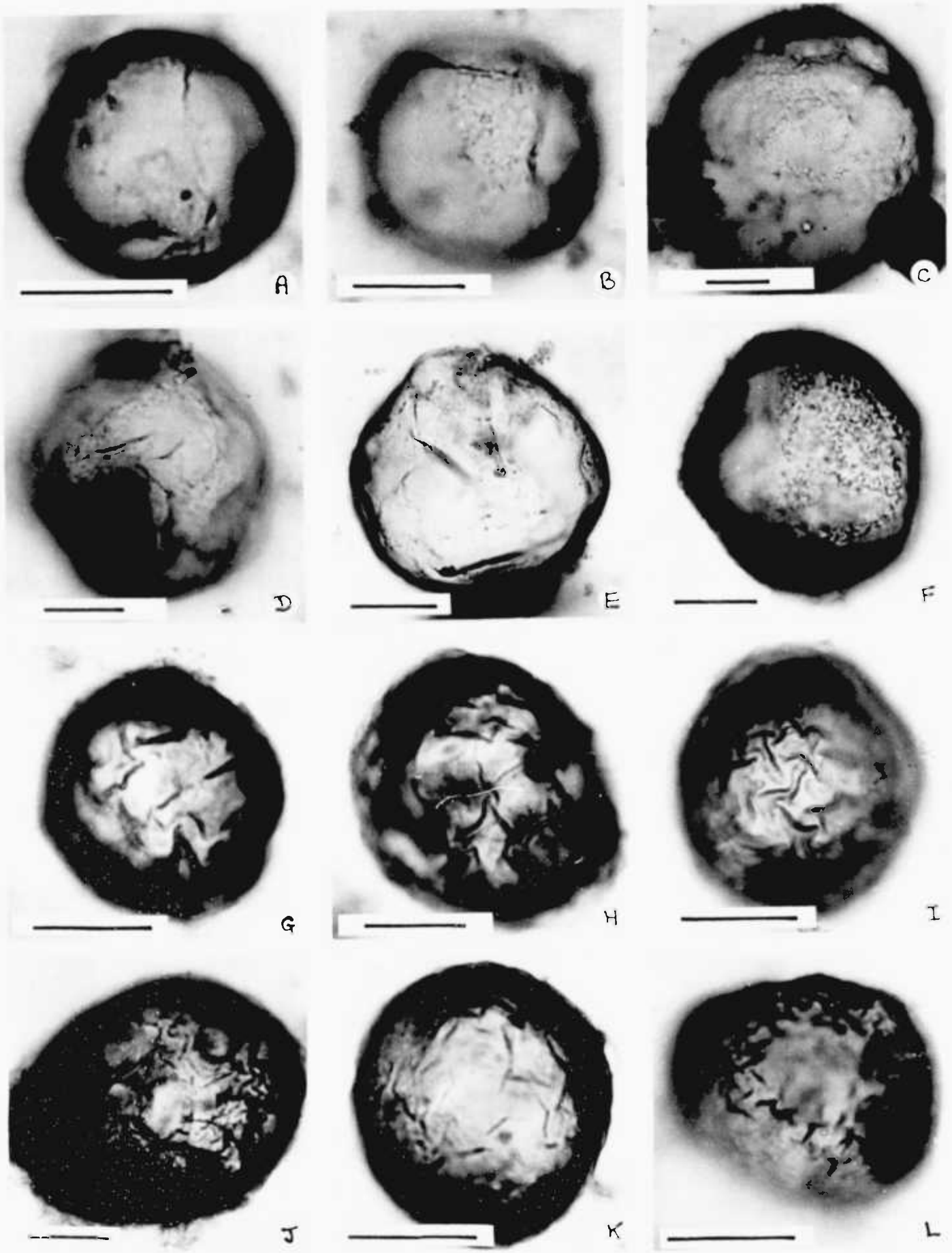


Plate 10

Scale bars A - L = 10 microns.

A - L. Type 5. Sphaeromorph cryptarchs with thin walls and a smooth to shagreenate surface texture. The vesicle wall is thrown into numerous medium to wide, interlocking sinuous wrinkles.
G & J, H & K, I & L are LM and SEM pictures of the same fossils.

A. MAC DDH M14 250'8-15/1209-069.
B. MAC DDH M14 250'8-15/1217-034.
C. MAC DDH M14 250'8-15/1140-034.
D. MAC DDH M14 250'8-20/052-0956.
E. MAC DDH M14 250'8-20/1047-059.
F. MAC DDH M14 250'8-15/1223-078.
G. MAC DDH M14 250'8-F191 LM.
H. MAC DDH M14 250'8-F187 LM.
I. MAC DDH M14 250'8-F159 LM.
J. MAC DDH M14 250'8-F191 SEM.
K. MAC DDH M14 250'8-F187 SEM.
L. MAC DDH M14 250'8-F159 SEM.

PLATE 10

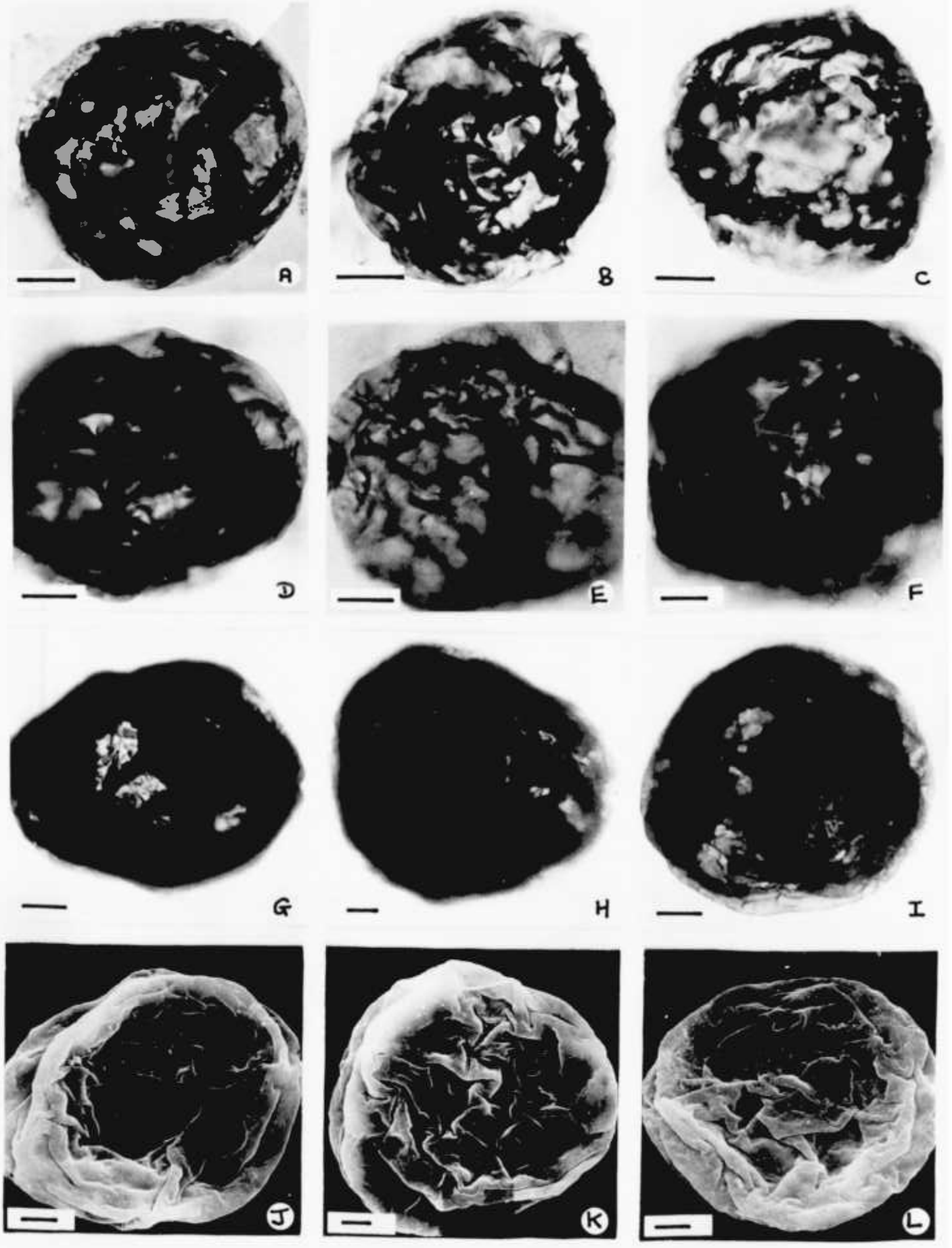


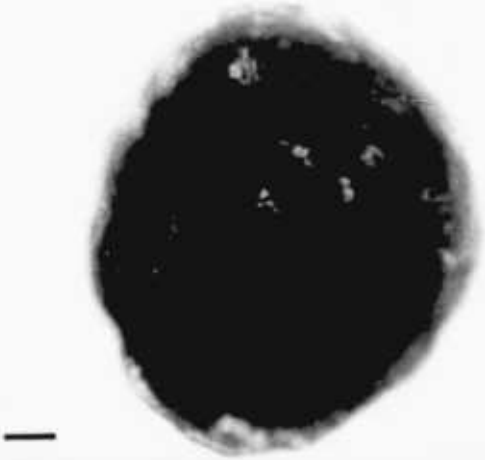
Plate 11

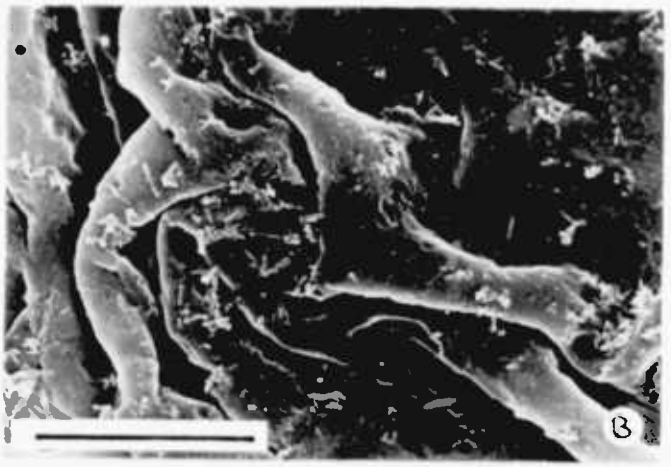
Scale bars A - F = 10 microns.
G - H = 1 micron.

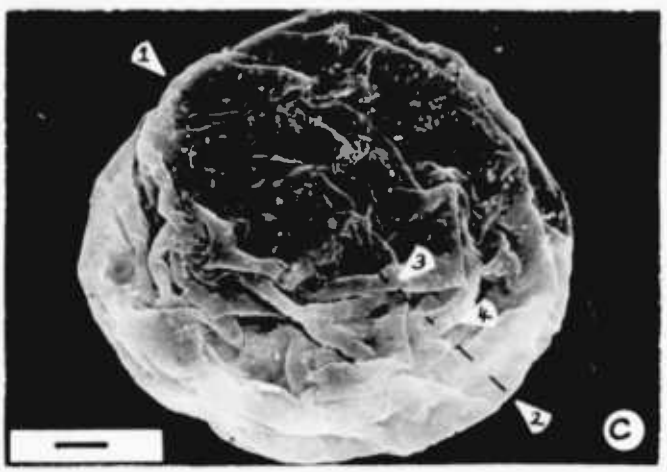
A - H. Type 5. Detailed structure of a single fossil.
MAC DDH M14 250'8 F161.
A = LM, B - D = SEM, E - H = TEM.

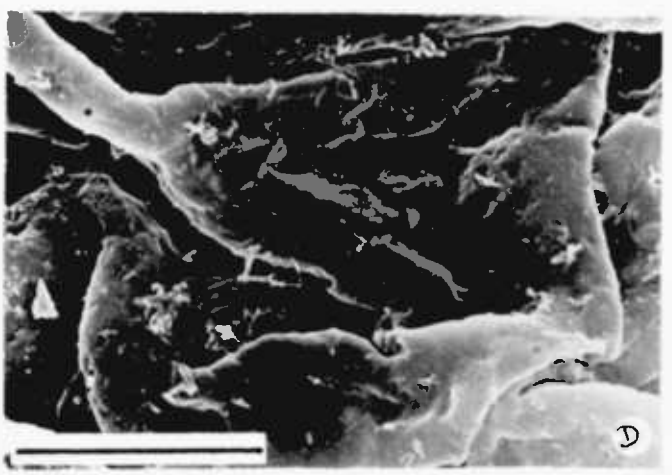
A and C are in the same orientation. The specimen was thin sectioned along the line 1 - 2 shown in C. Points 1, 3 and 4 are marked on C and F for comparison.
Point 5 shows the gold coating as an electron-dense line that has peeled away from the fossil.

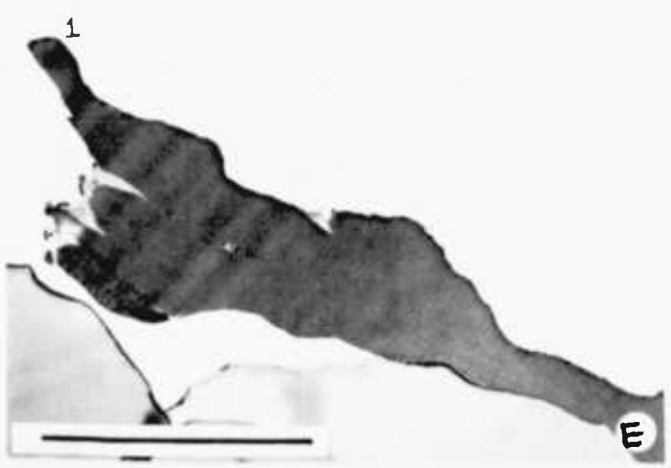
PLATE II

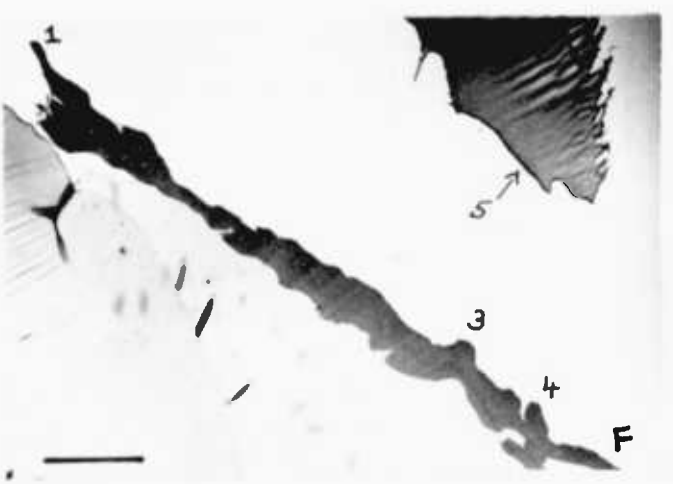

A

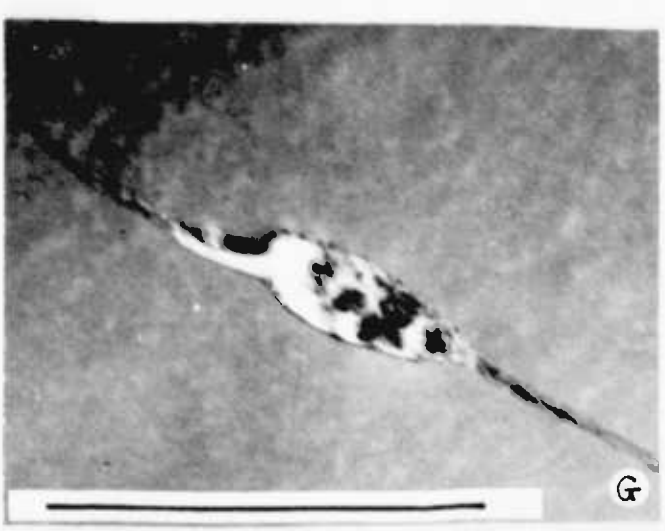

B




D






G

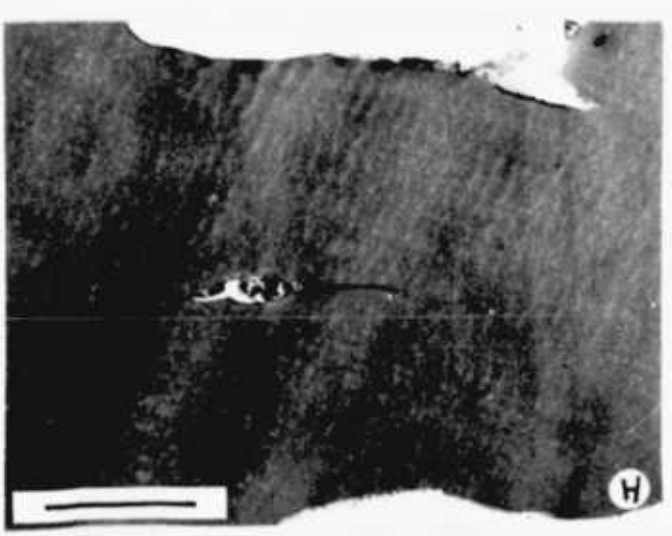

H

Plate 12

Scale bars A - L = 20 microns.

A - C. Type 6. Sphaeromorph cryptarchs with thin walls and a smooth outer surface. The wall is thrown into numerous short, thin to medium, sinuous wrinkles. The wrinkles are arranged at random and occur over the whole area of the vesicle.
B & C are LM and SEM pictures of the same fossil.

D - F. Type 7. Sphaeromorph cryptarchs with thin walls and a smooth to shagreenate outer surface. The wall is thrown into numerous long, thin to medium, curved or sinuous folds, arranged at random.
E & F are LM and SEM pictures of the same fossil.

G - I. Type 8. Sphaeromorph cryptarchs with thin walls and a smooth to shagreenate outer surface. The wall has a few straight to curved folds of narrow to medium width arranged at random.
H & I are LM and SEM pictures of the same fossil.

J - L. Type 9. Sphaeromorph cryptarchs with thin walls and a smooth outer surface, often with a pattern of very fine wrinkles. The wall has a few, straight to curved, medium or wide folds arranged at random.
K & L are LM and SEM pictures of the same fossil.

A. MAC DDH M14 250'8 F43 LM.
B. MAC DDH M14 250'8 F46 LM.
C. MAC DDH M14 250'8 F46 SEM.
D. MAC DDH M14 250'8-3/1044-105.
E. MAC DDH M14 250'8 F93 LM.
F. MAC DDH M14 250'8 F93 SEM.
G. MAC DDH M14 250'8 F1 LM.
H. MAC DDH M14 250'8 F33 LM.
I. MAC DDH M14 250'8 F33 SEM.
J. MAC DDH M14 250'8-3/1164-221.
K. MAC DDH M14 250'8 F91 LM.
L. MAC DDH M14 250'8 F91 SEM.

PLATE 12

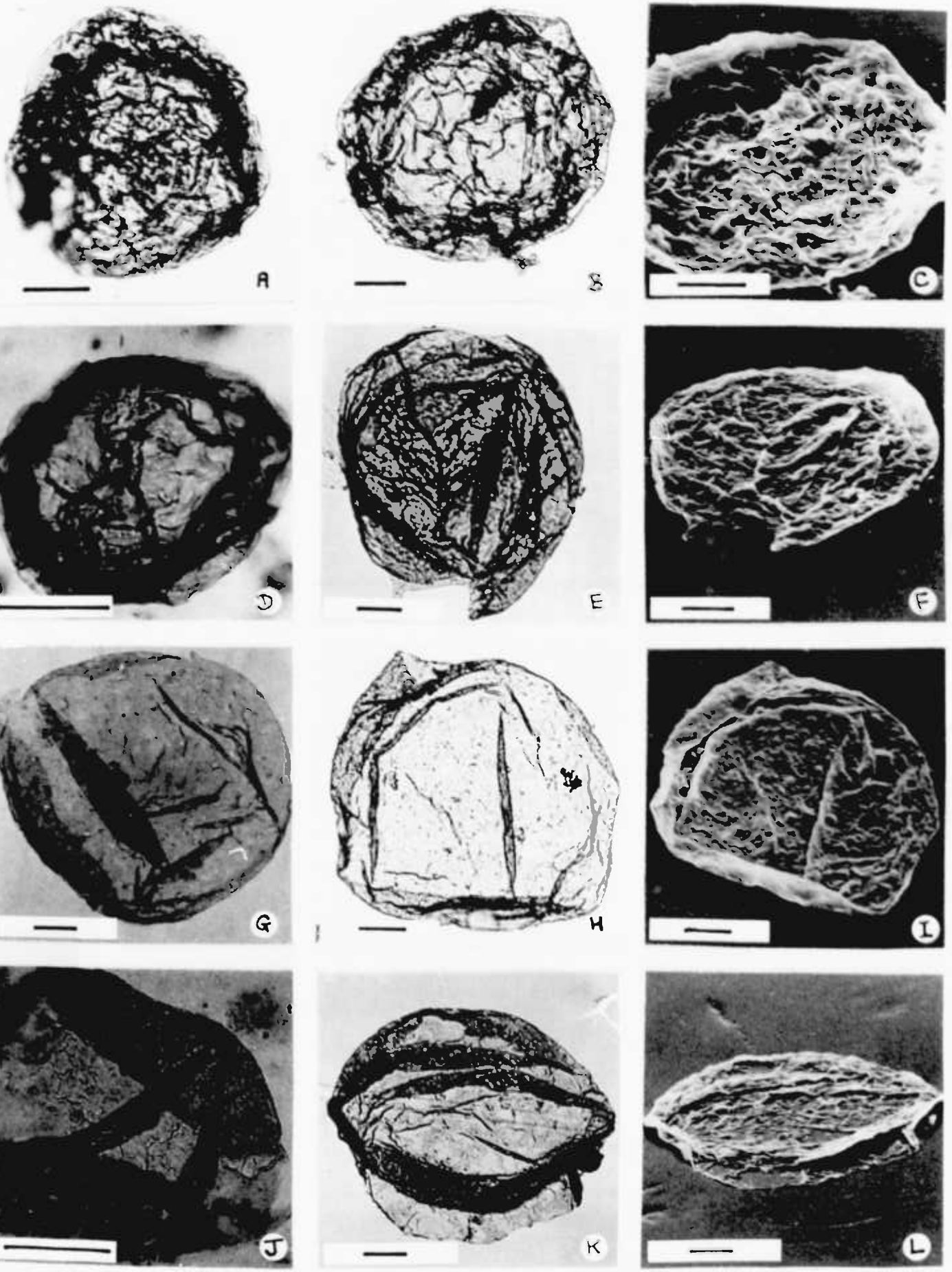


Plate 13

Scale bars A - I = 20 microns.

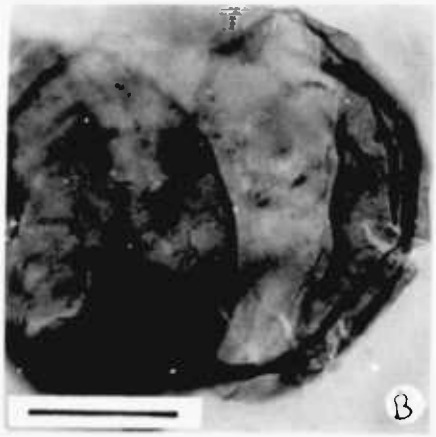
A - G. Type 10. Thin walled sphaeromorph cryptarchs opening by a median split into two equal halves joined by a narrow hinge. The surface of the vesicle is smooth to granular, sometimes with faint linear wrinkles. The wall may have thin folds or wrinkles. F & G are LM and SEM pictures of the same fossil.

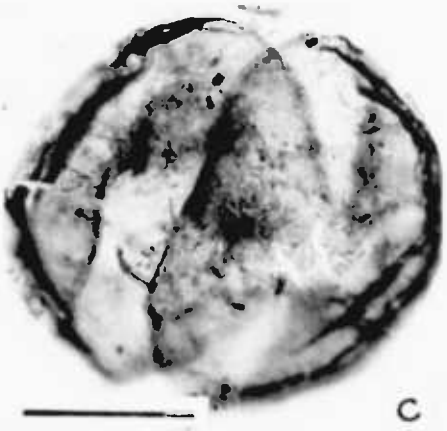
H - I. Type 11. Sphaeromorph cryptarchs with thin walls and a smooth to granular or shagreenate surface texture. They have numerous thin to medium folds arranged in a linear pattern or are rolled up so as to be fusiform in shape.

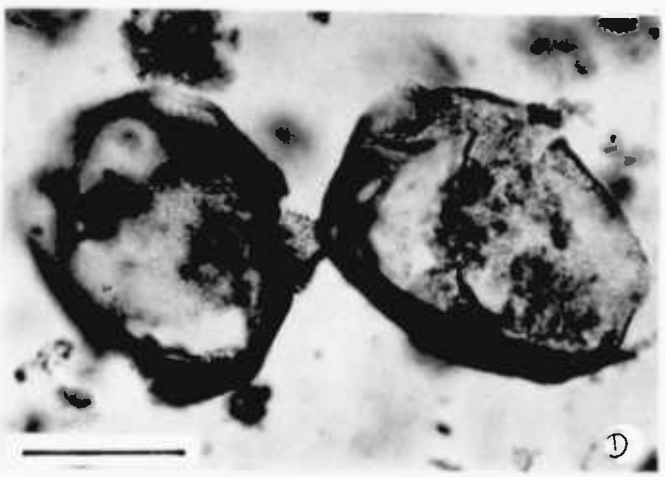
A. MAC DDH M14 250'8-18/1080-068.
B. MAC DDH M14 250'8-8/1054-155.
C. MAC DDH M14 250'8-15/1058-062.
D. MAC DDH B7 74'2-9/0959-205.
E. MAC DDH M14 250'8-18/1303-205.
F. MAC DDH M14 250'8 F88 LM.
G. MAC DDH M14 250'8 F88 SEM.
H. MAC DDH M14 250'8-18/1264-131.
I. MAC DDH M14 245'6-2/0972-064.

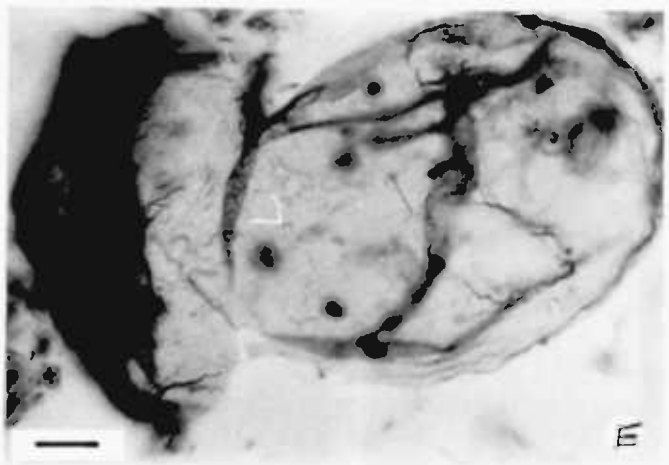
PLATE 13

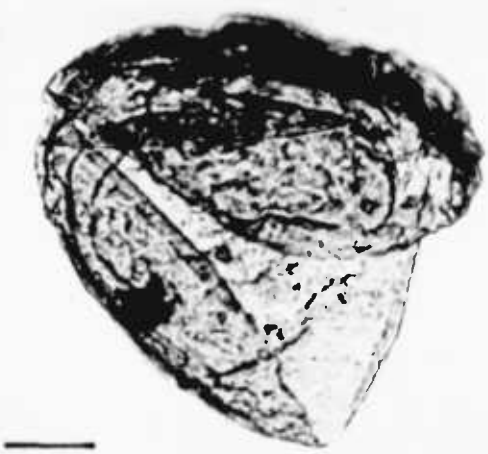


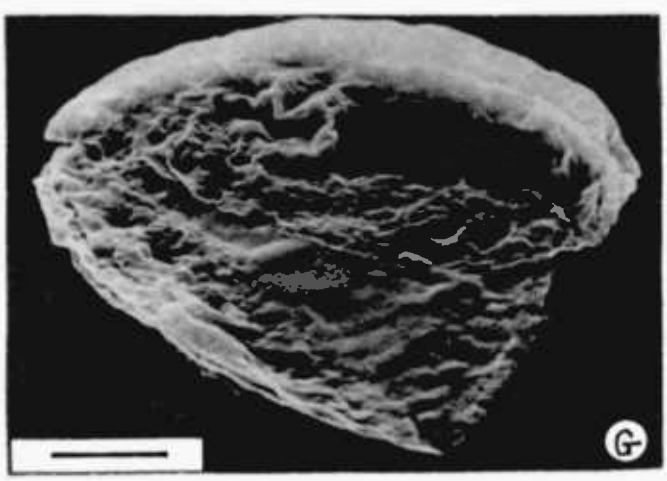


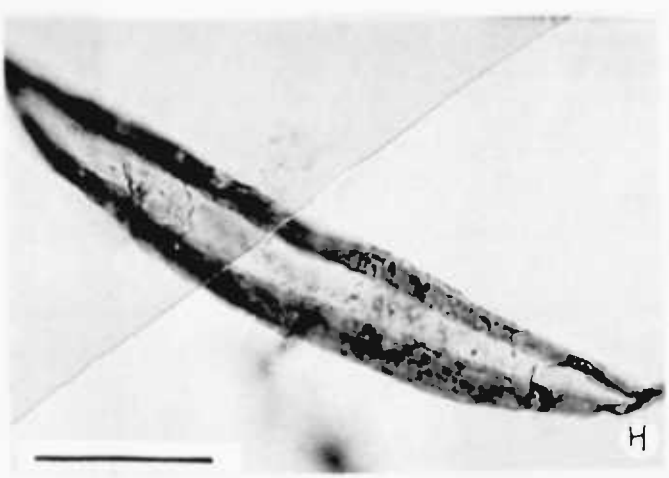












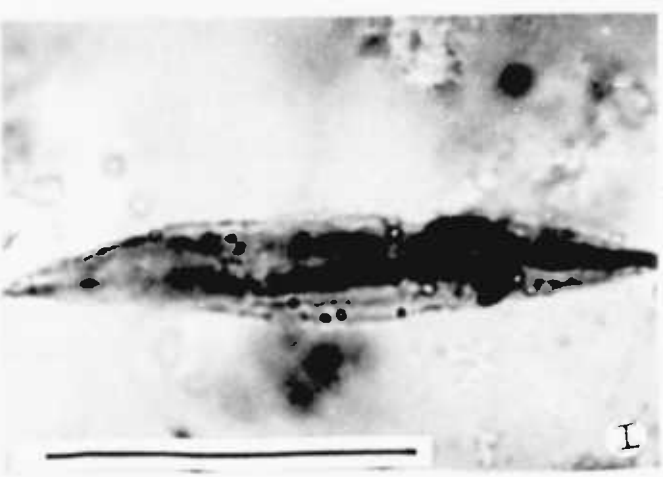


Plate 14

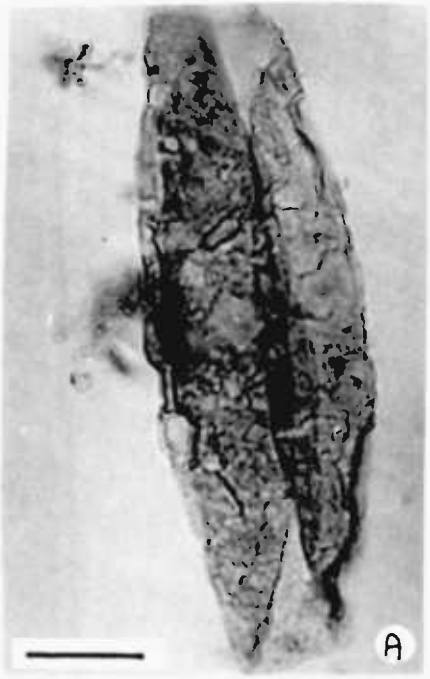
Scale bars A - J = 10 microns.
K = 100 microns.

A - E. Type 12. Thin walled sphaeromorph cryptarchs with a smooth to granular or shagreenate surface texture. The wall is folded into a few medium to broad folds arranged in a linear pattern.
D & E are LM and SEM pictures of the same fossil.

F - K. Type 13. Thin walled sphaeromorph cryptarchs with a smooth to granulate or shagreenate surface texture. They have few to several medium curved folds arranged around the edge of the vesicle, but rarely at the margin.

A. MAC DDH M14 250'8-18/1254-075.
B. MAC DDH M14 245'6-2/1132-214.
C. MAC DDH M14 245'6-2/1319-150.
D. MAC DDH M14 250'8 F196 LM.
E. MAC DDH M14 250'8 F196 SEM.
F. MAC DDH M14 250'8-20/1069-039.
G. MAC DDH M14 245'6-2/1165-164.
H. MAC DDH M14 250'8-15/1231-095.
I. MAC DDH M14 250'8-20/0987-056.
J. TS DDH M15 173'5-1/147-1020.
K. MAC DDH M14 250'8-12/1060-188.

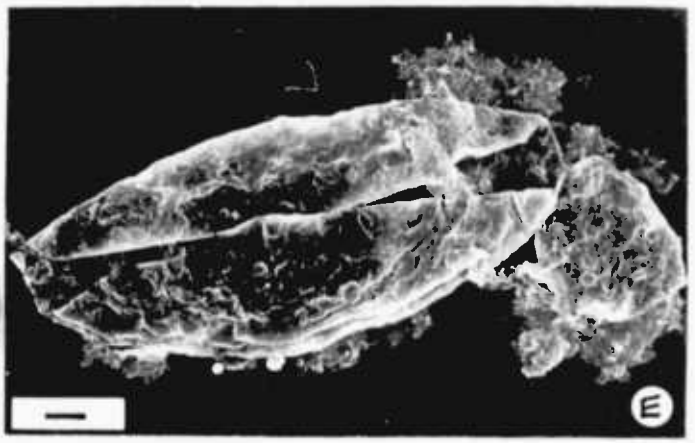
PLATE 14

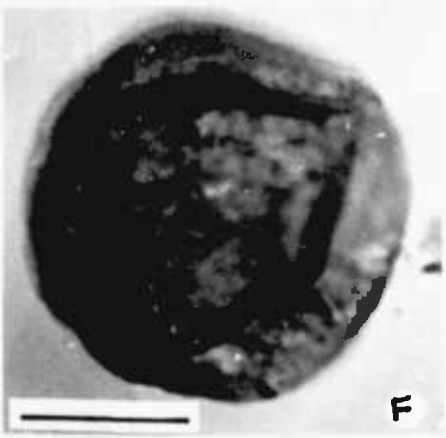


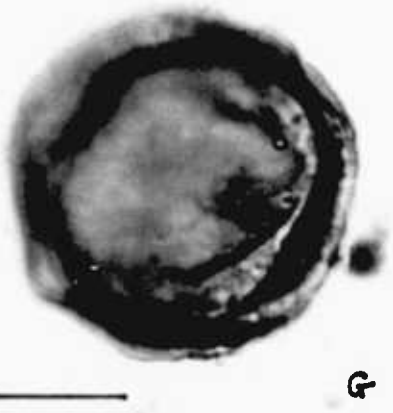


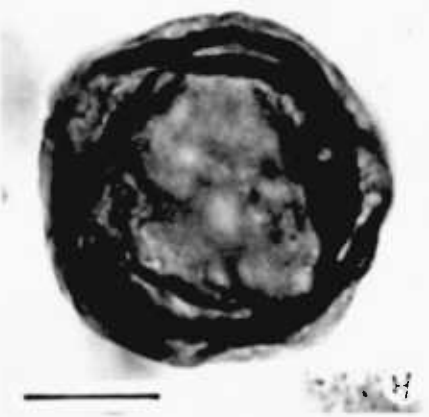


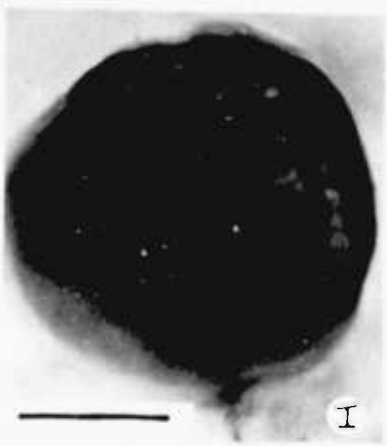














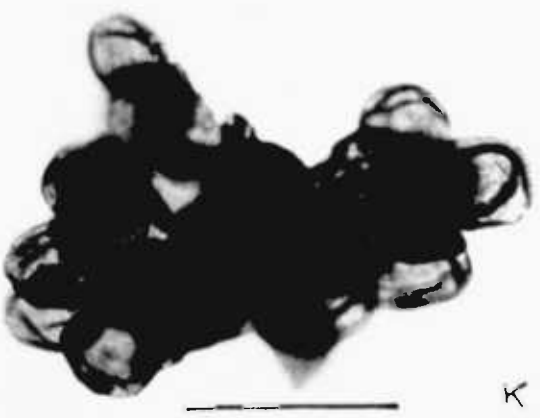


Plate 15

Scale bars A - J = 20 microns.
K = 0.5 microns.
L = 5 microns.

A - C. Type 14. Thin walled sphaeromorph cryptarchs with a smooth to granular surface texture. The vesicle walls have many curved thin folds and wrinkles at their margins but not in the central zones.

D - F. Type 15. Thin walled sphaeromorph cryptarchs with few to many sinuous folds of medium width arranged at random. The surface texture of the vesicles varies from smooth to granular or shagreenate.
E & F are LM and SEM pictures of the same fossil.

G - L. Type 16. Thin walled sphaeromorph cryptarchs with a smooth to granular or shagreenate surface texture. The wall has a few to several medium to wide, mostly straight folds arranged at random.
H, I, L & K are LM and progressively detailed SEM pictures of the same fossil.

A. MAC DDH B7 74'2-9/1092-142.
B. MAC DDH B7 74'2-3/1181-231.
C. MAC DDH B7 74'2-3/1126-216.
D. TS DDH M15 173'5-1/1015-098.
E. MAC DDH M14 250'8 F31 LM.
F. MAC DDH M14 250'8 F31 SEM.
G. MAC DDH M14 250'8-18/1054-038.
H. MAC DDH M14 250'8 F156 LM.
I. MAC DDH M14 250'8 F156 SEM.
J. MAC DDH M14 250'8-20/1075-042.
K.] Details of I.
L.]

PLATE 15

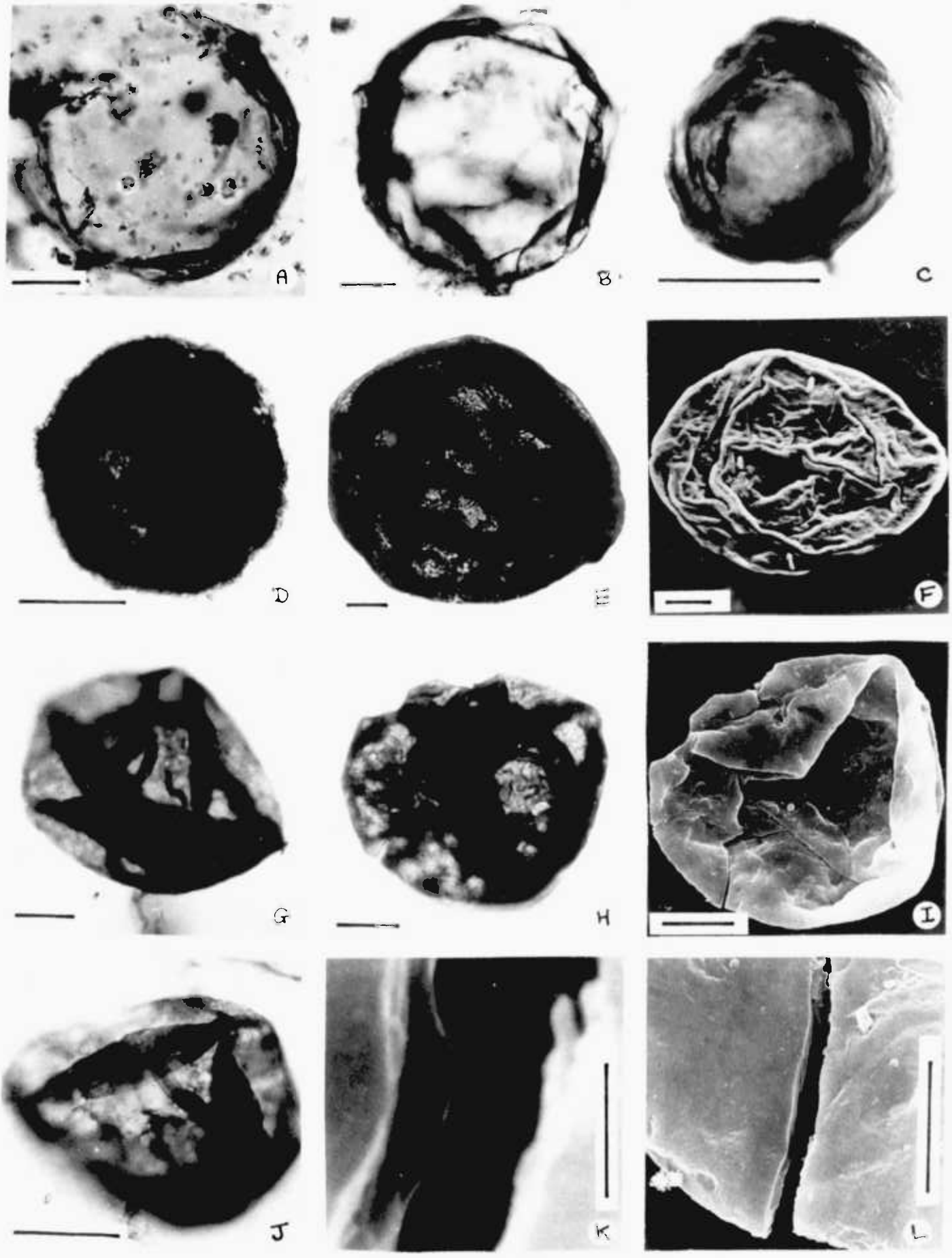


Plate 16

Scale bars A - B, D - E, G - H = 20 microns.
C, F = 5 microns.
I - L = 1 micron.

A - F. Type 17. Sphaeromorph cryptarchs with two thin walls, the outer transparent and membranous and the inner much denser. The surface of the vesicle is smooth to granular or shagreenate. The walls are thrown into thick wrinkles which form a polygonal network.
A & B, D & E are LM and SEM pictures of the same fossil.
F is a detail of C.

G - L. Type 18. Sphaeromorph cryptarchs with a thin wall and a smooth to granular or shagreenate surface texture. The vesicle wall is thrown into thick wrinkles which form a polygonal network.
G & H are LM and SEM pictures of the same fossil.
I - L are details of the broken edge of H.

A. MAC DDH M14 250'8 F 179 LM.
B - C. As A, SEM.
D. MAC DDH M14 250'8 F155 LM.
E. MAC DDH M14 250'8 F155 SEM.
F. As A, SEM.
G. MAC DDH M14 250'8 F181 LM.
H - L. MAC DDH M14 250'8 F181 SEM.

PLATE 16

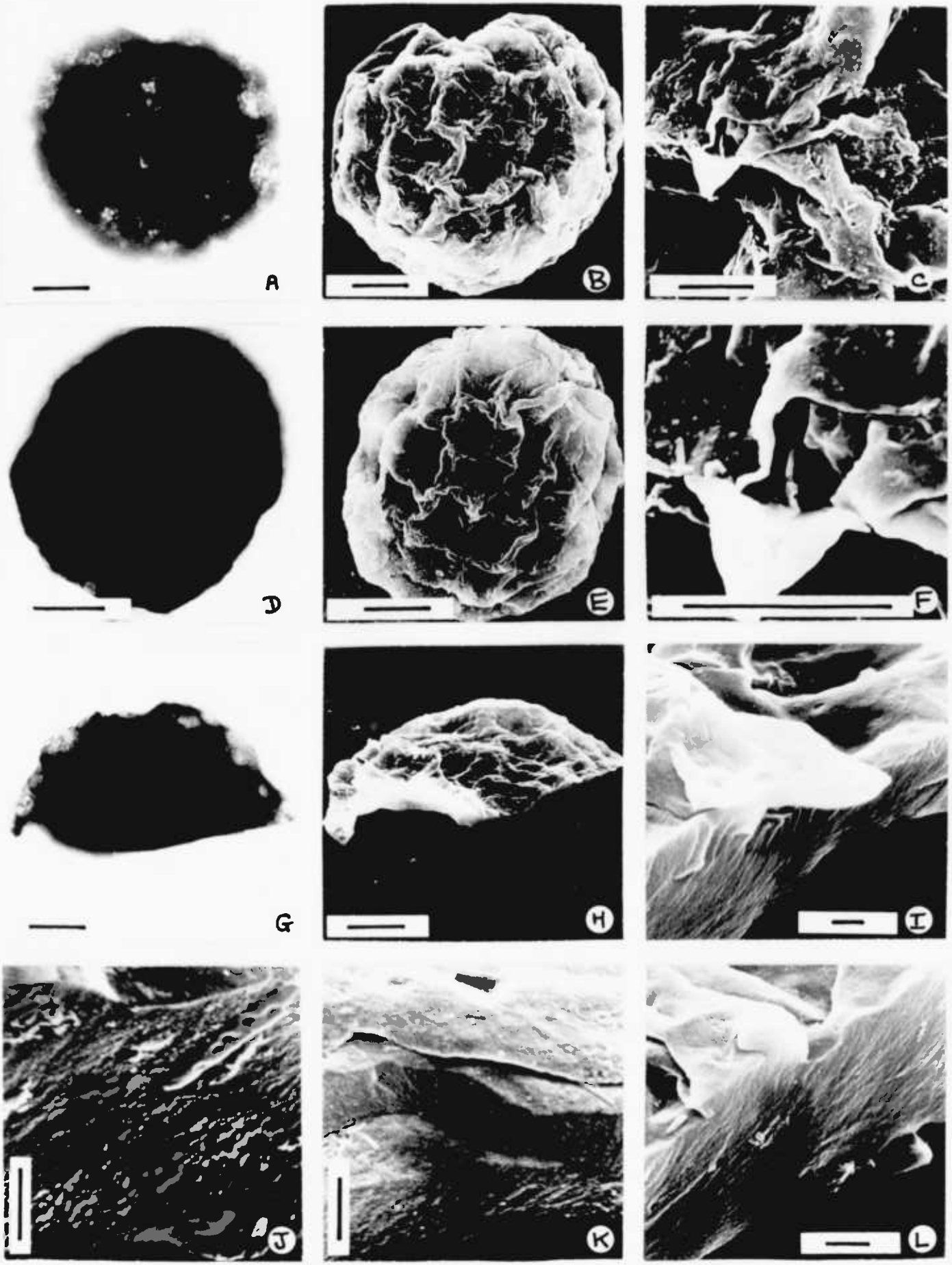


Plate 17

Scale bars A - F, H - K = 10 microns.
G = 100 microns.

A - C. Type 19. Thin walled sphaeromorph cryptarchs with a smooth to granulate or shagreenate surface texture. The vesicle wall has several to many, straight to curved folds of medium width arranged like the chords of a circle but rarely crossing the central zone of the vesicle.

D - F. Type 20. Thin walled sphaeromorph cryptarchs with a smooth to granulate or shagreenate surface texture. The vesicle has several to many, straight to curved folds of medium width arranged at random across it.

G - H. Type 21. Thin walled sphaeromorph cryptarchs with many straight or slightly curved wrinkles or folds of narrow to medium width arranged in a linear pattern parallel to the longer axis of the vesicle. The surface texture of the vesicle varies from smooth to coarsely granulate or coarsely shagreenate.

I - K. Type 22. Thin walled sphaeromorph cryptarchs with a few thick long, curved wrinkles arranged as shown in this plate. The surface of the vesicles varies from smooth to granulate or shagreenate.

A. MAC DDH M14 258'0-1/1252-168.
B. MAC DDH M14 245'6-2/1242-187.
C. MAC DDH B7 74'2-9/1252-170.
D. MAC DDH B7 74'2-10/1215-211.
E. MAC DDH B7 74'2-9/1307-100.
F. MAC DDH M14 245'6-2/0892-129.
G. MAC DDH B7 74'2-10/1297-216.
H. MAC DDH B7 74'2-9/1136-094.
I. MAC DDH B7 74'2-6/1214-154.
J. MAC DDH B7 74'2-4/1287-231.
K. MAC DDH B7 74'2-3/0989-089.

PLATE 17

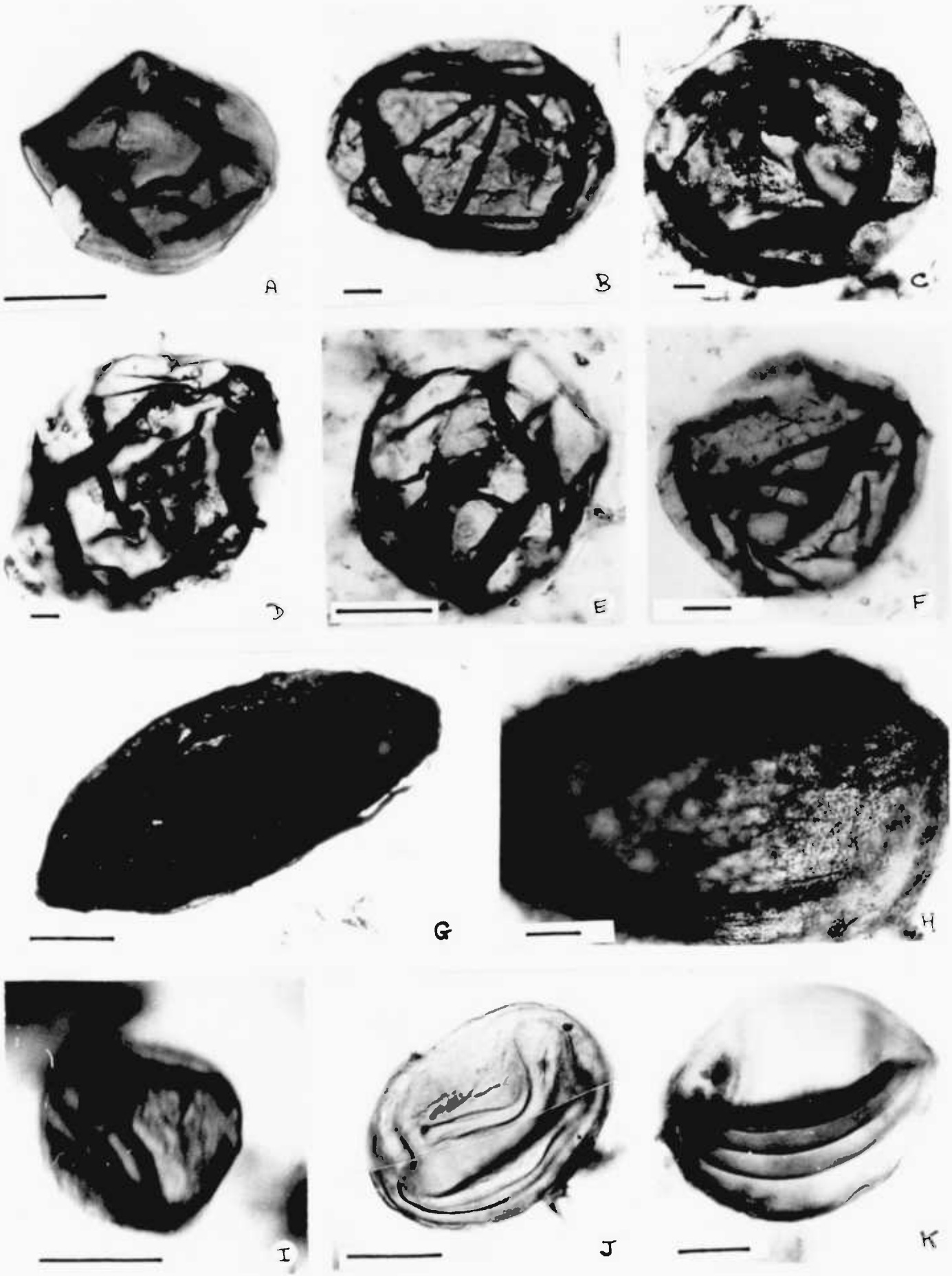


Plate 18

Scale bars A - I = 20 microns.
J - K = 200 microns.

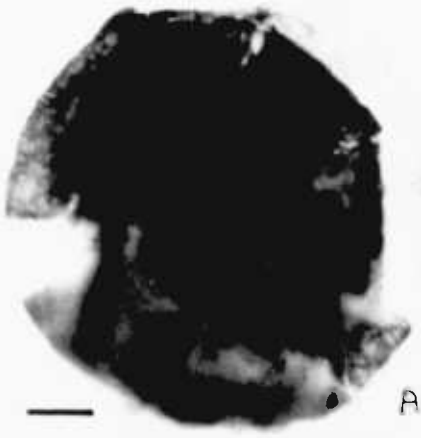
A - F. Type 23. Thin walled sphaeromorph cryptarchs, often with surface wrinkles or short, thin folds. The vesicle is split into segments and has a lobed appearance.

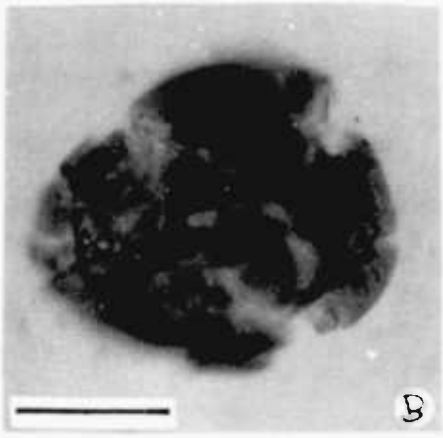
G - I. Sphaeromorph cryptarchs with broken openings.

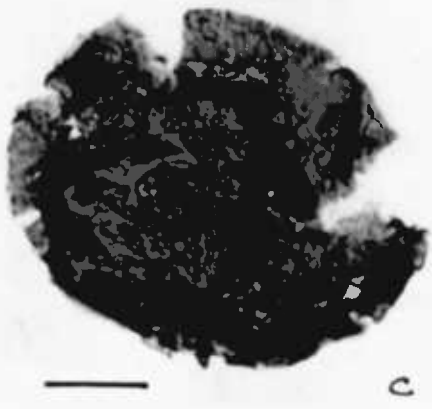
J - K. The largest sphaeromorph cryptarchs found so far.

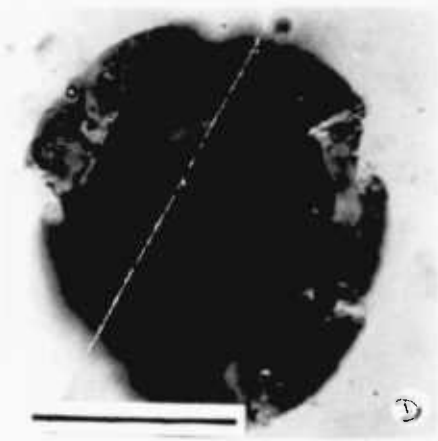
A. MAC DDH M14 250'8-18/1073-238.
B. MAC DDH M14 250'8-18/1279-052.
C. MAC DDH M14 250'8 F71 LM.
D. MAC DDH M14 245'6-2/0856-078.
E. MAC DDH M14 245'6-2/1313-067.
F. MAC DDH M14 250'8-8/1214-089.
G. TS DDH M15 173'5-1/1141-057.
H. TS DDH M15 173'5-1/1062-124.
I. MAC DDH B7 74'2-1/1260-193.
J. MAC DDH M14 73'8-10/0925-145.
K. MAC DDH M14 150'5-1/1130-024.

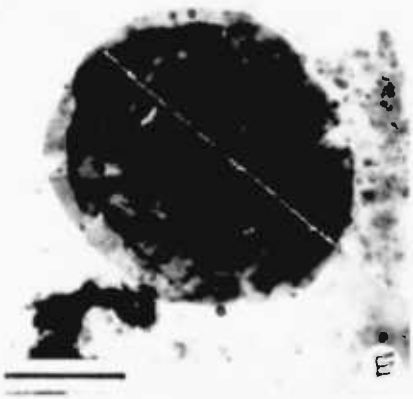
PLATE 18

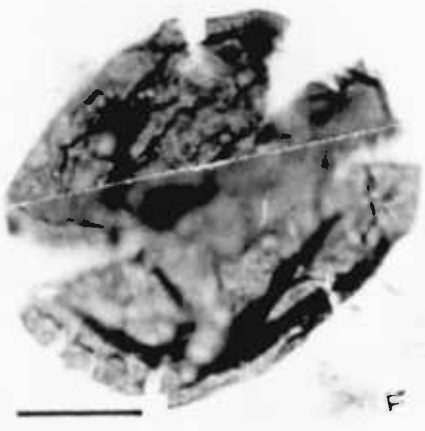

A

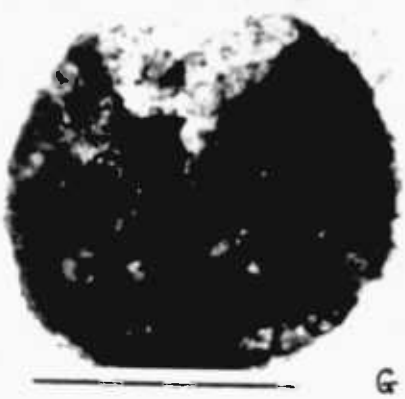

B

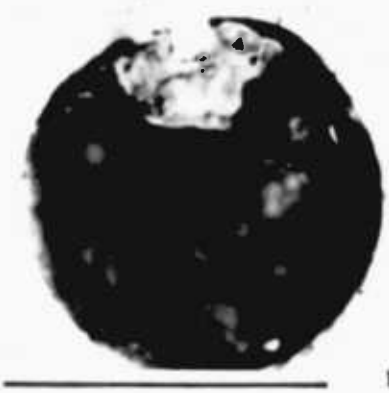

C


D

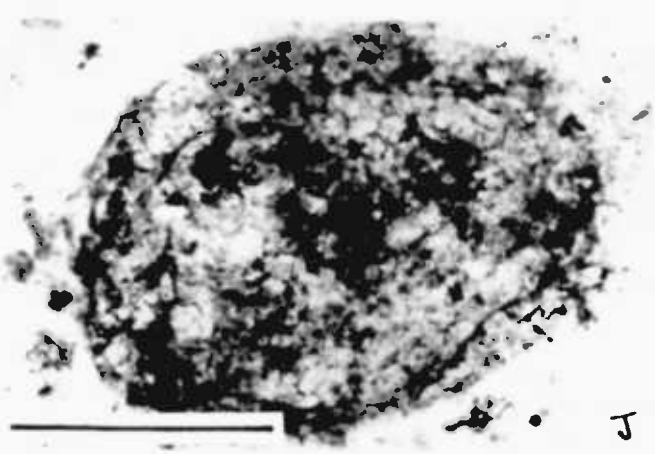

E


F


G


H


I


J

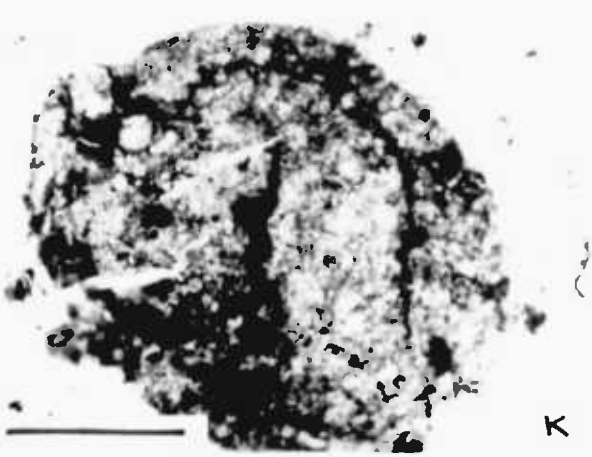

K

Plate 19

Scale bars A - E = 100 microns.
F - H = 20 microns.

A - H. Type 24. Fibrillar filaments and fibrillar membranes, often highly contorted, rarely branching.

These pseudofilaments are produced by the degradation of sphaeromorph cryptarchs.

A. MAC DDH B7 74'2-4/0969-181.
B. MAC DDH B7 74'2-5/1250-094.
C. MAC DDH B7 74'2-3/0951-138.
D. MAC DDH B7 74'2-3/1009-224.
E. MAC DDH B7 74'2-3/1289-221.
F. MAC DDH B7 74'2-4/1194-122.
G. MAC DDH B7 74'2-3/1289-221.
H. MAC DDH B7 74'2-4/1137-015.

PLATE 19

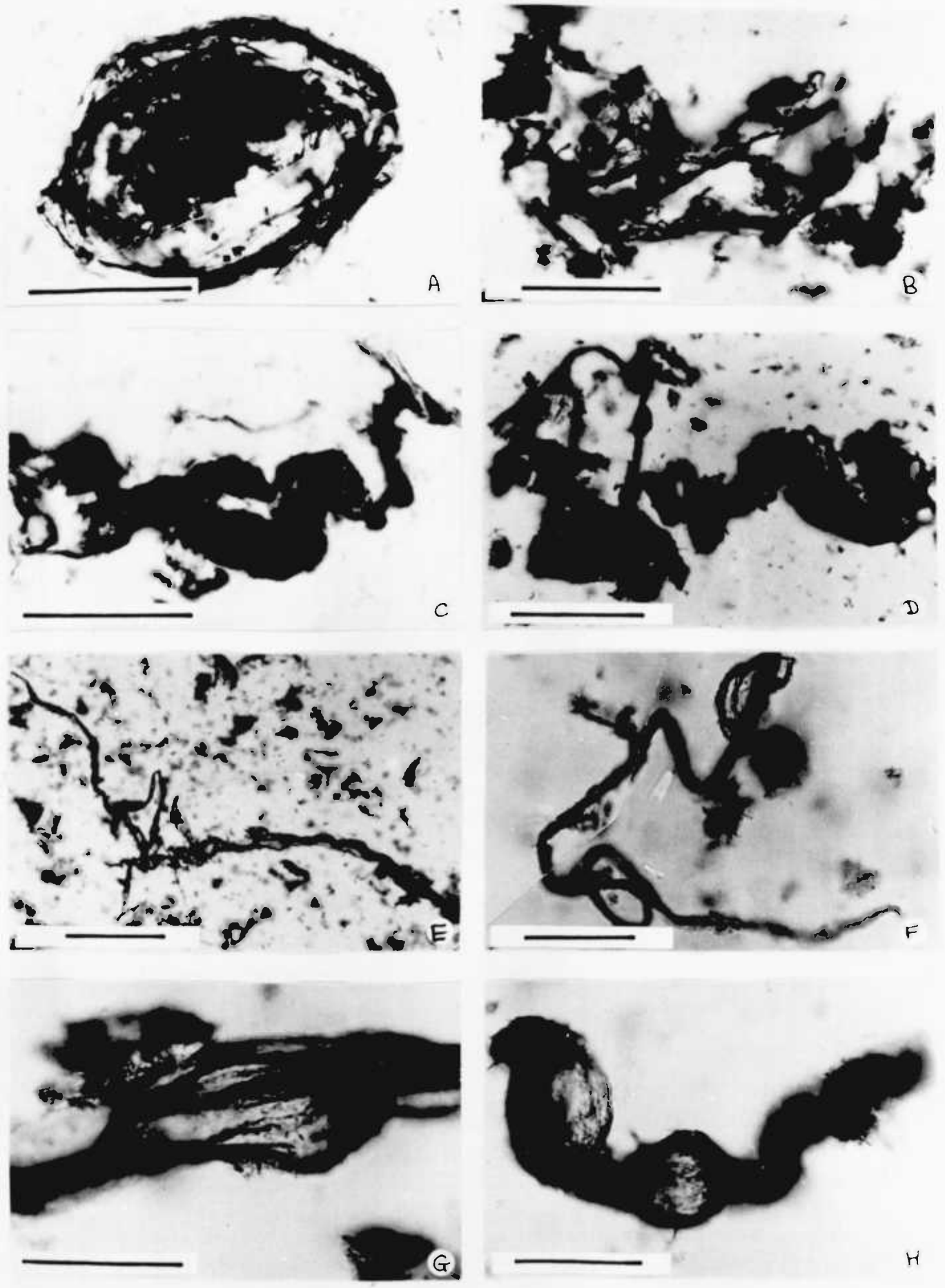


Plate 20

Scale bars A - L = 20 microns.

A - C. Type 25. Double walled sphaeromorph cryptarchs with a smooth to granular or shagreenate surface texture. Both walls are thin and the inner vesicle has numerous thin, curved folds around its margin.
A & B are LM and SEM pictures of the same fossil.
C is a detail of B.

D - F. Type 26. Double walled sphaeromorph cryptarchs consisting of an outer translucent membrane within which lies a thin-walled vesicle with thin to medium criss-crossing folds arranged at random.
D & E are LM and SEM pictures of the same fossil.
F is a detail of E.

G - L. Type 27. Double walled sphaeromorph cryptarchs consisting of an outer translucent membrane within which is a thin walled vesicle with several sinuous folds of narrow to medium width, arranged at random.
G & H and J & K are LM and SEM pictures of the same fossils.

A - C. MAC DDH M14 250'8 F87 LM and SEM.
D - F. MAC DDH M14 250'8 F184 LM and SEM.
G - H. MAC DDH M14 250'8 F186 LM and SEM.
I. MAC DDH M14 250'8-20/090 -169.
J - K. MAC DDH M14 250'8 F86 LM and SEM.
L. MAC DDH M14 245'6-2/1289-150.

PLATE 20

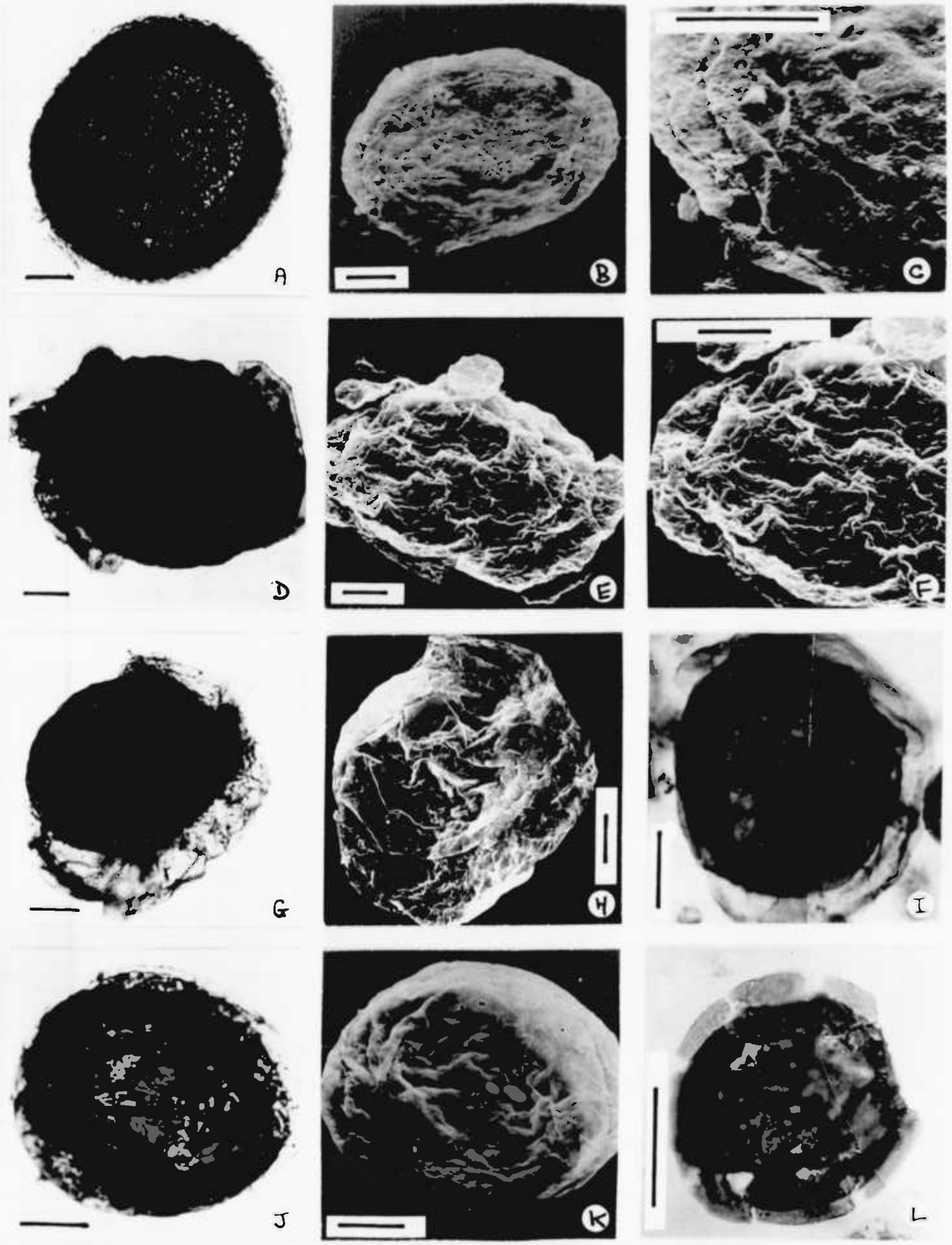


Plate 21

Scale bars A - K = 10 microns.

A - E. Type 28. Thin walled sphaeromorph cryptarchs within a thin membrane. The surface of the inner vesicle is smooth to granular or shagreenate and its wall is thrown into many interdigitating sinuous folds, narrow to medium in width, arranged at random.

F - K. Type 29. Thin walled sphaeromorph cryptarchs containing one relatively small, rounded, translucent granular body. The outer wall of the vesicle has a smooth to granular or shagreenate surface texture and is arranged in numerous wrinkles and thin folds around its margin.

A. MAC DDH M14 250'8-20/1111-050.
B. MAC DDH M14 250'8-8/1158-060.
C. MAC DDH M15 173'5-1/1128-164.
D. MAC DDH M15 173'5-1/1205-186.
E. MAC DDH M15 173'5-1/1099-092.
F. MAC DDH B7 74'2-2/1004-043.
G. MAC DDH B7 74'2-1/1159-158.
H. MAC DDH B7 74'2-4/0983-135.
I. TS DDH B7 74'2-9/1165-182.
J. TS DDH B7 74'2-9/1174-127.
K. MAC DDH B7 74'2-9/0996-138.

PLATE 21

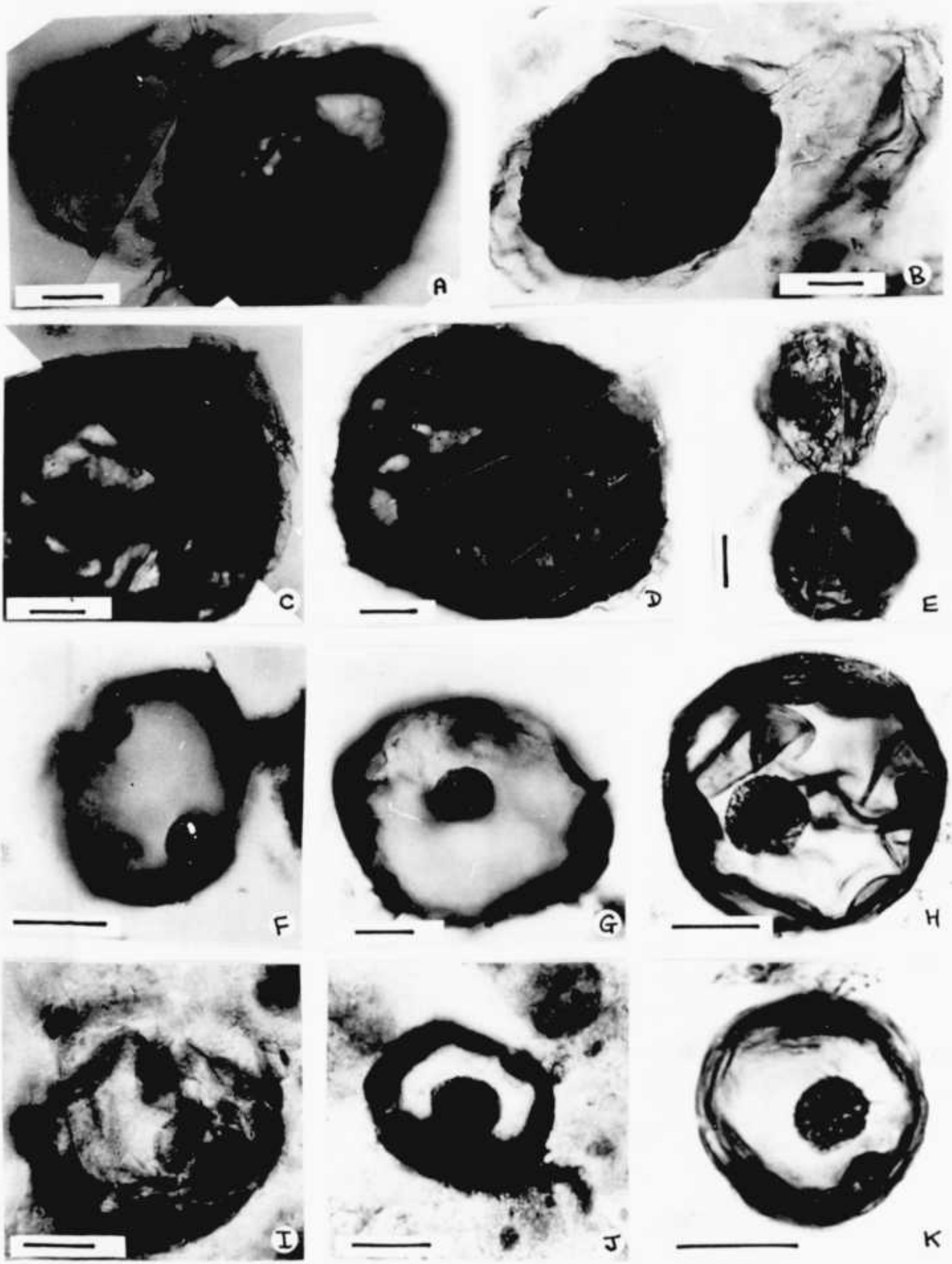


Plate 22

Scale bars A - L = 10 microns.

A - C. Type 30. Thin walled sphaeromorph cryptarchs containing one relatively small, rounded, opaque inner body. The surface of the vesicle wall is smooth to shagreenate or granular, usually with a few very fine wrinkles. The inner body has a rough outline.

D - F. Type 31. Thin walled sphaeromorph cryptarchs containing one relatively small, rounded, opaque inner body. The outer wall of the vesicle has a smooth to granulate or shagreenate surface texture, often with a few very fine wrinkles. The inner body has a smooth outline.

G. Type 32. Thin walled sphaeromorph cryptarchs containing a relatively small cluster of granules. The outer wall of the vesicle has a smooth to granulate or shagreenate surface texture, often with a few very fine wrinkles.

H. Type 33. Thin walled sphaeromorph cryptarchs containing a diffuse granular patch. The outer wall of the vesicle is smooth to granular or shagreenate, often with fine wrinkles.

I. Type 34. Thin walled sphaeromorph cryptarchs containing a diffuse granular patch within which lies a relatively small, rounded, opaque inner body. The outer wall of the vesicle has a smooth to granulate or shagreenate surface texture, often with fine wrinkles.

J - L. Type 36. Synaplomorph cryptarchs consisting of several to many associated vesicles. The vesicles are rounded in outline and most of them contain a relatively small opaque spot with a smooth outline. Some of the vesicles of the cluster are connected, but constricted at septa.

See Plate 23 for slide numbers and picture locations.

PLATE 22

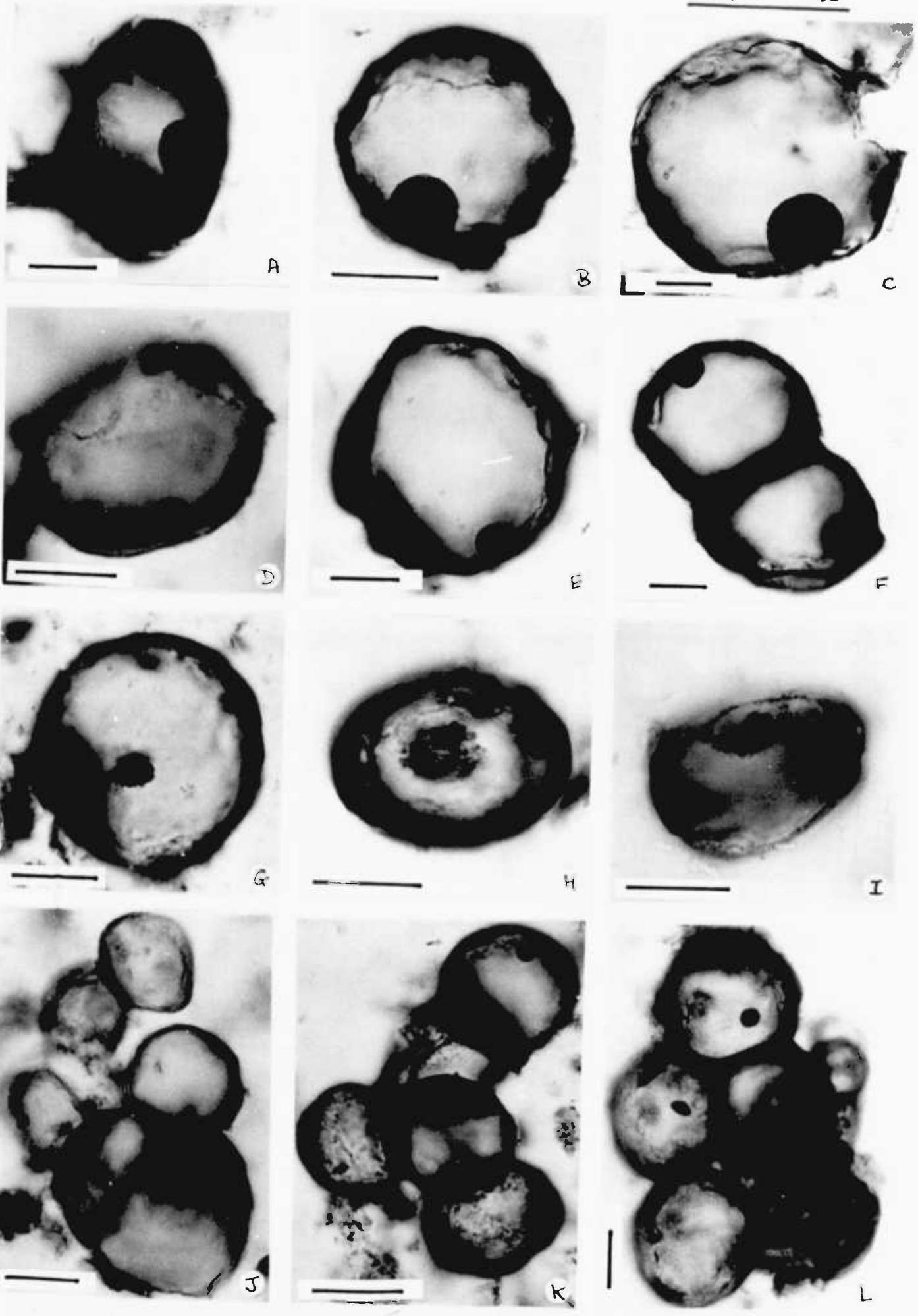


Plate 23

Scale bars A - F, H, J = 10 microns.
G, I = 100 microns.

A - B. Type 35. Thin walled sphaeromorph cryptarchs containing one relatively small, rounded, opaque spot with a smooth outline. The surface texture of the vesicle wall varies from smooth to granular or shagreenate; the wall is thrown into numerous short folds and wrinkles around the margin of the vesicle.
The inset in B shows the surface of the same fossil.

C - D. Type 37. Synaplomorph cryptarchs with vesicles tightly pressed together in colonies with a smooth outline.

E. Type 38. Synaplomorph cryptarchs consisting of closely associated vesicles within individual sheaths or membranes. Up to two vesicles occur within a common sheath. Paired vesicles are constricted at septa, but otherwise vesicles are separate.

F. Type 39. Synaplomorph cryptarchs consisting of numerous vesicles closely packed but separate, within a common organic matrix.

G - J. Type 40. Synaplomorph cryptarchs consisting of numerous separated, rounded dark inclusions, embedded in an unstructured organic matrix.
H is a detail of the colony in G.

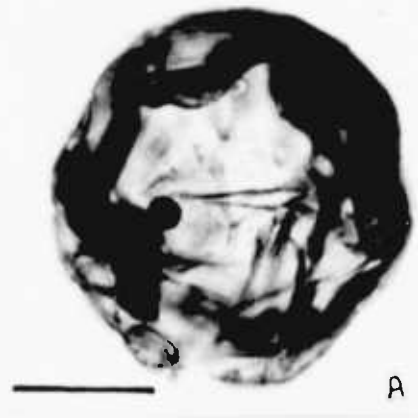
Plate 23

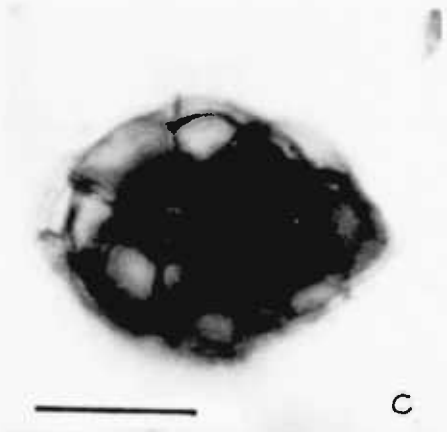
A. MAC DDH B7 74'2-1/1017-095.
B. MAC DDH B7 74'2-1/1207-219.
C. MAC DDH B7 74'2-4/1037-089.
D. MAC DDH B7 74'2-4/0994-112.
E. MAC DDH B7 74'2-3/1330-163.
F. MAC DDH B7 74'2-9/1233-107.
G. MAC DDH M14 150'5-1/1091-218.
H. MAC DDH M14 150'5-1/1091-218.
I. MAC DDH M14 150'5-1/1193-184.
J. MAC DDH M14 150'5-1/1131-077.

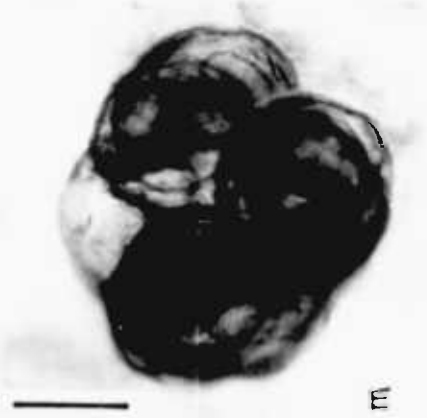
Plate 22

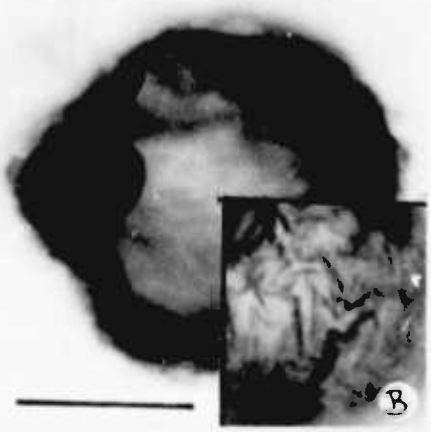
A. MAC DDH B7 74'2-9/1064-042.
B. MAC DDH B7 74'2-4/1085-091.
C. MAC DDH B7 74'2-3/0936-031.
D. MAC DDH B7 74'2-4/0999-105.
E. MAC DDH B7 74'2-10/0990-058.
F. MAC DDH B7 74'2-2/1329-045.
G. MAC DDH B7 74'2-4/1335-207.
H. MAC DDH B7 74'2-4/1244-014.
I. MAC DDH B7 74'2-4/1285-080.
J. MAC DDH B7 74'2-3/0993-085.
K. MAC DDH B7 74'2-8/1310-112.
L. MAC DDH B7 74'2-3/1115-088.

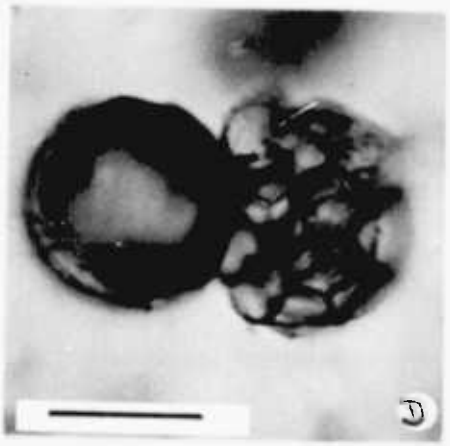
PLATE 23

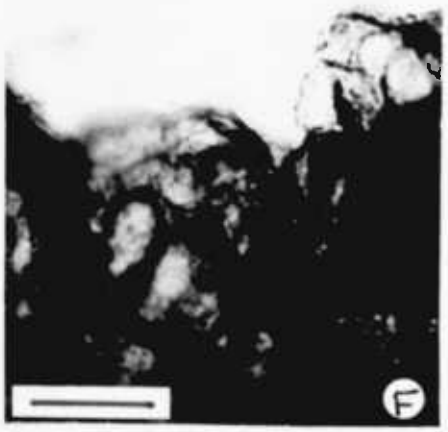

A

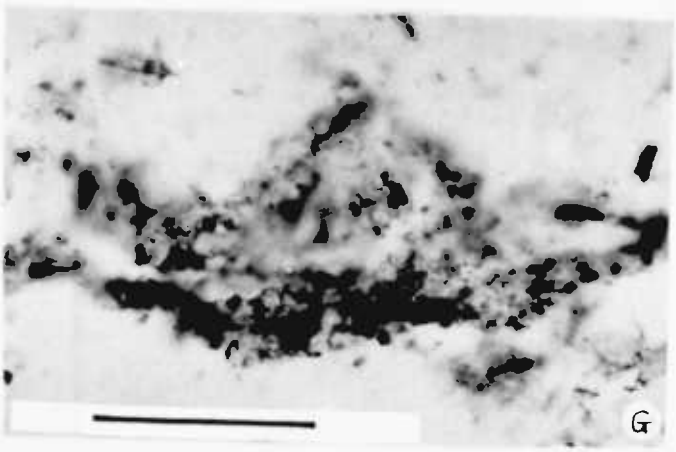

C

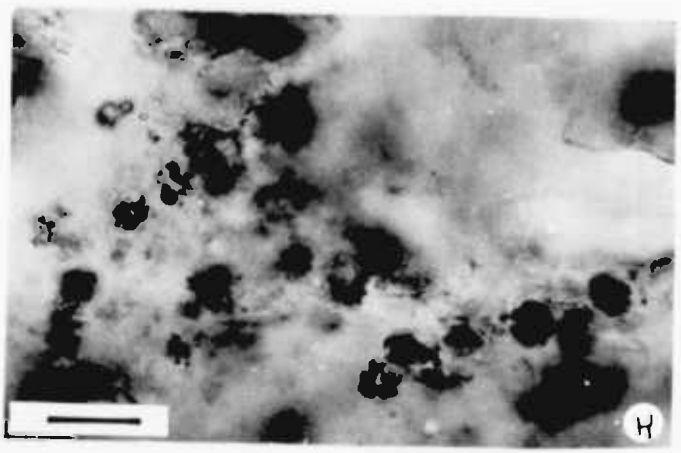

E

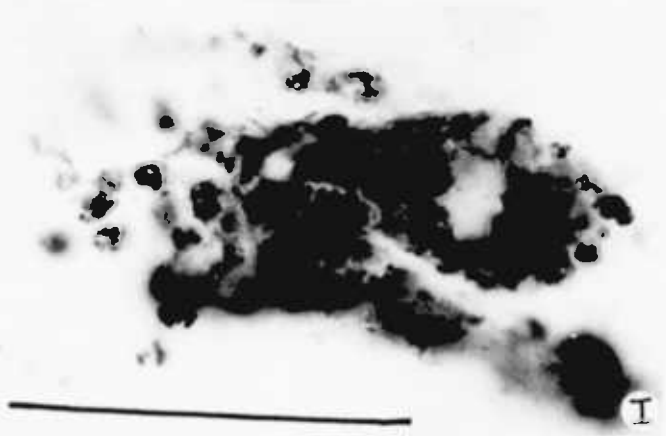

B


D


F


G


H


I

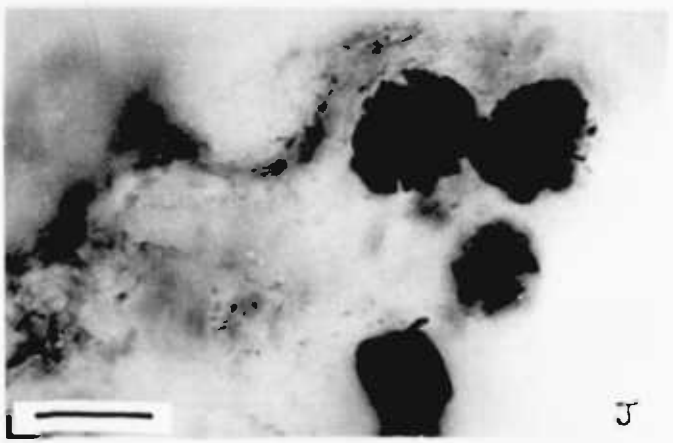

J

Plate 24

Scale bars A - L = 10 microns.

A - L. Type 41. Synaplomorph cryptarchs in the form of rounded envelopes containing rounded vesicles. The inner vesicles are separate, not packed together.

A. MAC DDH M14 245'6-2/1007-101.
B. MAC DDH M14 250'8-15/0986-114.
C. MAC DDH M14 245'6-2/1132-214.
D. MAC DDH M14 245'6-2/1222-181.
E. MAC DDH M14 250'8-20/1099-068.
F. MAC DDH M14 250'8-15/0976-142.
G. MAC DDH M14 250'8-15/1289-054.
H. MAC DDH M14 250'8-15/0922-140.
I. MAC DDH M14 250'8-18/1326-199.
J. TS DDH M14 250'8-1/1197-104.
K. MAC DDH M15 173'5-1/0991-151.
L. MAC DDH M14 250'8-18/1097-040.

PLATE 24

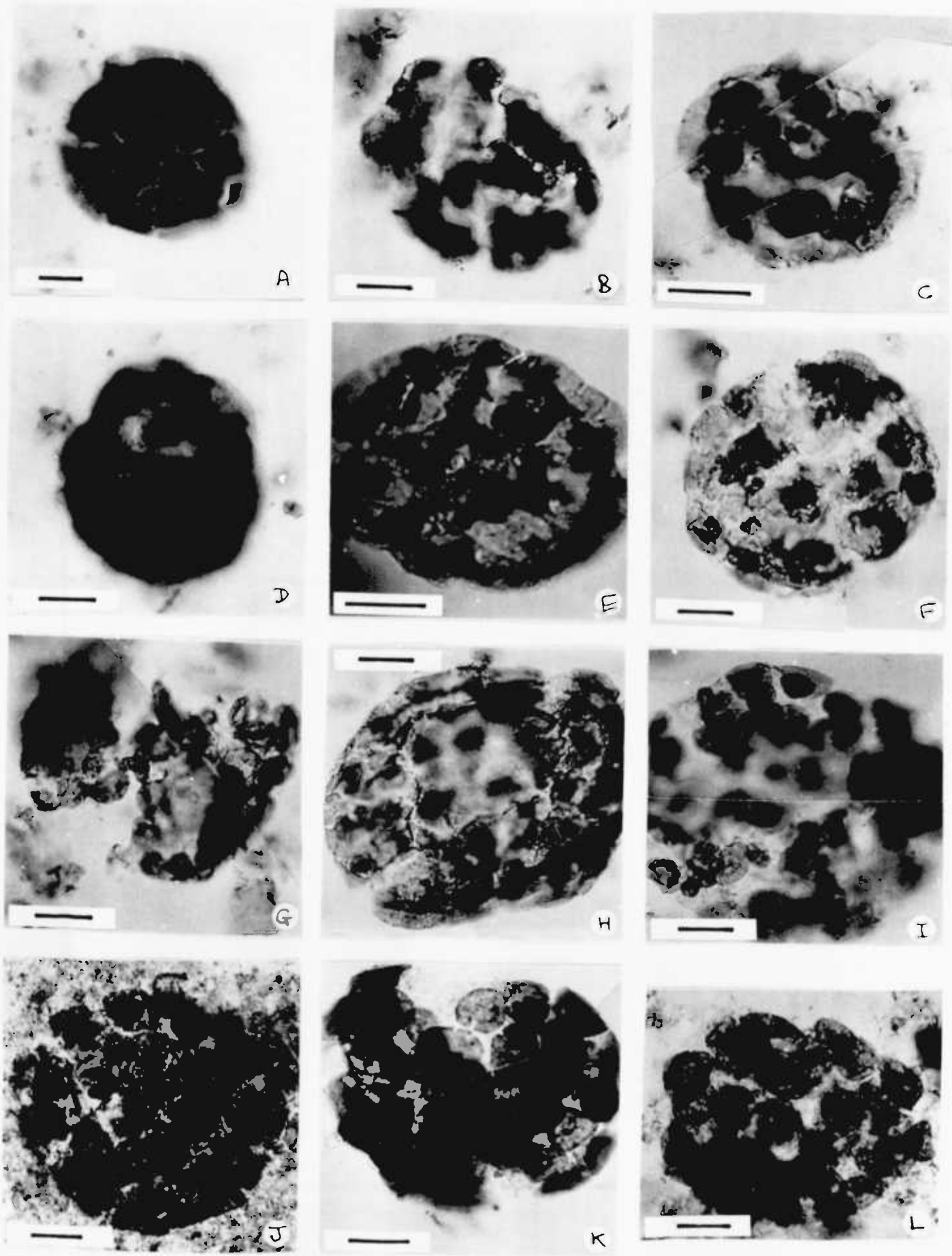


Plate 25

Scale bars A - L = 10 microns.

A - F. Type 42. Synaplomorph cryptarchs consisting of three or more vesicles closely associated in colonies. Septa are constricted only at the edge of larger colonies.

G - L. Type 43. Synaplomorph cryptarchs consisting of three or more vesicles closely associated in colonies. Many vesicles contain a relatively small opaque spot or granular patch. Septa are constricted only at the edge of larger colonies.

A. MAC DDH B7 74'2-3/1167-233.
B. MAC DDH B7 74'2-11/1126-097.
C. MAC DDH B7 74'2-4/0953-068.
D. MAC DDH B7 74'2-3/0932-229.
E. TS DDH B7 74'2-9/1169-094.
F. MAC DDH B7 74'2-1/1376-102.
G. MAC DDH B7 74'2-9/1089-134.
H. MAC DDH B7 74'2-4/1174-075.
I. MAC DDH B7 74'2-3/1123-196.
J. MAC DDH B7 74'2-4/0886-040.
K. MAC DDH B7 74'2-10/0974-036.
L. MAC DDH B7 74'2-9/1081-145.

PLATE 25

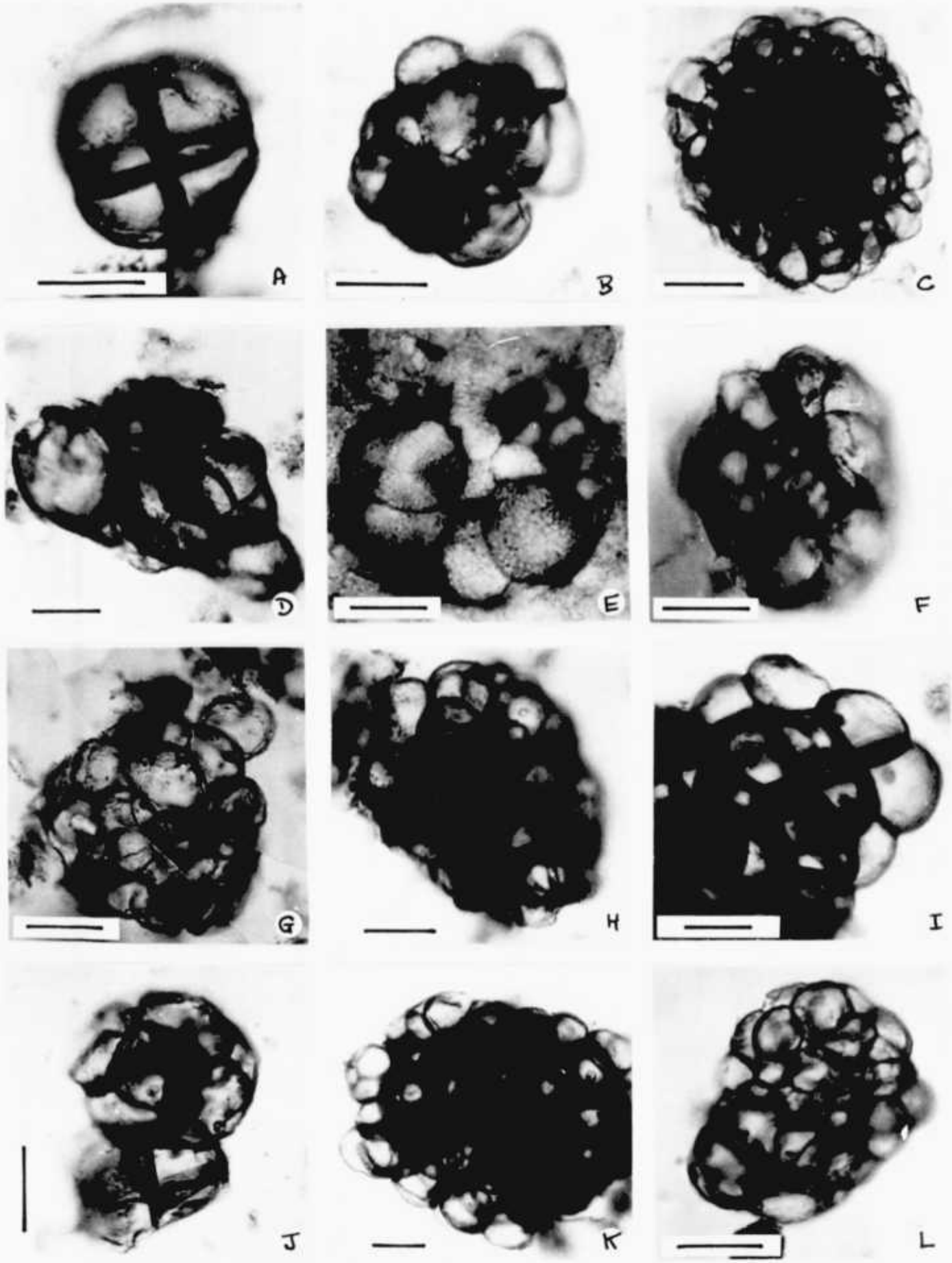


Plate 26

Scale bars A = 100 microns.
B - L = 10 microns.

A - F. Type 44. Synaplomorph cryptarchs consisting of three or more vesicles closely associated in colonies. Septa are constricted only at the edge of larger colonies.

G - L. Type 45. Synaplomorph cryptarchs consisting of three or more vesicles closely associated in colonies. Many vesicles contain a relatively small dense spot or granular body. Septa are constricted only at the edge of larger colonies.
J & K are LM and SEM pictures of the same fossil.
L is a detail of K.

A. MAC DDH M14 245'6-2/0946-065.
B. MAC DDH B7 74'2-4/1323-211.
C. MAC DDH M14 250'8-8/1034-034.
D. MAC DDH B7 74'2-3/1091-066.
E. MAC DDH B7 74'2-4/0912-125.
F. TS DDH B7 74'2-10/1127-064.
G. MAC DDH B7 74'2-3/1089-214.
H. MAC DDH B7 74'2-3/1045-063.
I. MAC DDH B7 74'2-3/1037-097.
J. MAC DDH B7 74'2-F1 LM.
K - L. As J, SEM.

PLATE 26

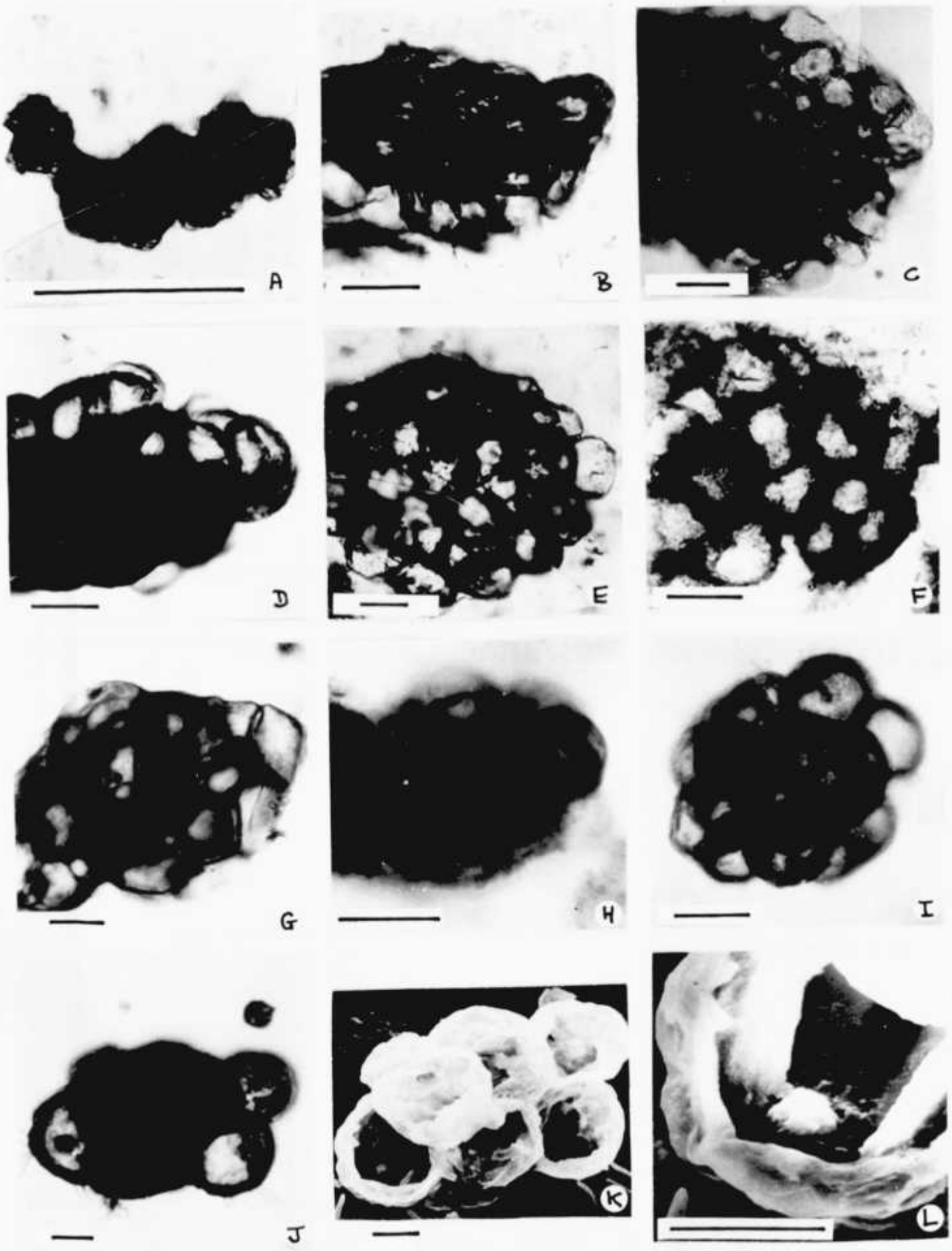


Plate 27

Scale bars A - K = 10 microns.

A - G, K. Type 46. Nematomorph cryptarchs in the form of solitary, unbranched granular threads.

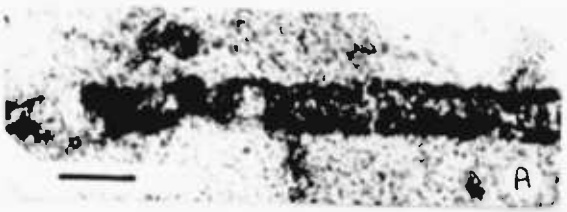
H. Type 48. Nematomorph cryptarchs consisting of an aseptate, unbranched, hollow tube.

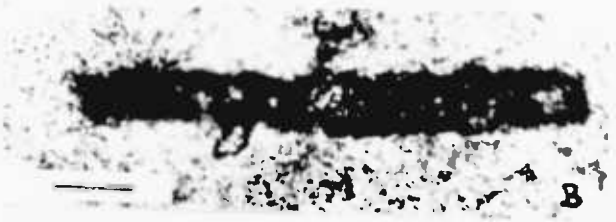
I. Type 49. Nematomorph cryptarchs consisting of an unbranched, uniseriate chain of vesicles with a length/width ratio of less than 0.5, and not constricted at septa.

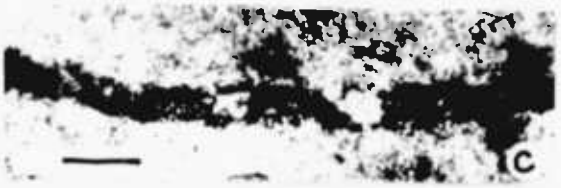
J. Type 50. Nematomorph cryptarchs consisting of an unbranched uniseriate chain of approximately equidimensional vesicles not constricted at septa.

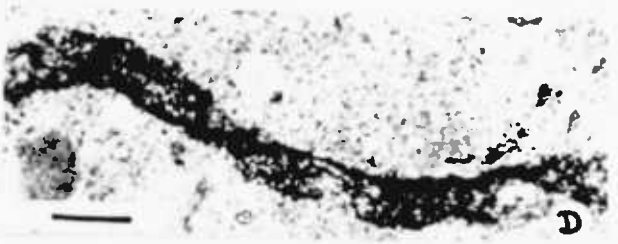
A. TS DDH A9 73'9-12/1204-093.
B. TS DDH A9 73'9-12/1214-074.
C. TS DDH A9 73'9-12/1217-125.
D. TS DDH A9 73'9-12/1214-074.
E. TS DDH B8 143'0-9/1115-126.
F. TS DDH B8 143'0-9/1066-127.
G. MAC DDH B7 74'2-2/1285-048.
H. MAC DDH B7 74'2-3/1171-215.
I. MAC DDH B7 74'2-9/1010-076.
J. MAC DDH B7 74'2-4/1321-151.
K. MAC DDH B7 74'2-7/1117-166.

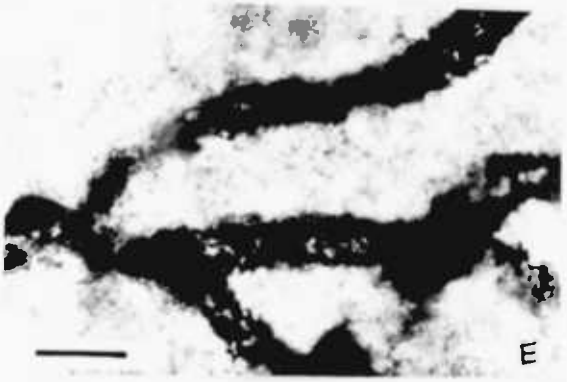
PLATE 27

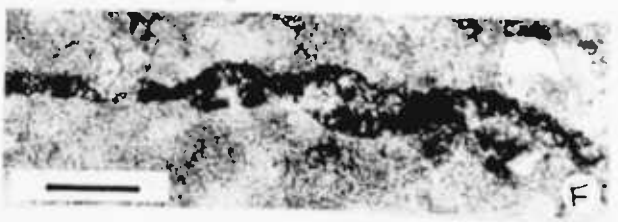




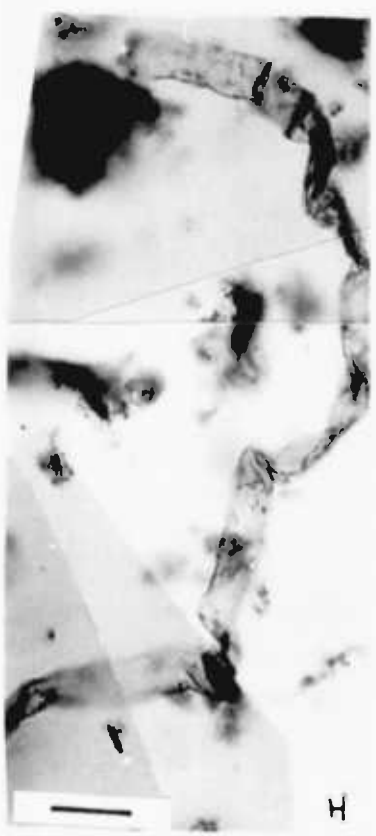












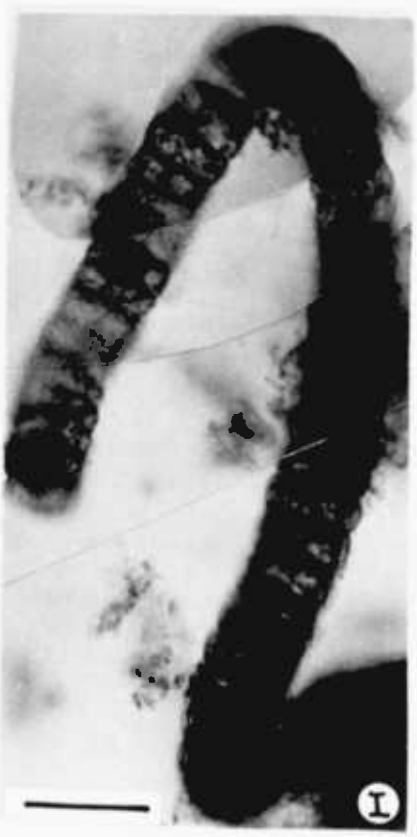






Plate 28

Scale bars A - E = 10 microns.

A, C. Type 51. Nematomorph cryptarchs consisting of sinuous, granular, unbranched filaments twisted together. The filaments are sometimes associated with unstructured organic material.

B. Type 47. Nematomorph cryptarchs in the form of solitary, unbranched, granular filaments.

D - E. Type 52. Nematomorph cryptarchs consisting of branching granular filaments, each with a single denser strand running down the centre.

A. TS DDH A9 73'9-19/1110-101.
B. TS DDH B8 143'0-7/0994-083.
C. TS DDH A9 73'9-19/1117-123.
D. TS DDH A9 73'9-12/1235-057.
E. TS DDH A9 73'9-12/1105-094.

PLATE 28

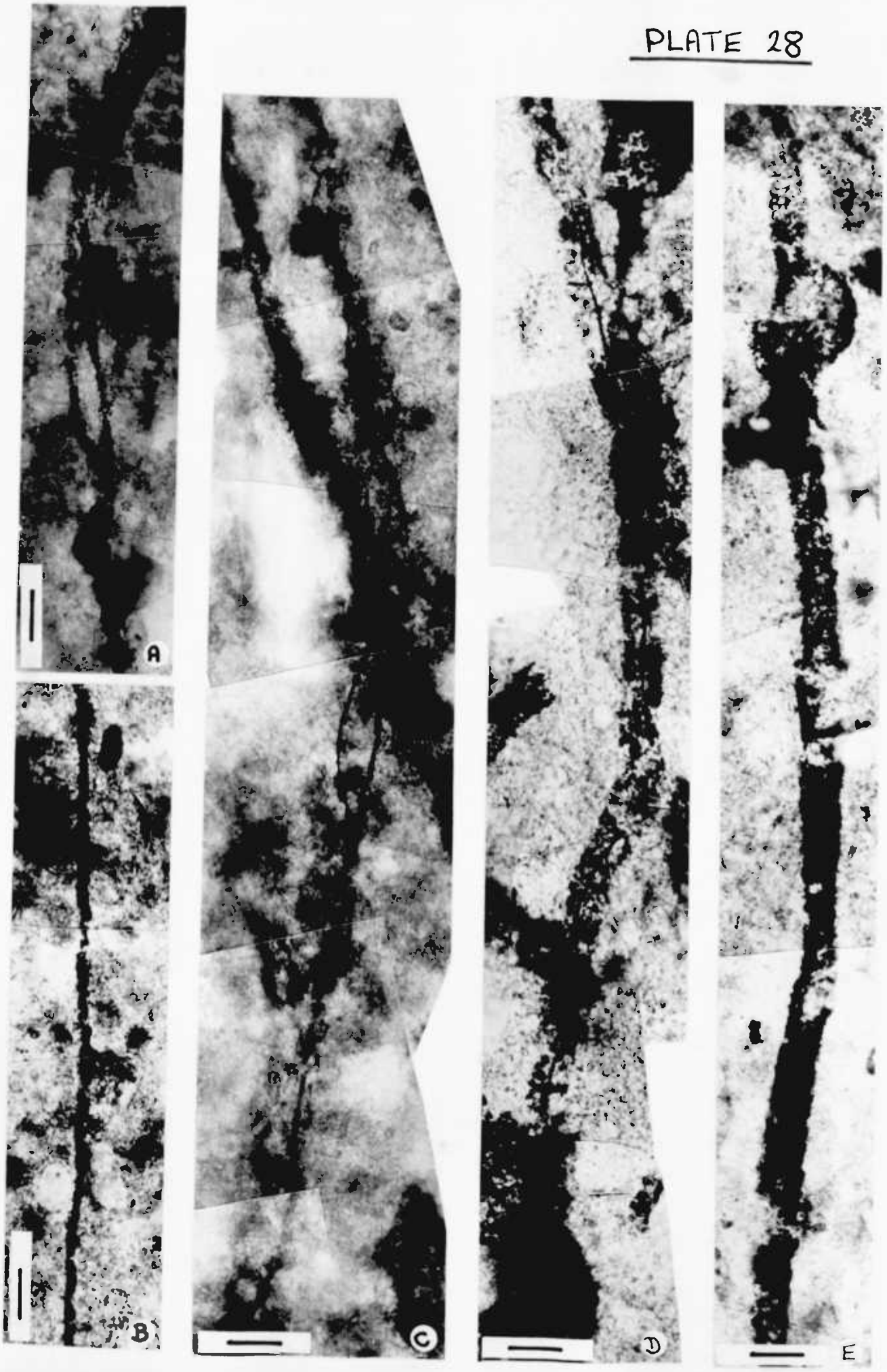


Plate 29

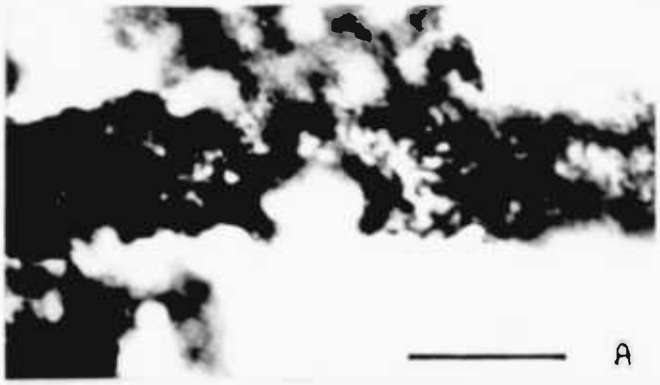
Scale bars A, D = 10 microns.
B, E - H = 100 microns.
C, I - K = 20 microns.

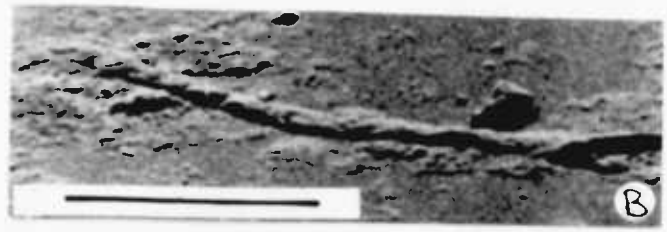
A - B, D. Type 46. See Plate 27 for diagnosis. A & B are LM and SEM pictures of the same fossil. D is a detail of B.

C, E - K. Type 53. Nematomorph cryptarchs consisting of unbranched, thin walled hollow tubes with transverse striations. The surface texture of the tubes varies from granular to very rough and flaky.
J & K are LM and SEM pictures of the same fossil.

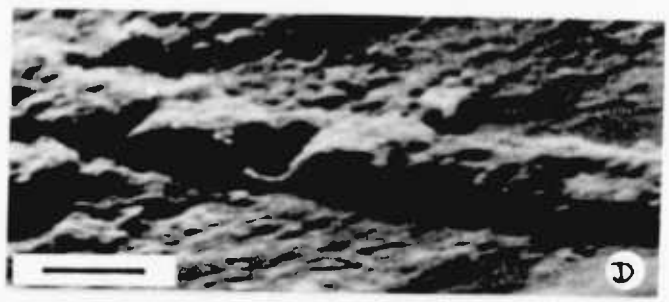
A. MAC DDH C6 94'11-LM (Strew mount).
B, D. As A, SEM.
C. MAC DDH M14 250'8-15/1225-079.
E. MAC DDH B7 74'2-8/1054-152.
F. MAC DDH B7 74'2-3/0991-062.
G. MAC DDH B7 74'2-1/1238-135.
H. MAC DDH B7 74'2-8/0965-029.
I. MAC DDH B7 74'2-3/0924-142.
J. MAC DDH B7 74'2 F3 LM.
K. As J, SEM.

PLATE 29

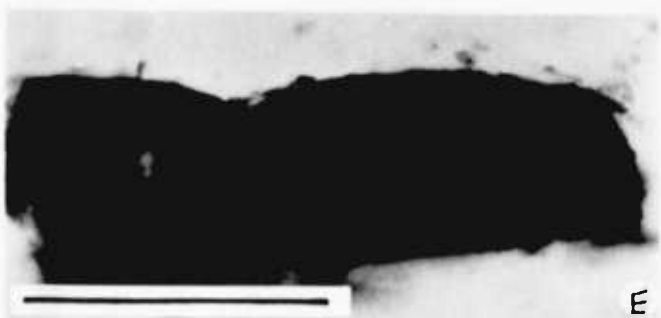

A

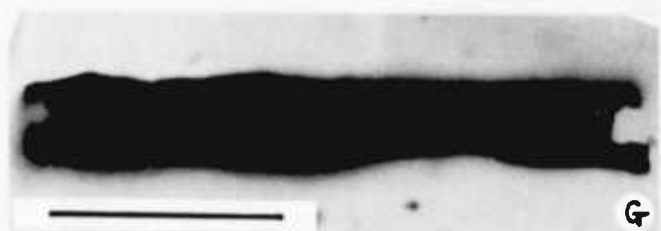

B

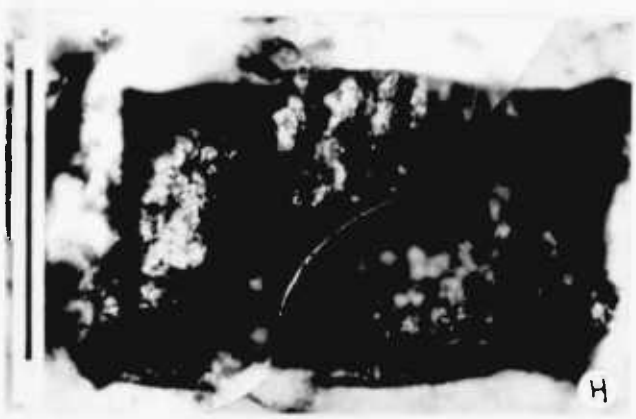

C


D


F


E


G


H


I


J

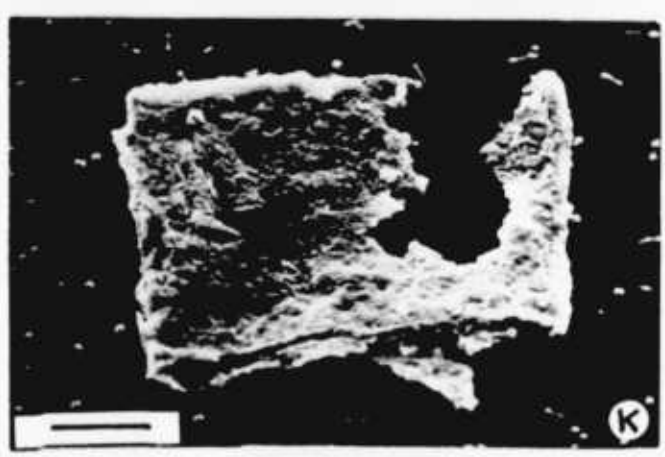

K

Plate 30

Scale bars A, I = 10 microns.
B - F = 100 microns.
G, H = 50 microns.

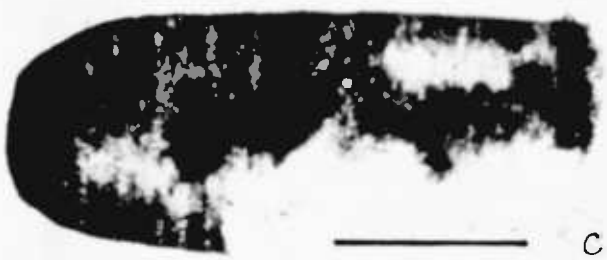
A - I. Type 53. For diagnosis see Plate 29.
E & F, and G & H are LM and SEM pictures of the same fossils. I is a detail of F.

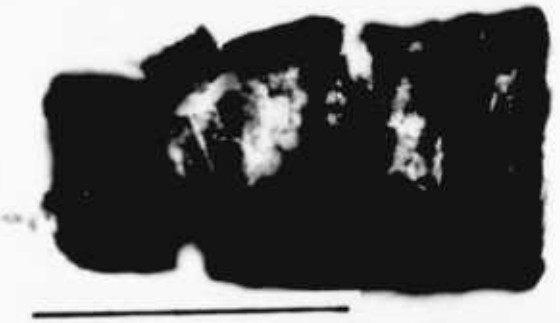
A. MAC DDH B7 74'2-9/1012-173.
B. MAC DDH M14 250'8-3/0973-098.
C. MAC DDH B7 74'2-4/0956-041.
D. MAC DDH B7 74'2-10/1194-226.
E. MAC DDH B7 74'2 F41 LM.
F. As E, SEM.
G. MAC DDH B7 74'2 F22 LM.
H, I. As G, SEM.

PLATE 30

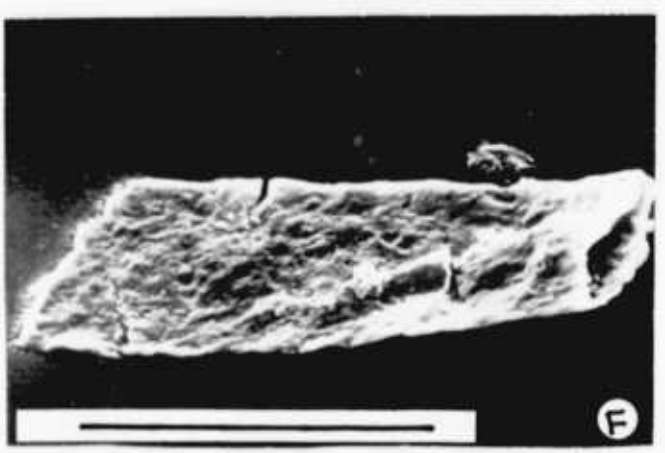

A


B


C


D


E


F


G


H

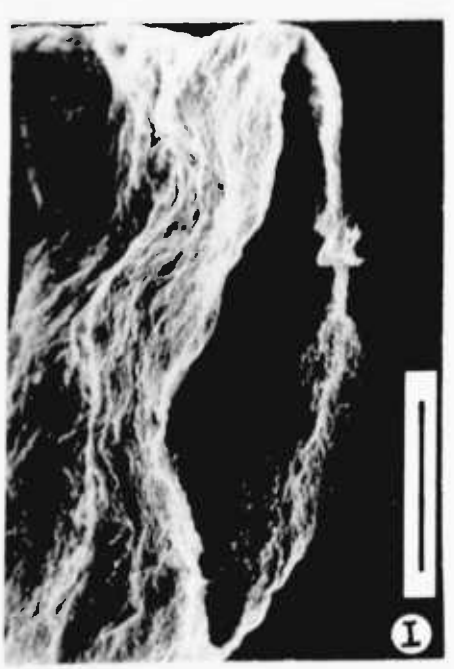

I

Plate 31

Scale bars A - C, G = 100 microns.
D - F = 10 microns.

A - D. Type 53. For diagnosis see Plate 29.
A - D are LM and SEM pictures of the same fossil.
A is the left end of C, B is the right end of C.
D is a detail of A & C.

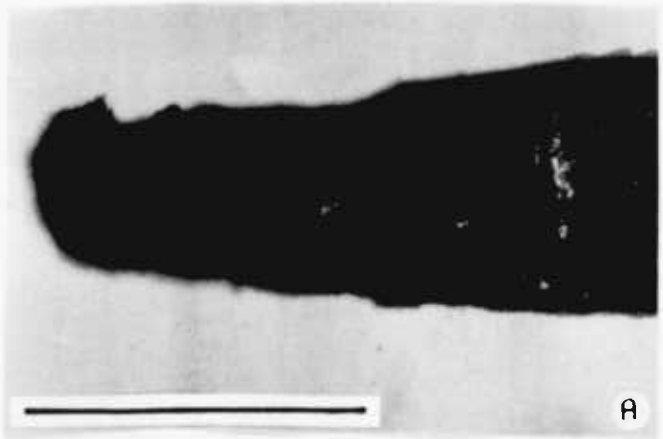
E. Filaments replaced by pyrite. The branching may not be real.

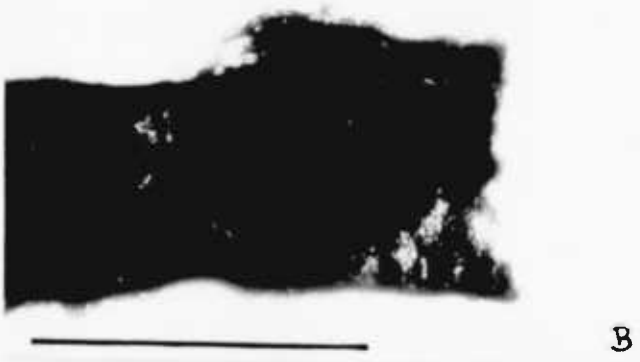
F. Type 54. Branching granular filaments arising from a central organic mass.

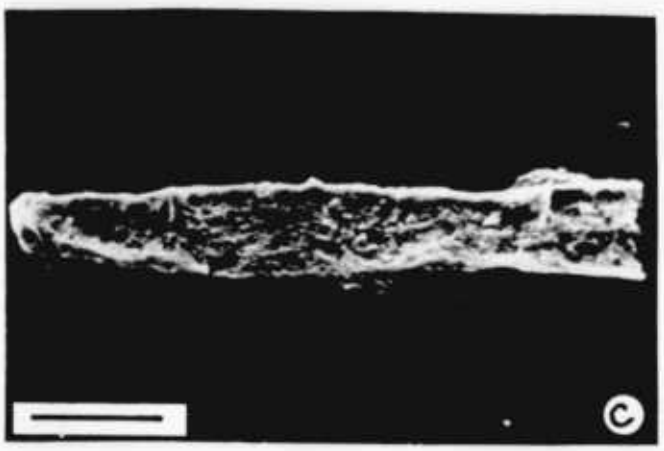
G. Type 55. Numerous opaque filaments radiating from an opaque central body. Some of the filaments branch.

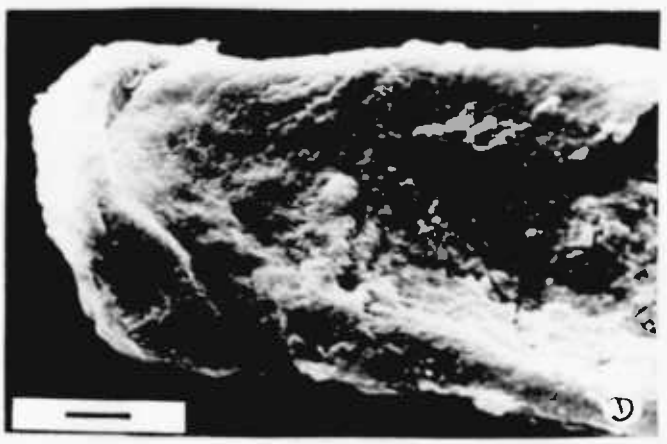
A. MAC DDH B7 74'2 F27 LM.
B - D. As A, LM and SEM.
E. TS DDH A9 73'9-19/1110-107.
F. TS DDH A9 73'9-12/1068-146.
G. TS DDH A9 73'9-12/1235-101.

PLATE 31

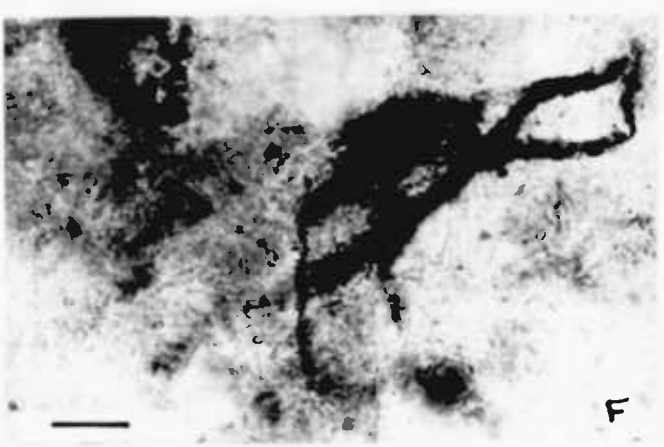


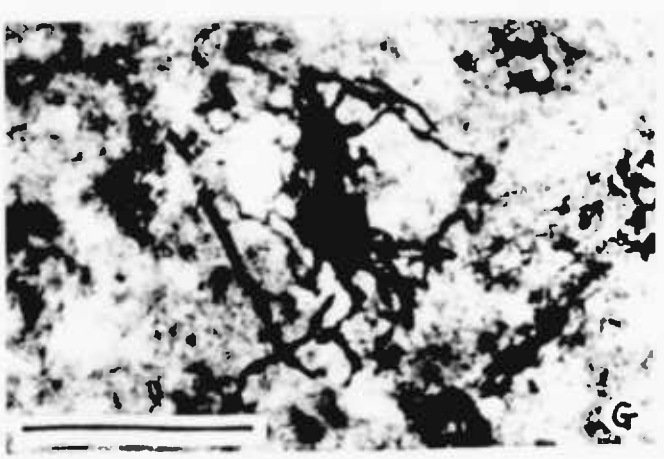










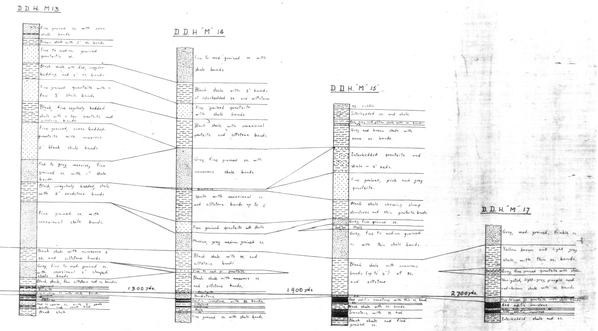


STRATIGRAPHIC COLUMNS

McMINN FORMATION

FROM DIAMOND DRILL CORES





19000 yds

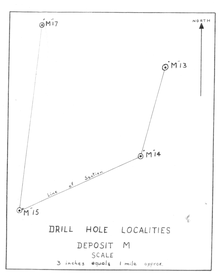
SCALE OF COLUMNS

1 inch = 40 feet

Stated distances (in yards) refer to distances between drill holes

Stratigraphic information obtained by diamond drilling by B.H.P (1958).
Drill core logged by B.H.P. geologists (1958). Descriptions and Terminology in columns based on these logs.

Stratigraphic columns compiled by K. Plumb — B.M.R. (1959)
Broad correlations of iron ore horizons carried out by B.H.P.
Detailed correlations by K. Plumb — B.M.R.



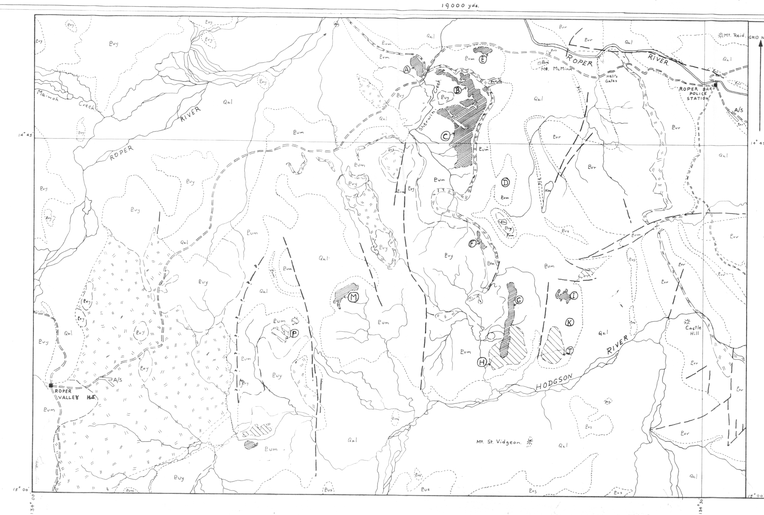
DRILL HOLE LOCALITIES

DEPOSIT M

SCALE

3 inches equals 1 mile approx.





LOCALITY MAP

SHOWING GENERALISED GEOLOGY AND IRON ORE DEPOSITS

Geological Map after B.H.P. (1958)

Terminology after B.M.R. (1959)

SCALE

1 inch equals 2 miles

REFERENCE

QUATERNARY — Alluvium and soil cover

CRETACEOUS — MULLAMAN BEDS

UPPER PROTEROZOIC
- KYALLA FORMATION
- McMINN FORMATION
- ST. VIDGEON FORMATION
- ROPER GROUP (Undifferentiated)

IGNEOUS ROCKS — Basic intrusives

High grade iron ore

Low grade iron ore

Established Geological Boundary — position approximate

Established Alluvium Boundary — position approximate

Established Fault — position approximate

Inferred Fault — position approximate

Iron Ore Deposit

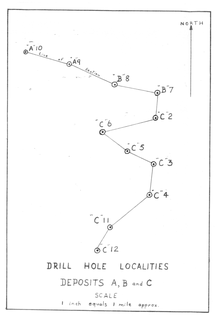
Homestead

Airstrip

Vehicle Track

Hill

Watercourse



DRILL HOLE LOCALITIES

DEPOSITS A, B and C

SCALE

1 inch equals 2 miles approx.

Bureau of Mineral Resources, Geology and Geophysics, Canberra. December 1959