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Devonian palynology of samples from Caithness

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Devonian palynology of samples from Caithness

M H Stephenson

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Summary

The palynology of samples from the Dounreay-2 Borehole and from outcrop in the Dounreay area, is described. The palynological assemblages recovered are sparse or barren, and the organic residue of the rocks is dominated by brown amorphous organic material (AOM) of possible lacustrine algal origin, though material of probable land plant origin is also present at certain levels in Dounreay-2. Spores are poorly preserved and many show the effects of pyrite growth. A few assemblages contain *Rhabdosporites langii* and one (from Quarry on Bannerman's Farm; MPA 50686, PY735, 0407 6656,) contains *Grandispora velata*; these taxa allow a date to be suggested using standard Devonian biozonations. This and other evidence suggests that the Dounreay-2 sequence and the palyniferous outcrop samples are Eifelian in age.

On the basis of palynostratigraphical trends and other lithological evidence Bolt & Cole (1992) suggested a position for the Achanarras horizon in Dounreay-1 and simple lithostratigraphic correlation based on this implies a position for the Achanarras horizon at approximately 275m in Dounreay-2 (see Fig. 3). Such a position appears to be broadly consistent with admittedly sparse palynostratigraphic data.

Most of the surface samples contain *Rhabdosporites* spp. and *Ancyrospora* spp. but all lack *G. lemurata*, in these characteristics they are similar to those recorded within the studied parts of Dounreay-1 and -2 and can therefore be considered to be broadly correlative. Two of the surface samples contain assemblages that can be related more precisely to palynostratigraphic trends within the Dounreay boreholes, these are MPA 50689 [0433 6504] and MPA 50686 [0407 6656]. Both of these samples probably correlate with a level above 260.25m in Dounreay-1 and MPA 50686 probably correlates to a level not more than 60m stratigraphically above the Achanarras horizon.

Unpublished palynostratigraphical information on the Caithness Middle Devonian has been documented and this, combined with information from this and further studies, should help in the development of a local biozonation scheme to support mapping activities in Caithness.

1 Introduction

This report describes the palynology of 56 samples from the Dounreay No. 2 Borehole (299588 966914), Caithness and 19 outcrop samples from the Dounreay area.

The objectives of the study are to:

1. determine the age of assemblages using standard Devonian biozonation schemes;
2. where possible, establish a local/regional biozonation to support local mapping programmes and offshore/onshore, Orkney/Shetland correlation.

2 Review of Orcadian Basin palynological studies

Devonian palynological studies began in the Orcadian Basin with Lang (1925). Later research did not take place until the 1960s with Richardson (1960, 1962 and 1965). These papers are mainly taxonomic, though some limited correlation was attempted. Between 1965 and 1981, very little work was published apart from brief accounts of palynomorph assemblages and short taxonomic lists (e.g. Owens & Richardson 1972, Collins & Donovan 1977, Donovan et al. 1974). In recent years, Allen & Marshall (1981) Marshall & Allen (1982) and Marshall (1988, 1996, 2000) further developed taxonomy and stratigraphic palynology in the Orcadian Basin, but these papers are mainly concerned with Orkney and Shetland.

The most important biozonation schemes for the Devonian of the ORS continent (Richardson & McGregor 1986, Streel et al. 1987) are applicable in the Orcadian Basin and this has allowed international stage dates to be applied to the succession. Broadly the Middle Devonian in Orkney and Shetland can be assigned to the Eifelian and Givetian stages (Fig. 1). These biozonation schemes do not, however, have sufficient resolution to be of value in local stratigraphy and correlation within the Middle Devonian in the Dounreay region.

Fig. 1 Correlation and ages of Orkney and Caithness successions based on Marshall (2000) and House (2000)

		Orkney	Caithness	Biozonation
Middle Devonian	Givetian	Middle Eday Sandstone Fm.	John O’Groats Flagstone Group	lemurata- magnificus ↕
		Eday Flagstone Fm.		
		Lower Eday Sst Fm.		
	Eifelian	Rousay Flagstone Fm.	Upper Caithness Flagstone Group	devonicus- naumovii ↕
		U Stromness Flagstone Fm	Achanarras Fish Bed	
		Sandwich Fish Bed		
		L Stromness Flagstone Fm	Lower Caithness Flagstone Group	velatus- langii

2.1 PALYNOLOGY OF THE DEVONIAN SUCCESSIONS OF THE DOUNREAY AREA

Apart from brief descriptions of palynomorphs from the Murkle Bay area by Richardson (1962, 1965) there is no published work on the Devonian palynology of the Dounreay area.

Recent unpublished work as part of the NIREX Project includes that of McNestry (1991) on the Dounreay-1 Borehole, and Turner (1991) on exposure samples from the Dounreay area. Other work includes that of Bolt & Cole (1992) who studied the Dounreay-1 Borehole.

These studies confirm a general Eifelian-Givetian age for the sediments of the Middle Devonian in the area on the basis of comparison with standard biozonations.

2.1.1 Exposure samples of the Dounreay area studied by Turner (1991)

62 samples were studied by Turner from localities listed in Table 1. Ages and biozone assignments suggested are also shown in the table. Turner (1991) described very low recovery which he considered precluded detailed local scale correlation but allowed broad ages to be assigned on the basis of comparison with standard biozonations. Turner noted the high occurrence of yellow-brown AOM which is also characteristic of samples in this study.

Table 1 Summary of Dounreay area outcrop palynology described by Turner (1991)

Locality	MPA Number	Age assigned	Biozone assigned
Meilvich Bay	35316-35323	No older than Early Eifelian	velatus-langii
Wester Clett	35324-35325	No older than Middle Devonian	N/A
Red Point	35326	Middle Devonian	N/A
Sandside Bay	35327-35336	No older than Early Eifelian	velatus-langii
Dounreay Complex East Shore Section	35341-35344	Mid-Eifelian to Early Givetian	devonicus-naumovi
Crosskirk Bay	35337-35340	Mid-Eifelian to Early Givetian	devonicus-naumovi
Port of Brims	35345-35346	No older than Early Eifelian	velatus-langii
Scrabster Hill Quarry	35347-35348	Mid-Eifelian to Early Givetian	devonicus-naumovi
Thurso Bay	SAL 3741-3745	Early Eifelian	velatus-langii
Murkle bay	SAL 3732-3738	Early Eifelian	velatus-langii
Gill's Pier	SAL 3739-3740	Mid-Eifelian to Early Givetian	devonicus-naumovi/lemurata-magnificus
Ackergill Bay, Ness Beds	SAL 3758-3762	Middle Devonian	N/A
Ackergill Bay, Ackergill Beds	SAL 3746-3757	Early Eifelian	velatus-langii

2.1.2 Studies of Dounreay-1

18 samples within an interval 16.07-364.57m in the Dounreay-1 Borehole were studied by McNestry (1991) who reported poor to moderate organic residue recovery and common AOM. Most of the assemblages allowed only a broad mid-upper Devonian age to be assigned but

sample MPA 34731 (91.06-94.04m) contained an assemblage that McNestry assigned to the Eifelian Age (Fig. 2).

More comprehensive work on the Dounreay-1 borehole was carried out by Bolt & Cole (1992) and Marshall (pers. comm.). A summary of this work is shown in Fig. 2. Bolt & Cole (1992) reported low yields of organic material in their samples but were able to identify a number of age diagnostic taxa including *Densosporites devonicus* and *Rhabdosporites langii* which allowed an assignment to the *velatus-langii* (Eifelian) and *devonicus-naumovii* (Mid-Eifelian to ?early Givetian) Biozones of Richardson & McGregor (1986) (Fig. 2).

Bolt & Cole (1992) suggested a position for the Achanarras horizon within the Dounreay-1 Borehole on palynostratigraphic and lithostratigraphic evidence. The first appearance datum (FAD) of *Ancyrospora grandispinosa* and the sharp quantitative decrease in *Ancyrospora longispinosa* within the borehole were used to suggest that the Achanarras horizon occurs within the range 109-264m. Bolt & Cole (1992) considered that within this range only one thick lacustrine cycle with subordinate limestone occurs, at 196m, and therefore considered this to be correlative with the Achanarras horizon (Fig. 2).

2.2 LOCAL ORCADIAN TRENDS IN PALYNOSTRATIGRAPHY

Unpublished work (Bolt & Cole 1992, Marshall pers. comm.) and work of Marshall (1988, 1996, 2000) has indicated that local Orcadian palynostratigraphic trends are present in the Middle Devonian that may be of use in local correlation:

- ? *Rhabdosporites langii* decreases in size through the Middle Devonian.
- ? The quantitative occurrence of *Ancyrospora longispinosa* drops dramatically 60m above the Achanarras horizon.
- ? *Ancyrospora grandispinosa* appears a short distance above the Achanarras horizon.
- ? The appearance of *Geminospora lemurata* indicates the earliest part of the Givetian Stage.
- ? *Ancyrospora ancyrea* var. *brevispinosa* increases quantitatively in the Givetian Eday Group in Orkney.

3 Description of assemblages

3.1 OUCROP SAMPLES

Overall the assemblages recovered are very sparse, and the majority of samples are barren. The organic residue of the rocks is dominated by brown amorphous organic material of possible lacustrine algal origin. Spores are rare and poorly preserved; many show the effects of pyrite growth. One sample only contains an assemblage allowing a date to be suggested using standard Devonian biozonations.

3.1.1 Melvich Bay-Sandside Bay

3.1.1.1 MPA 50681, 89132 65330, FORESHORE, EAST SIDE OF MELVICH BAY

Very sparse; contains indeterminate spores and possible specimens of *Ancyrospora*. Pyrite damage evident.

Interpretation

No age date can be suggested.

3.1.1.2 MPA 50680, 89132 65330, FORESHORE, EAST SIDE OF MELVICH BAY

Barren

Interpretation

No age date can be suggested.

3.1.1.3 MPA 50683, MM4, 9578 6622, FORESHORE, NORTH SIDE OF SANDSIDE HARBOUR

Very sparse; contains indeterminate spores and possible specimens of *Ancyrospora* and *Rhabdosporites*.

Interpretation

No age date can be suggested.

3.1.1.4 MPA 50682, MM3, 9578 6622, NORTH SIDE OF SANDSIDE HARBOUR

Barren

Interpretation

No age date can be suggested.

3.1.1.5 MPA 50685, MM6, 95776571, FORESHORE, SOUTH SIDE OF SANDSIDE HARBOUR

Very sparse; consists almost entirely of indeterminate spores and possible specimens of *Rhabdosporites* sp..

Interpretation

No age date can be suggested.

3.1.1.6 MPA 50684, MM5, 9577 6571, FORESHORE, SOUTH SIDE OF SANDSIDE HARBOUR

Very sparse; contains only indeterminate spores.

Interpretation

No age date can be suggested.

3.1.2 Yellow Moss area

3.1.2.1 MPA 50694, PY726, 0173 6512, FORESTRY TRACK NEAR YELLOW MOSS

Very sparse; contains *Rhabdosporites* sp. and *Punctatisporites* sp..

Interpretation

No age date can be suggested.

3.1.2.2 MPA 50695

Sparse; contains *Rhabdosporites langii*, *Ancyrospora/Hystricosporites* sp., *Verrucosisporites* sp., *Ancyrospora ancyrea*, *Retusotriletes* sp. and *Acinosporites ?lindlarensis*.

Interpretation

The presence of *Rhabdosporites langii* and a specimen similar to *Acinosporites lindlarensis lindlarensis*, and the absence of *G. lemurata* indicates an Eifelian Age (Richardson & McGregor 1986, Marshall 2000), but the sparseness of the assemblage allows only tentative age assignment.

3.1.2.3 MPA 50700

Very sparse; contains *Rhabdosporites* sp..

Interpretation

No age date can be suggested.

3.1.3 Forss Water area

3.1.3.1 MPA 50698, 0437 6559, PY 723, QUARRY NW OF BAILLIE

Very sparse; contains *Rhabdosporites* sp., many indeterminate spores and a single specimen of *Emphanisporites annulatus*.

Interpretation

The presence of *Emphanisporites annulatus* indicates a range Emsian-Givetian (Richardson & McGregor 1986). The sparseness and poor preservation of the assemblage precludes a more precise date.

3.1.3.2 MPA 50696, 0377 6660, PY 734, STEMPETER HILL

Very sparse; contains a specimen similar to *Retusotriletes* sp.

Interpretation

No age date can be suggested.

3.1.3.3 MPA 50691, PY739, 04986738, QUARRY EAST SIDE OF FORSS WATER

Very sparse; contains *Rhabdosporites langii* and an indeterminate trilete spore.

Interpretation

The presence of *Rhabdosporites langii* indicates a range from Eifelian to Frasnian (Richardson & McGregor 1986, Marshall 2000), but the sparseness of the assemblage allows only tentative age assignment.

3.1.3.4 MPA 50690, PY718, 0432 6404, ACHIVEIGLE QUARRY

Sparse; contains indeterminate trilete spores, *Ancyrospora* sp., relatively common but poorly preserved *Rhabdosporites* spp., common *Ancyrospora ancyrea*, spores assignable to either *Ancyrospora* or *Hystricosporites* and *Leisphaeridia* sp.. Some relatively well preserved cuticle material is present. Many spores show the effect of pervasive pyrite damage.

Interpretation

This assemblage contains no taxa of significance in detailed age dating, but the overall assemblage indicates a probable Middle Devonian age.

3.1.3.5 MPA 50689, PY719, 0433 6504, QUARRY SW OF BAILLIE

Very sparse; contains indeterminate spores ?*Rhabdosporites* sp., ?*Ancyrospora* sp., and *Grandispora* cf. *velata*.

Interpretation

The presence of *Grandispora* cf. *velata* indicates a probable range of Eifelian-Frasnian (Richardson & McGregor 1986). The sparseness and poor preservation of the assemblage precludes a more precise date.

3.1.3.6 MPA 50688, PY716, 0486 6344, KNOCKGLASS, FORSS WATER

Very sparse; consists almost entirely of indeterminate spores though *Ancyrospora* sp. may be present.

Interpretation

No age date can be suggested

3.1.3.7 MPA 50686, PY735, 0407 6656, QUARRY ON BANNERMAN'S FARM

[See Plates 1-13]

Relatively rich assemblage; preservation poor except in the larger spores. The assemblage contains: *Leiosphaeridia* sp., *Rhabdosporites* spp., *Rhabdosporites langii*, *Cristatisporites mediconus*, indeterminate trilete spores, *Retusotriletes* spp., *Dibolisporites echinaceus*, *Grandispora velata*, *Ancyrospora ancyrea*, *Ancyrospora longispinosa*, *Camptotriletes* sp., ?*Trileites langii*, *Apiculiretusispora* sp., *Ancyrospora ancyrea* var. *brevispinosa*, *Emphanisporites* sp., ?Dyad, *Verrucosisporites scurrus*, *Discernisporites macromanifestus* and *Verrucosisporites* cf. *polygonalis*.

Interpretation

This assemblage allows dating using the biozonation scheme of Richardson & McGregor (1986). On the basis of the occurrence of *G. velata* and *R. langii*, the assemblage is likely to be at least

early Eifelian in age (*velatus-langii* Biozone) and is unlikely to extend into the middle or late Givetian since *Geminospora lemurata* is absent. The presence of *Verrucosisporites* cf. *polygonalis* is surprising since the latter ranges from Siegenian to Emsian (Richardson & McGregor 1986).

3.1.3.8 MPA 50697, PY717, 0494 6339, KNOCKGLASS, FORSSWATER.

Very sparse; contains indeterminate spores, common poorly preserved spores likely to be *Rhabdosporites* and *Ancyrospora*, *Ancyrospora ancyrea*, *Cristatisporites* sp., *Auroraspora* sp., *Apiculiretusispora* sp., and various palynomorphs of possible algal origin.

Interpretation

The assemblage lacks taxa of age significance, but the presence of common *Ancyrospora* and *Rhabdosporites* probably indicates a broad Middle Devonian age.

3.1.3.9 MPA 50693, PY740, 0499 6694, BURN OF BRIMSIDE

Very sparse; contains indeterminate spores and a possible specimen of *Rhabdosporites*.

Interpretation

No age date can be suggested.

3.1.3.10 MPA 50687, PY720, 0410 6526, QUARRY WEST OF BAILLIE

Barren

Interpretation

No age date can be suggested

3.2 SAMPLES FROM THE DOUNREAY-2 BOREHOLE (299588 966914)

56 samples were analysed between 562.50m and 139.66m; detailed assemblage and palynofacies characteristics are shown in Fig. 3. The taxa recorded were:

Indeterminate palynomorphs

Ancyrospora spp.

Rhabdosporites spp.

Leiosphaeridia spp.

Ancyrospora ancyrea

?*Acinosporites* sp.

Spore Type A

Rhabdosporites langii

Ancyrospora ancyrea var. *brevispinosa*

Retusotriletes spp.

?*Ancyrospora* sp.

?*Retusotriletes* sp.

Discernisporites macromanifestus

Trileites langii

Ancyrospora cf. *longispinosa*

Large oval spore?
Thick walled spore
Cristatisporites mediconus
? *Rhabdosporites* sp.
? *Leiosphaeridia* sp.

The assemblages were uniformly poorly preserved and sparse. Few palynomorphs were preserved well enough for specific or even generic determination to be made. In most cases the organic residue was dominated by yellow-brown amorphous organic matter (AOM) of probable lacustrine algal origin, though in a few samples more structured material of probable terrestrial plant origin dominated. The formations above the 'Lower Devonian' unit (the 'Luachair Formation') all yielded some palynomorphs, but the former was effectively barren, possibly because of the aridity of the environment in which it was deposited.

The scarcity of age diagnostic palynomorphs makes age determination of the sequence tentative, however the presence of *R. langii* and the absence of *G. lemurata* indicates a probable Eifelian age for the section between 358m and 139.66m (see Marshall 2000). Below 358m, assemblages are too sparse to allow dating.

A few samples yielded assemblages which merit separate description. There are:

3.2.1 MPA 50720, 166.95m

The assemblage contained: *Leiosphaeridia* sp., common *Rhabdosporites* spp. (including *R. langii*), common *Ancyrospora* spp. (including *A. ancyrea*) and a possible specimen of *Acinosporites*.

3.2.1.1 INTERPRETATION

Although the organic residue of this sample contained common spores, few were well preserved and those that were identifiable did not allow precise age determination. The presence of *R. langii*, however indicates an Eifelian or younger age (Richardson & McGregor 1986, Marshall 2000).

3.2.2 MPA 50721, 172.67m

The assemblage contained: *Rhabdosporites* spp. (including *R. langii*) and *Ancyrospora* spp. (including *A. ancyrea* var. *brevispinosa*).

3.2.2.1 INTERPRETATION

As above the presence of *R. langii* indicates an Eifelian or younger age.

3.2.3 MPA 50736, 237.1m

The assemblage contains: *Rhabdosporites* spp. (including *R. langii*), *Ancyrospora* spp. (including *A. ancyrea* var. *brevispinosa*), *Retusotriletes* sp. and *Discernisporites macromanifestus*.

3.2.3.1 INTERPRETATION

As above the presence of *R. langii* indicates an Eifelian or younger age.

3.2.4 MPA 50737, 241.84m

The assemblage contains: *Rhabdosporites* spp. (including *R. langii*), common *Ancyrospora* spp. (mostly undifferentiated), common *A. ancyrea* var. *brevispinosa*, *A. ancyrea*, *A. cf. longispinosa* and *Trileites langii*.

3.2.4.1 INTERPRETATION

As above the presence of *R. langii* indicates an Eifelian or younger age.

3.2.5 MPA 50751, 310m

The assemblage contains: *Rhabdosporites* spp., *Ancyrospora* spp., ?*Leiosphaeridia* sp. and *Cristatisporites mediconus*.

3.2.5.1 INTERPRETATION

The presence of *Cristatisporites mediconus* suggests an age range of Emsian-Givetian (Marshall & Allen 1982).

3.2.6 Palynofacies of Dounreay-2

Simple palynofacies analysis was carried out on the Dounreay-2 samples. The organic residue of the samples was divided into three categories: yellow-brown AOM, black fragments and palynomorphs. The trends within the borehole are shown in Fig. 3.

In the Middle Devonian sequence, the dominance of yellow/brown amorphous organic matter in residues is consistent with persistent lacustrine depositional conditions. The rare dominance of dark coloured, more structured organic material (black fragments and palynomorphs) indicates influxes of terrestrially derived plant material possibly related to more proximal conditions.

The lack of almost any organic material (including palynomorphs) in samples from the Lower Devonian 'Luachair Formation' suggests that a very poorly vegetated terrestrial hinterland was present at the time, perhaps due to aridity.

4 Correlation

4.1 POSITION OF THE ACHANARRAS HORIZON IN THE DOUNREAY BOREHOLES

On the basis of certain trends and other lithological evidence (see above), Bolt & Cole (1992) suggested that the correlative equivalent of the Achanarras horizon in Dounreay-1 is a horizon just above the Fresgoe Sandstone Member at approximately 196m. A simple lithostratigraphic correlation based on this suggested level implies a position for the Achanarras horizon at approximately 275m in Dounreay-2 (Fig. 3). Such a position appears to be consistent with admittedly sparse palynostratigraphic data.

4.2 CORRELATION OF DOUNREAY-1 AND DOUNREAY-2

The sparse nature of assemblages prevents reliable palynological correlation between the wells because presence or absence of significant palynomorphs is probably as much a matter of chance as evolution. In this case given the short distance between the two boreholes, lithostratigraphic correlation is probably most reliable (see UK NIREX Report No. 658, Figure 2.2).

The two boreholes have a number of palynostratigraphic characteristics in common, however. *Rhabdosporites* spp. (in the form of *R. langii*) first occurs in Dounreay-1 at 290.85m, just above the Bighouse Limestone Member and similar specimens (?*Rhabdosporites* sp.) first occur at approximately the same stratigraphic horizon within Dounreay-2 (Figs 1 and 2). In Dounreay-1 *Ancyrospora* spp. also first occurs at 290.85m and with *Rhabdosporites* spp. goes on to dominate assemblages through the studied section. In broad terms this is similar to the quantitative character of the Dounreay-2 borehole between 384.53 and 139.66m. Also similar is the occurrence of *C. mediconus* which occurs first between the Bighouse Limestone Member and Fresgoe Sandstone Member in both boreholes. Both boreholes also lack the Givetian marker *G. lemurata* within the studied sections.

4.3 CORRELATION BETWEEN SURFACE AND SUBSURFACE

Most of the surface samples contain *Rhabdosporites* spp. and *Ancyrospora* spp. but all lack *G. lemurata*, in these characteristics they are similar to those recorded within the studied parts of Dounreay-1 and -2 and can therefore be considered to be broadly correlative. Only two of the surface samples contain assemblages that can be related to palynostratigraphic trends within the Dounreay boreholes, these are MPA 50689 and MPA 50686. Both of these samples contain specimens similar to *G. velata*, and on the basis of the latter's range in Dounreay-1, would be expected to be correlate with a level above 260.25m in that borehole. MPA 50686 also contains *D. echinaceus* and *C. mediconus* which occur in the subsurface. *D. echinaceus* occurs only above 178.85m in Dounreay-1 and *C. mediconus* occurs above 290.85m in Dounreay-1 and above 310.00m in Dounreay-2 (one occurrence only). This would tend to suggest that MPA 50686 is probably stratigraphically above the Achanarras horizon. The presence of fairly common *A. longispinosa* in the sample may suggest a level not more than 60m above the Achanarras horizon (see 2.2 above). In any case, the lack of *G. lemurata* in the sample suggests that it is not younger than the youngest sediments studied in the Dounreay boreholes.

5 Further Work

That palynological yield is clearly low in the Devonian sediments of north Caithness is the chief obstacle to palynostratigraphic correlation in the area. However, a small proportion of samples do yield enough to allow comparisons to be made with the steadily evolving palynostratigraphy of the Middle Devonian of the Orcadian Basin. Such comparisons should allow local correlation in the long term. I recommend more sample collection from stratigraphically located localities to allow the construction of a local palynostratigraphy.

Sampling and further palynological work on the highest part of the Dounreay-2 borehole may allow a better understanding of the higher parts of the Middle Devonian section, not preserved in Dounreay-1.

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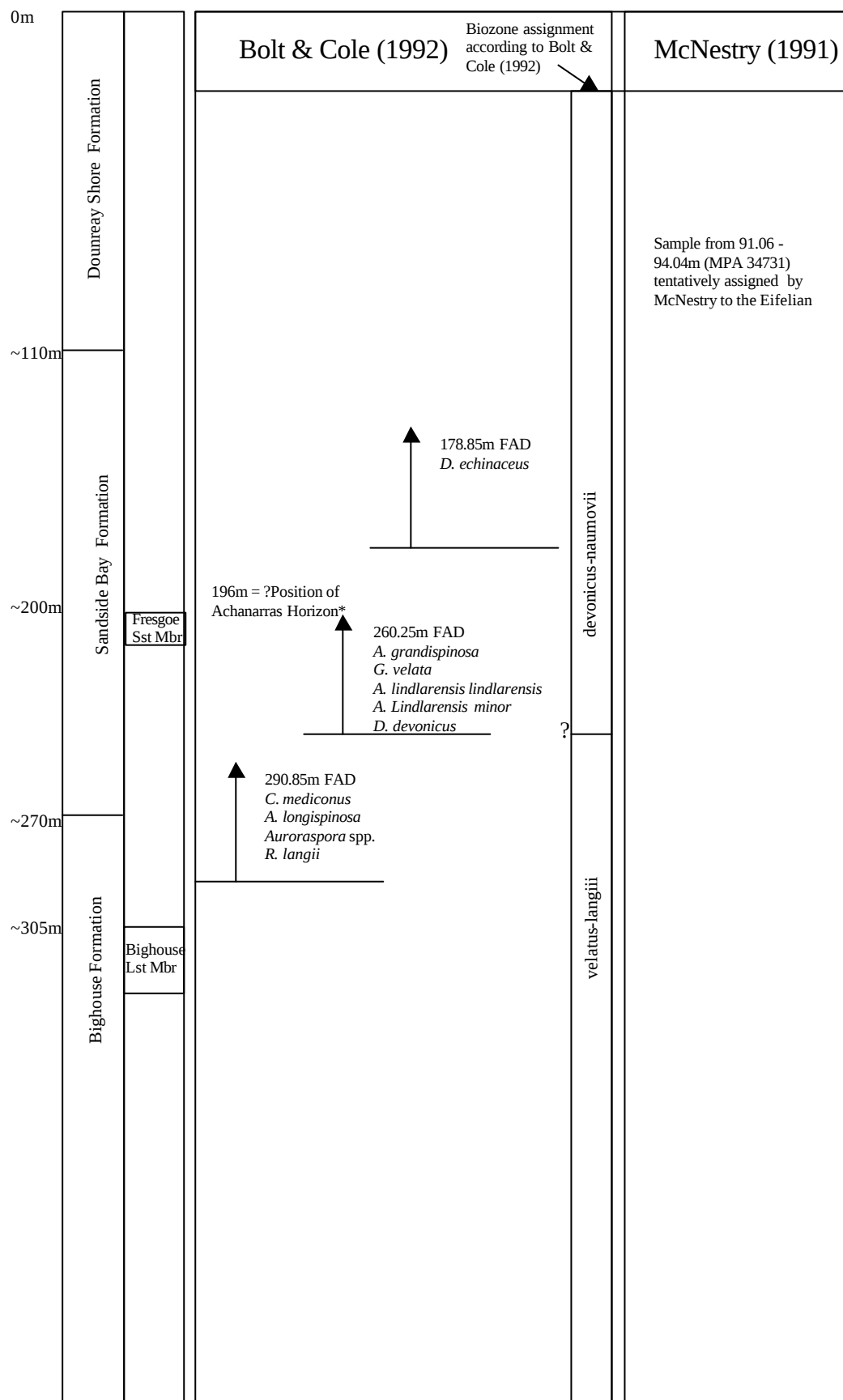
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Appendix 1 Plates

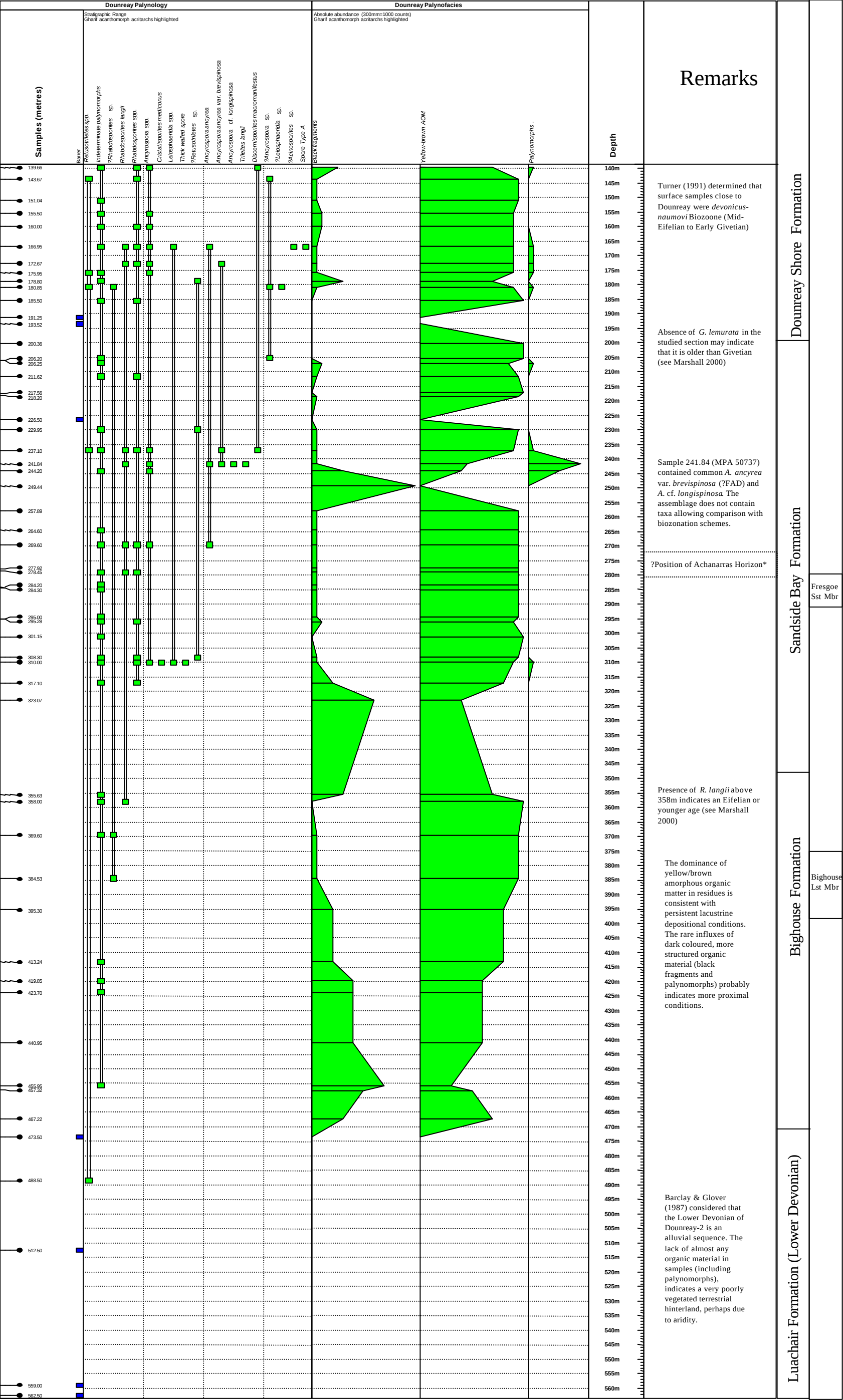
Plates 1-12. Specimens from MPA 50686 (0407 6656), quarry on Bannerman's Farm, Caithness.

Fig. 2 Summary of unpublished palynological information on Dounreay-1, Caithness
After Bolt & Cole (1992) and McNestry (1991)

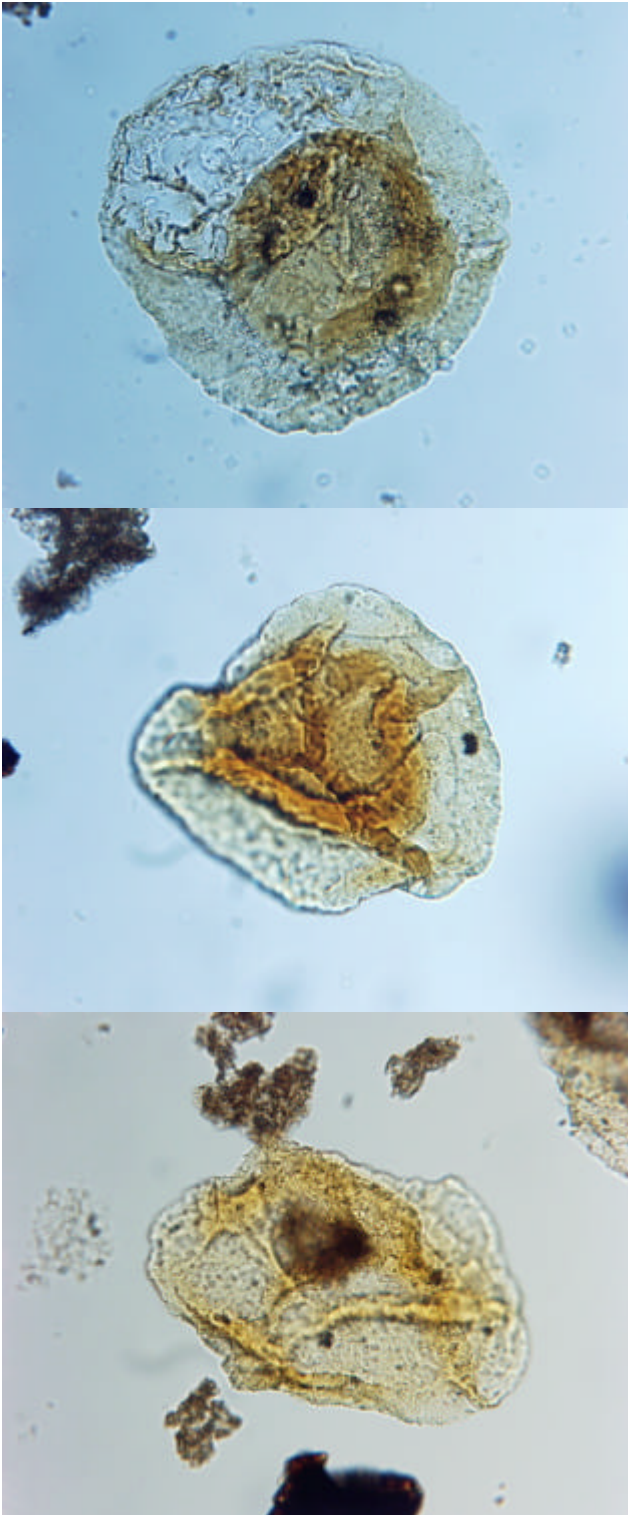


*Based on suggested position of Achanarras in Dounreay-1 (Marshall pers. comm.; see also Bolt & Cole (1992))

Fig. 3 Summary of Dounreay-2 palynology and palynofacies

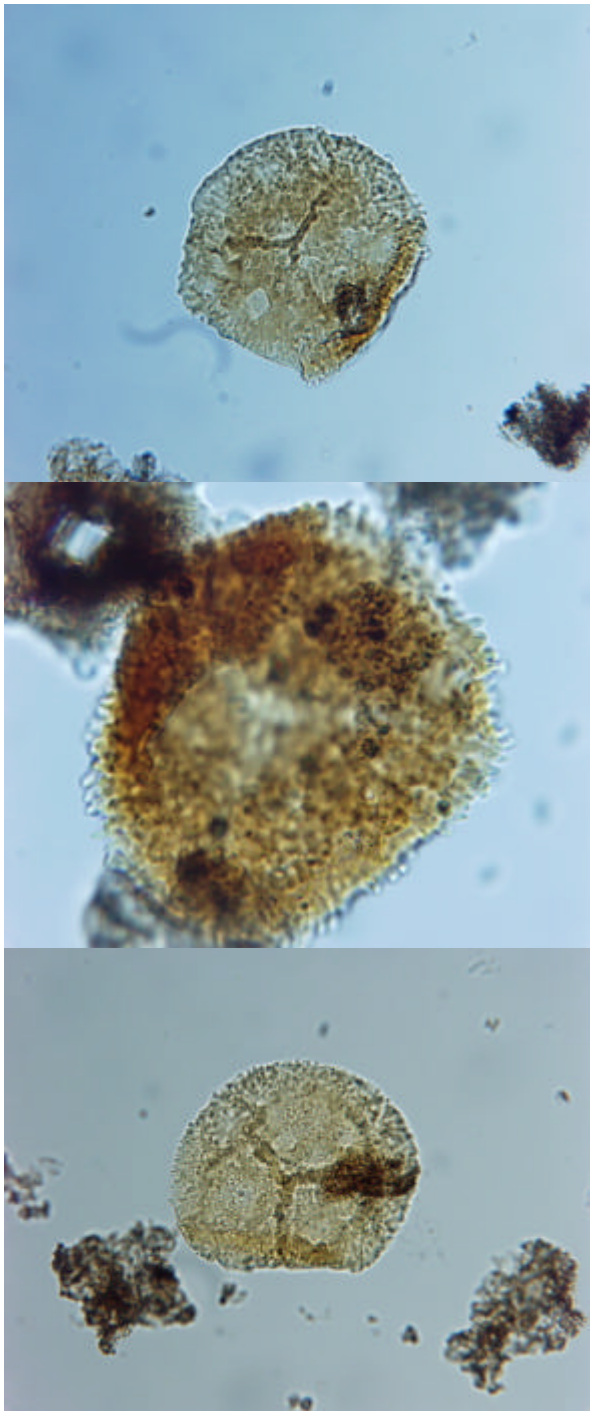


*Based on suggested position of Achanarras in Dounreay-1 (Marshall pers. comm.; see also Bolt & Cole (1992))

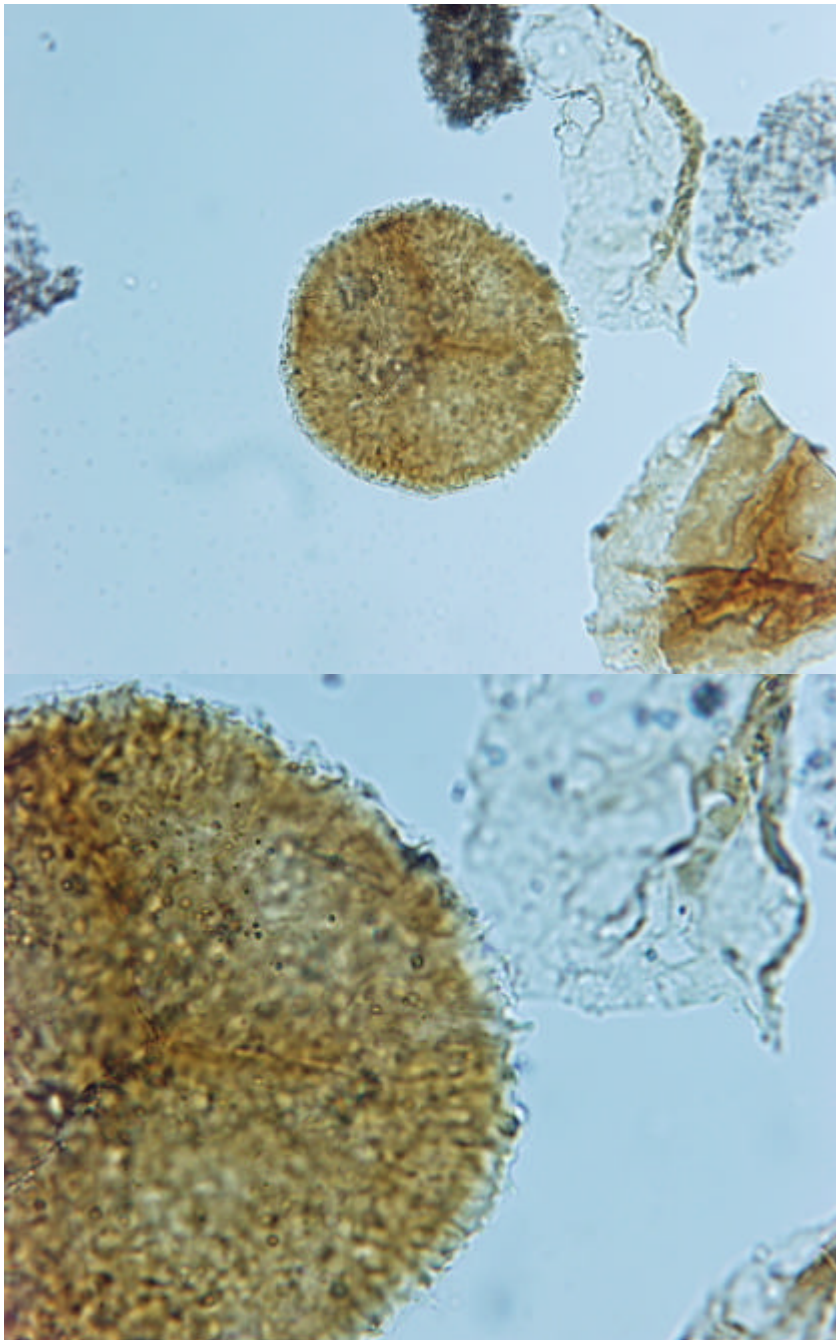


Rhabdosporites spp. (top, F8/3; middle F23; bottom J22/3).

These specimens are all rather poorly preserved and the exoexinal ornament is restricted to grana in the two upper specimens. In the lower specimen densely set bacula are present. The lower may be a poorly preserved specimen of *R. langii* Marshall & Allen 1982. Mag. approx. x1000. Range of *R. langii* = Eifelian – Frasnian (Richardson & McGregor 1986)

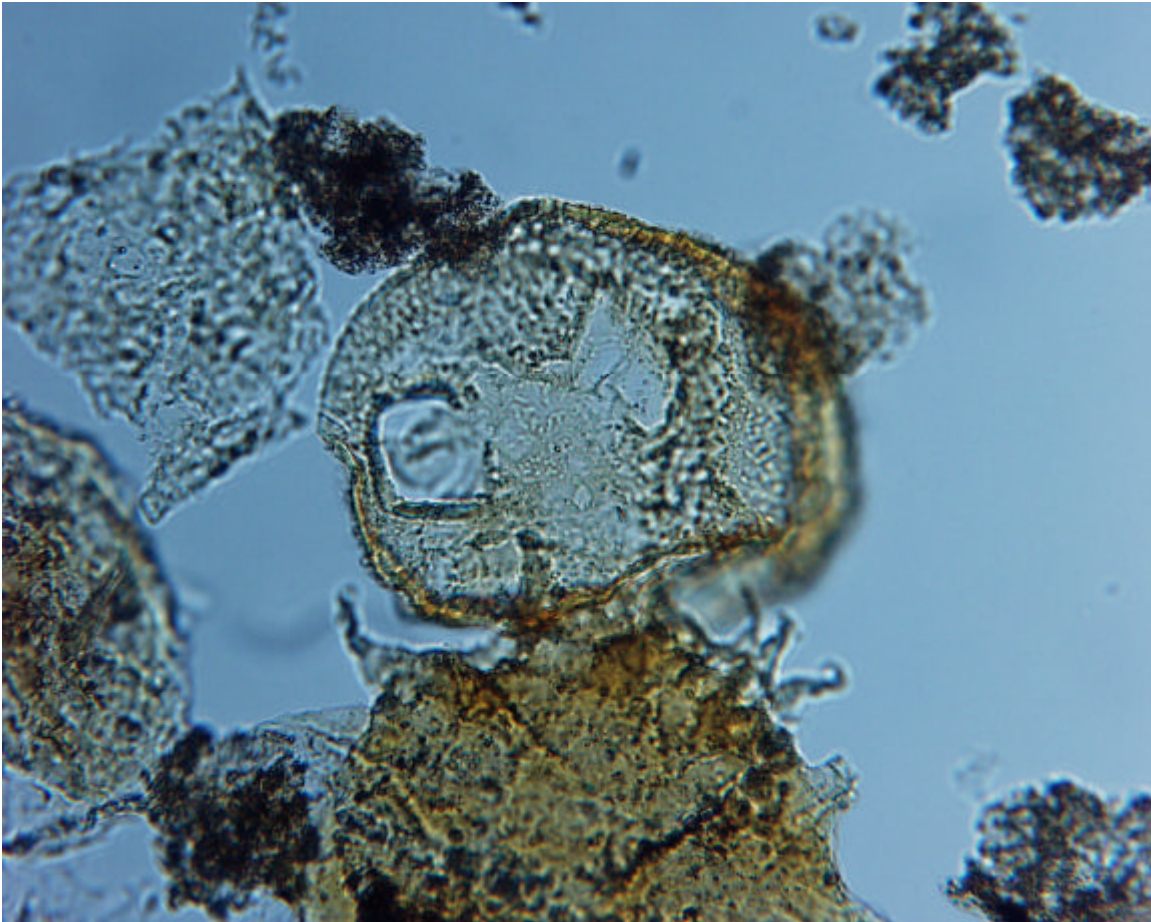


Diboldisporites cf. *echinaceus* (top D17, middle G33/1; bottom P15/2(2)). Mag. Approx. x1000.
Range of *Diboldisporites echinaceus* Emsian – Frasnian (Richardson & McGregor 1986)

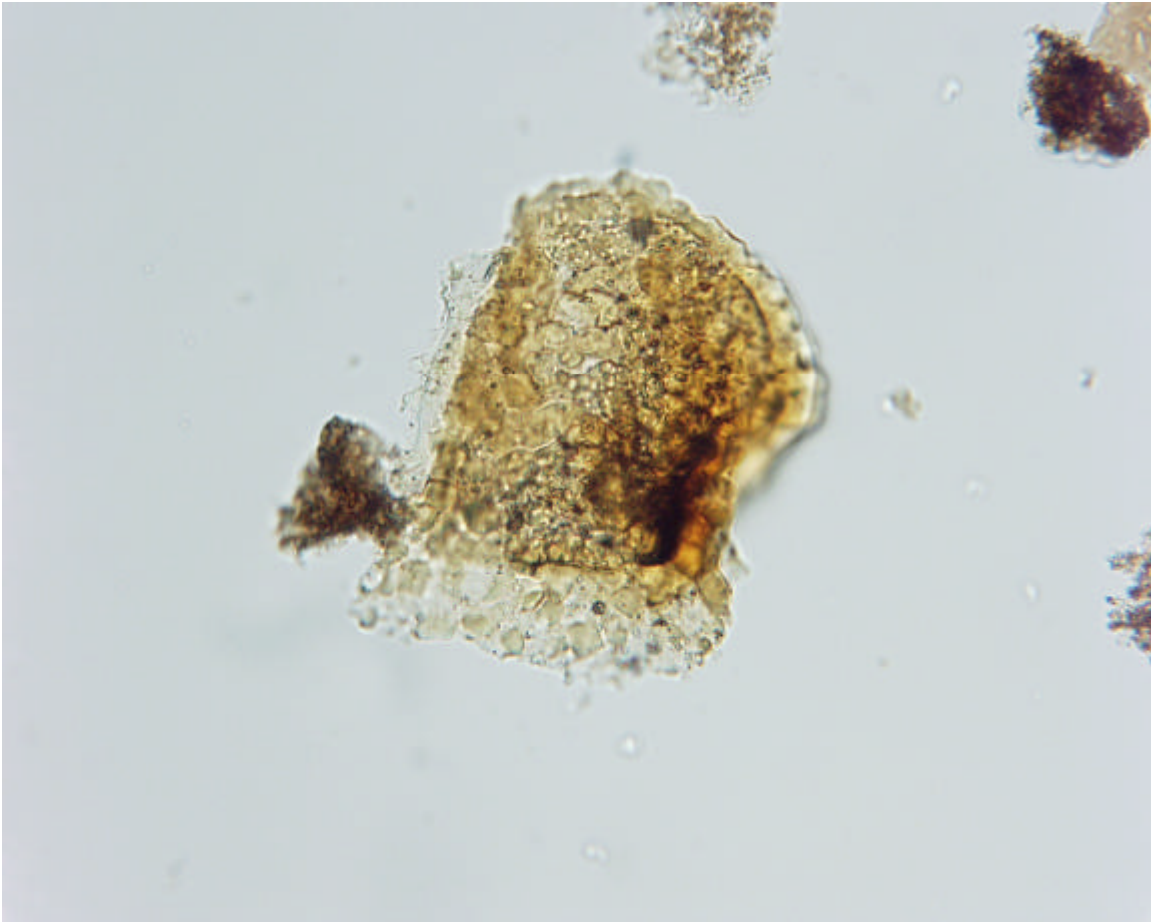


With thick distal wall (thickness 2-3 μ m). Ornament of distal surface best preserved in the marginal parts of the distal surface. Ornament consists of fine, thin, often bent, bacula <1 μ m wide but up to 5 μ m long. Spines and biform elements of similar size also occur. Elements are very closely spaced (<1 μ m apart) and frequently are too densely distributed to distinguish. Dense distal and distal marginal ornament gives the spore margin a slightly 'fibrous' appearance. Trilete rays distinct, with thin lips; extend 70% of the spore radius. Spore may be two layered; outer layer bears ornament; inner layer ?laevigate. Proximal surface is ?laevigate.

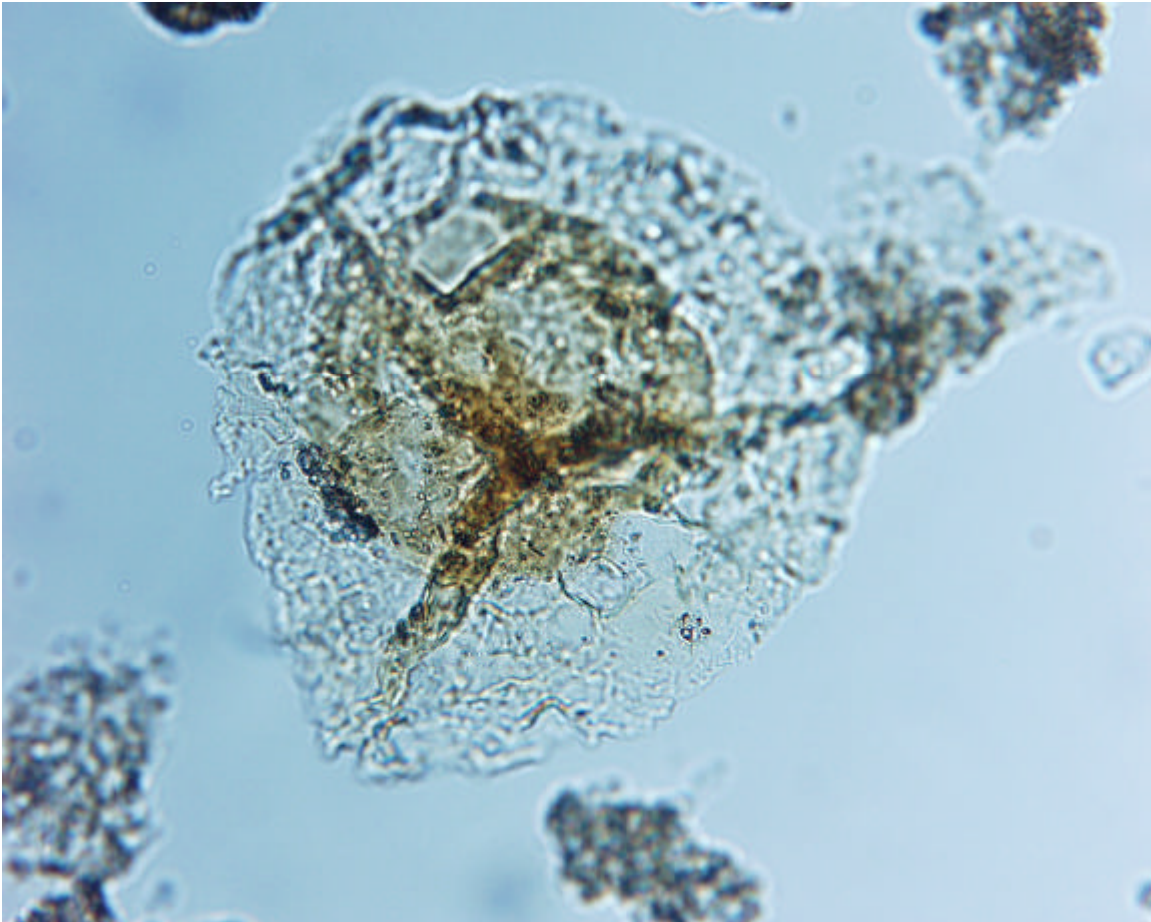
Most similar to *D. echinaceus* and *Dibolisporites* sp. A of Riegel (1968). Specimen 80 μ m diameter. Specimen location G33.



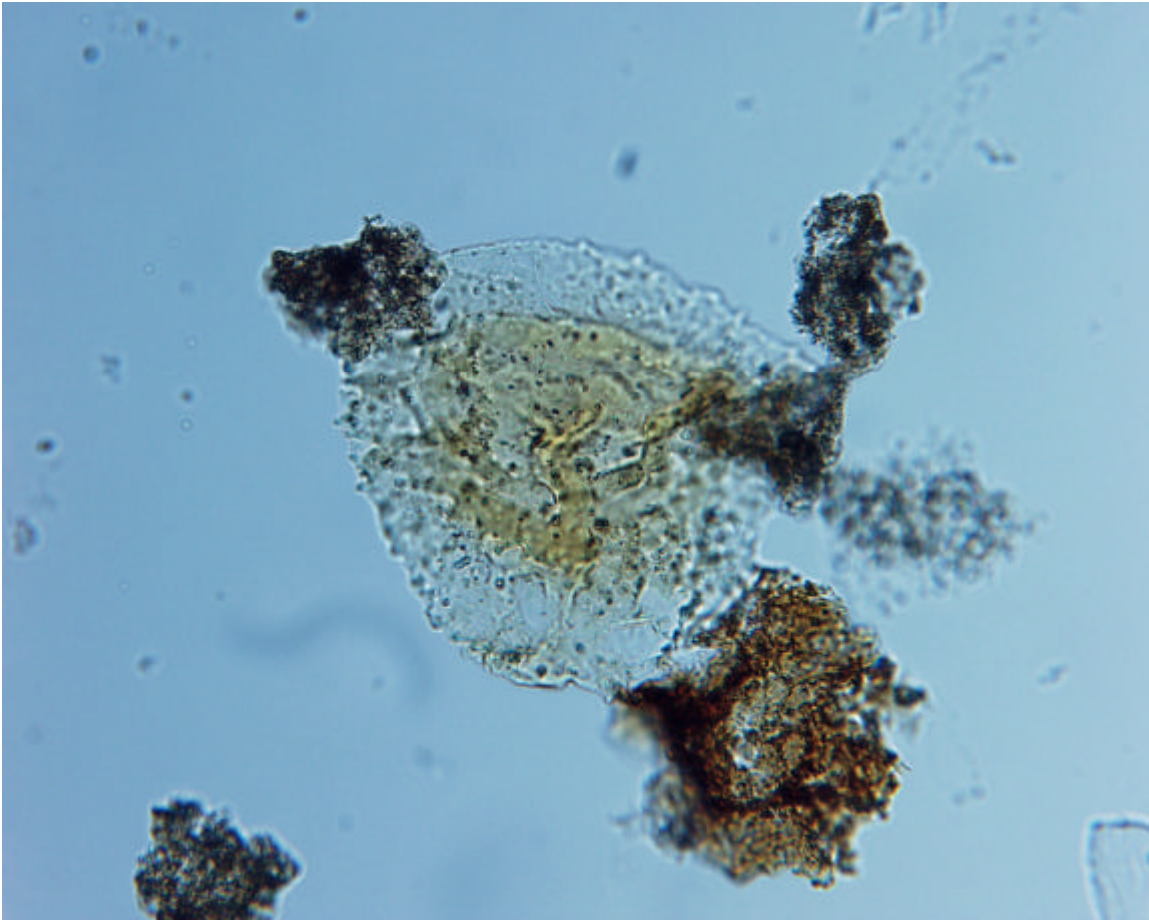
Diboldisporites cf. echinaceus. Mag. x1000 approx



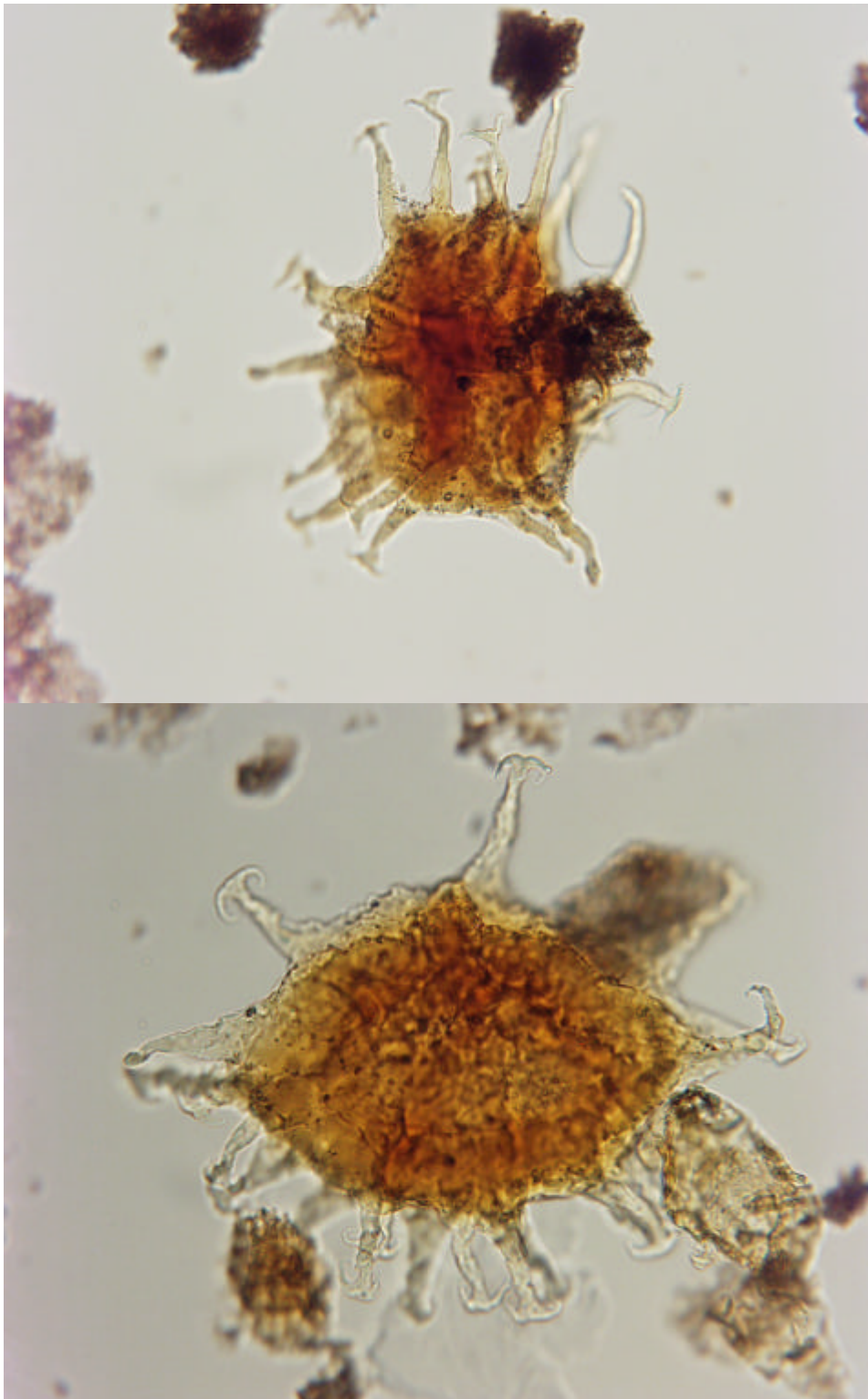
Poorly preserved zonate spore; laesurae obscure. Zona thin, width approximately one third of the radius of the spore; ornamented with large cones, often blunt ended or coalescent to form larger more irregular shaped paired ornament elements. Central distal area slightly obscure but ornamented with coarse cones and other very closely spaced irregularly shaped thickenings. This specimen is similar to *Cristatisporites orcadensis* Richardson 1960 and *C. mediconus* Richardson 1960 and may fall within continuous variation (see Marshall & Allen 1982) within the latter species. The specimen does not display a ring of distal ornament present in *C. conannulatus*. Also similar to *Samarisporites praetervisus* Allen 1965. Range of *Cristatisporites orcadensis* Eifelian – Givetian (from Marshall & Allen 1982). Range of *C. mediconus* Emsian-Givetian (from Marshall & Allen 1982). Max. dimension 100 µm, location J5/4.



Auroraspora macromanifestus. Mag. Approx. x1000.



Poorly preserved zonate spore. Zona wide approx. 30% of the spore radius; thin; ornamented very sparsely with small cones and fat spines (up to 10 μm apart). Some cores are rather blunt ended but this may be due to preservation state. Cones and other elements 2-3 μm high, 1-2 μm wide at the base. Distal central area also sparsely ornamented with similar sized cones. Laesurae accompanied by large upstanding exine folds which extend to the spore margin. Width of specimen 90 μm ; location J21/4. Poorly preserved *Grandispora velata* (Eisenack) Playford 1971. Range of the latter Eifelian – Frasnian (Richardson & McGregor 1986); Siegenian (Pragian) - Frasnian (Marshall & Allen 1982).

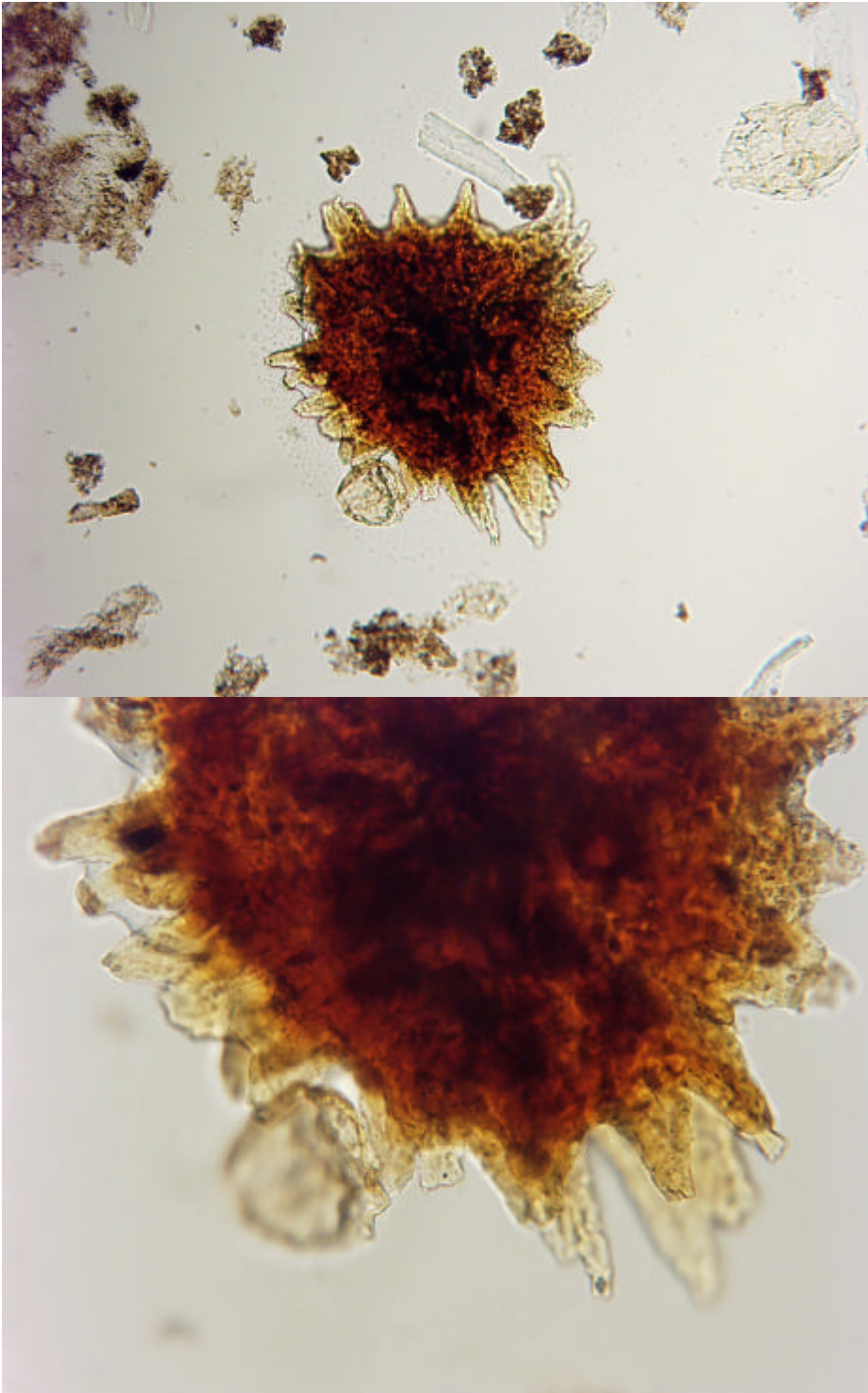


Ancyrospora ancyrea (Eisenack) Richardson 1962

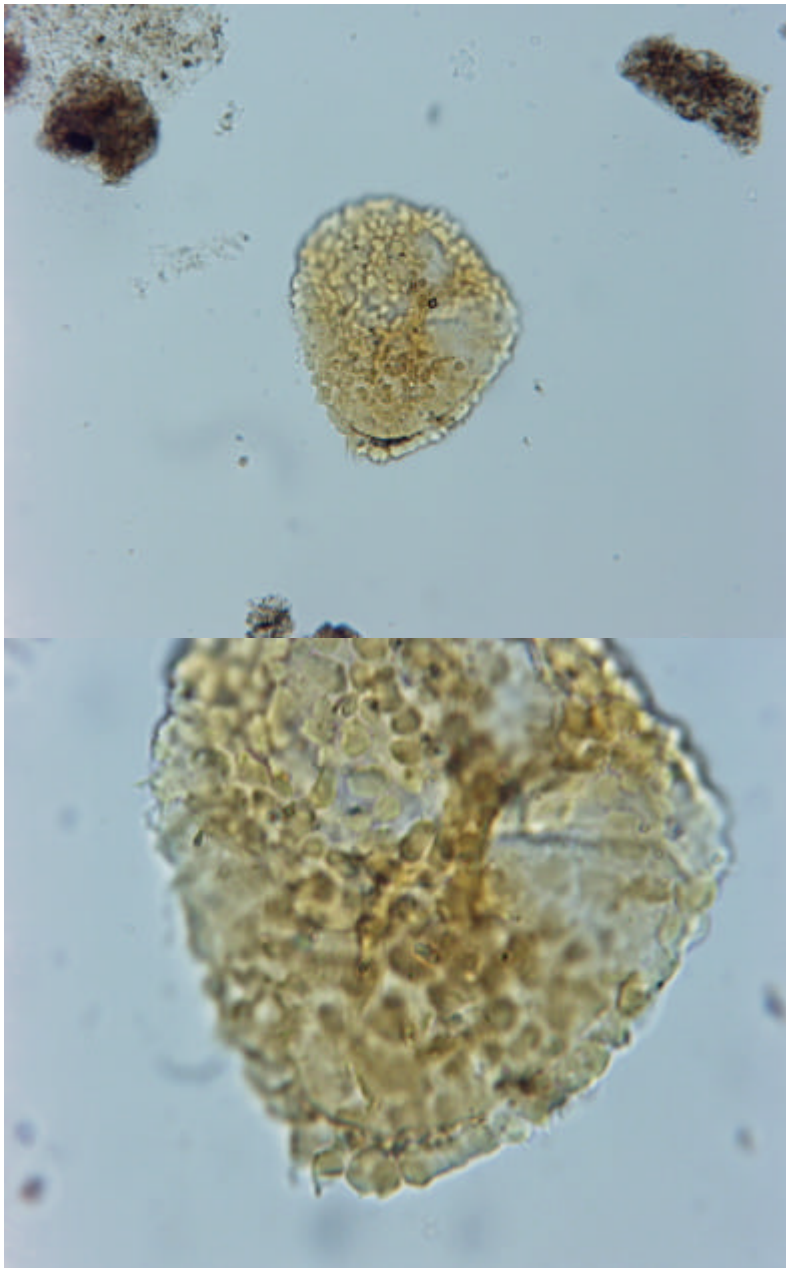
Upper specimen (N8/2) body 75µm in diam.; process length 35-45µm; grapnel tips up to 10µm wide.

Lower specimen (K12/3)(2) body 110 µm; max. process length 45 µm. The upper specimen has a poorly and inconsistently developed flange (or may be laterally compressed), which as Marshall & Allen (1982) observed, causes certain taxonomic difficulties. Range Emsian – Fammenian (Marshall & Allen 1982).

NB All specimens from MPA 50686 (0407 6656), quarry on Bannerman's Farm, Caithness

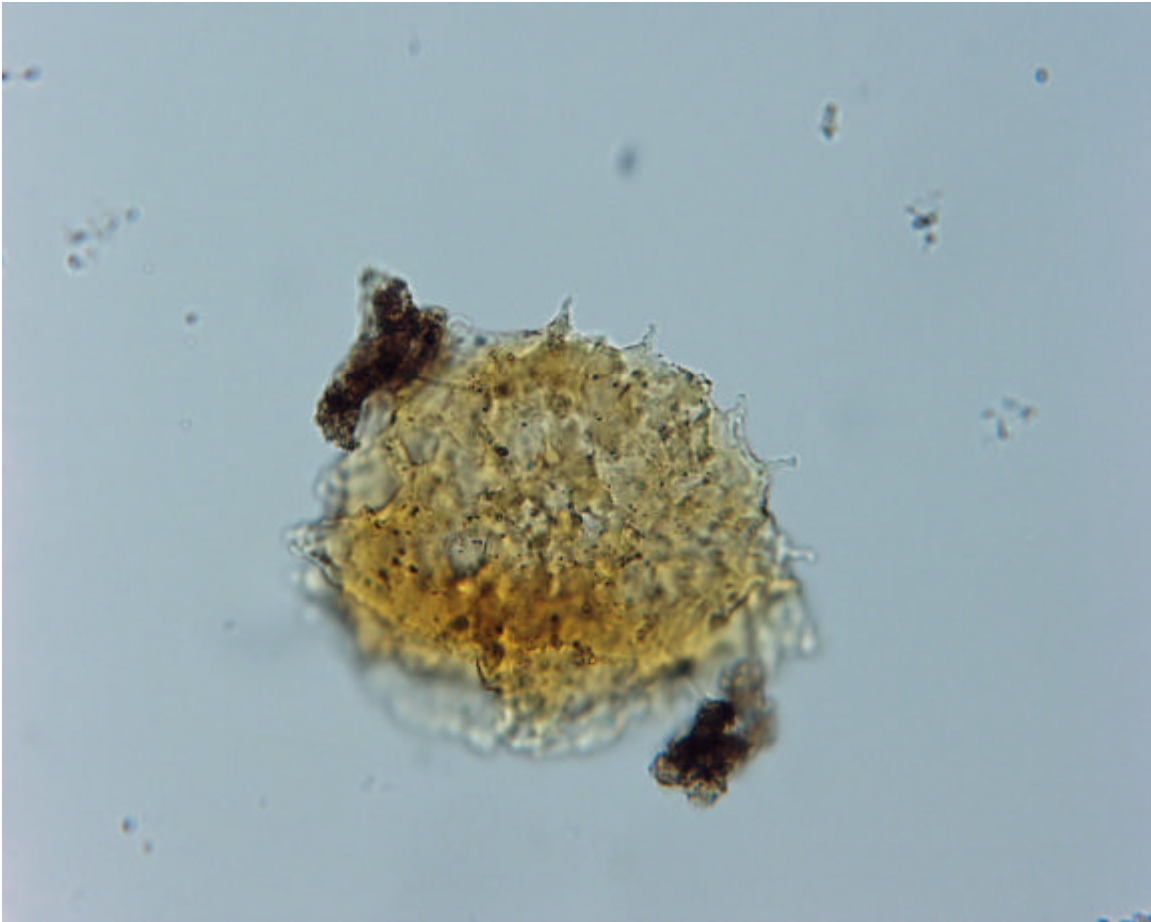


Ancyrospora longispinosa Richardson 1962. Location of specimen M8/4. Width of body 180 μm ; spines approximately 60 μm long; very few grappels preserved. This taxon terminates close to the Achanarras Horizon in the Orcadian Basin (Owens & Richardson 1972; Marshall 1988; Bolt & Cole, unpublished MSc thesis, Univ. Southampton, 1992). The Achanarras Horizon is dated as late Eifelian on fish faunas (Westoll 1979).

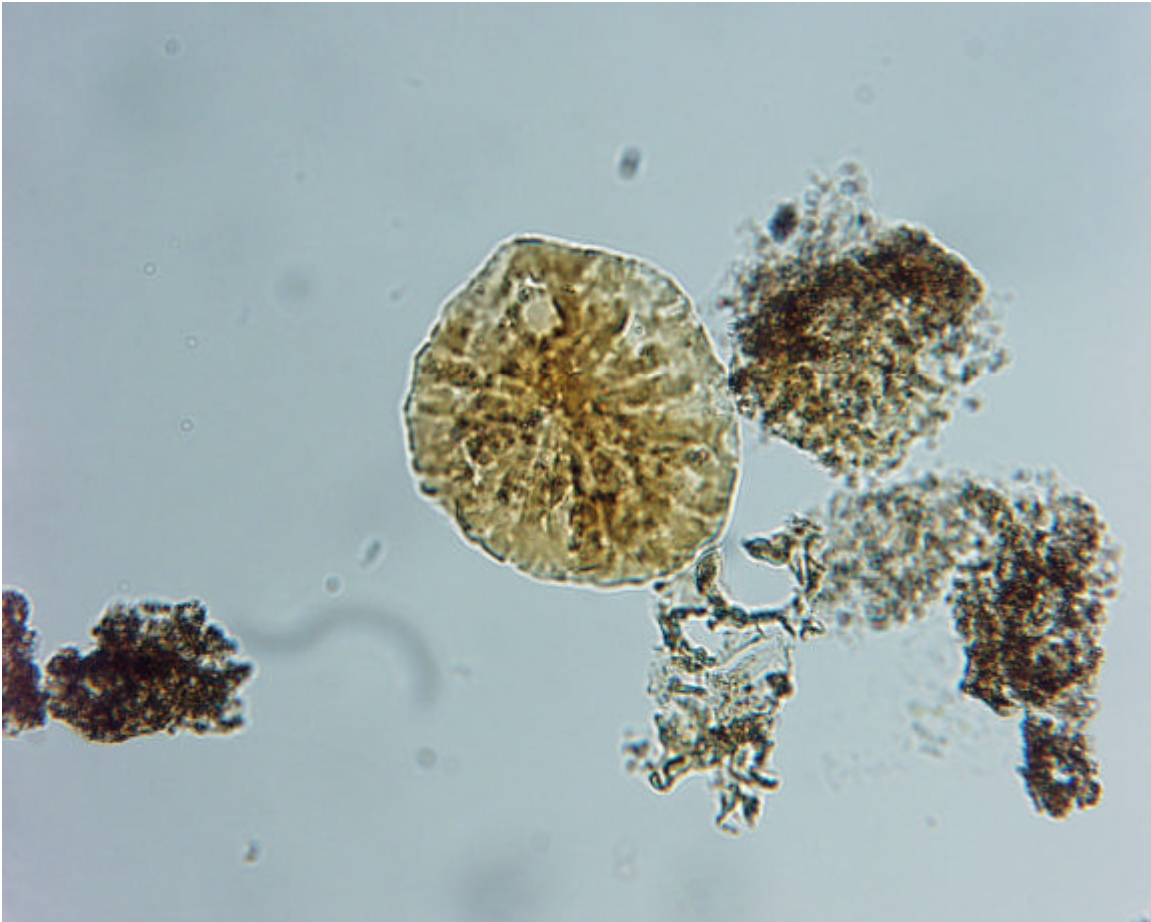


Verrucosisporites cf. *polygonalis* of McGregor 1973

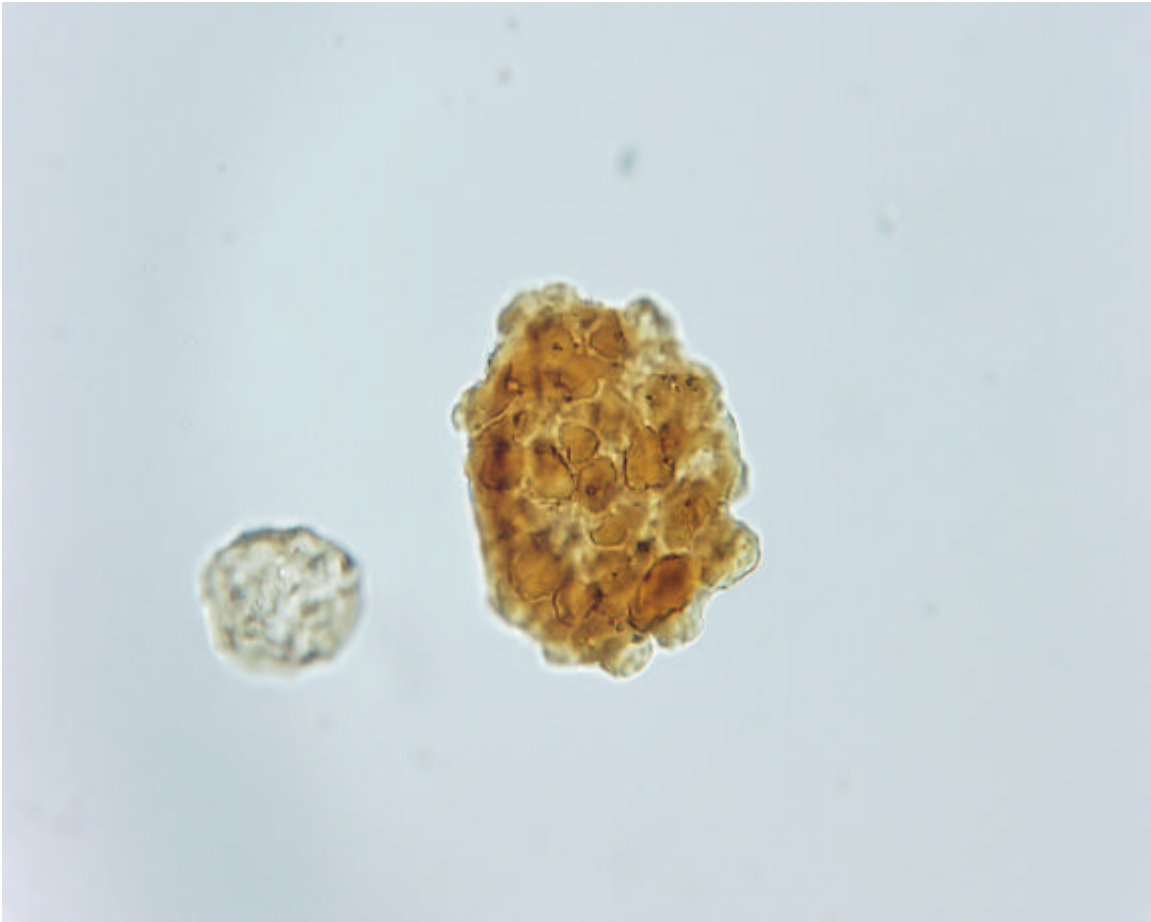
Max diameter of specimen 72 μm ; location W30/1. This specimen has closely packed verrucae sometimes with polygonal outlines. A number of the larger verruca at the margin are surmounted by small spines. This feature was not noted by Lanninger (1968), but McGregor (1973) described them. This specimen is closely similar to the specimen figured by McGregor (1973; Plate 4, fig. 25-26). The specimen displays areas of depleted ornamentation also noted by McGregor (1973; Plate 4, fig. 17). Range of *Verrucosisporites polygonalis* Siegenian-Emsian (Richardson & McGregor 1986).



Ancyrospora ancyrea var. *brevispinosa* Richardson 1962. Max. dimension 90 μm excluding spines. Length of spines 8-10 μm ; width of grapnels 1-2 μm . Range in Fair Isle: Ward Hill to Bu Ness Group (Marshall & Allen 1982).



Emphanisporites cf. *robustus* McGregor 1961. Location E45/2, mag. Approx. x1000. Range Battery Point Formation to Onondaga Formation, Gaspe, Canada (McGregor 1961)



Verrucosisporites ?scurrus. Location E32/1. Mag. Approx. x1000.