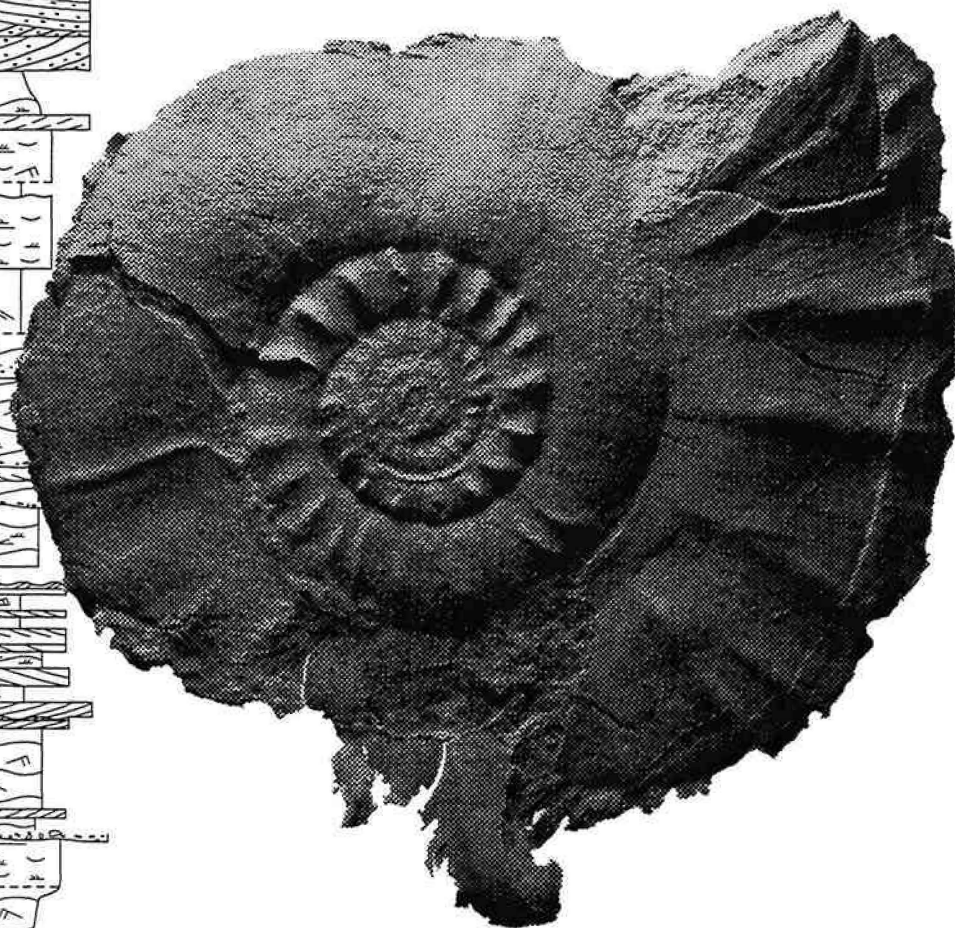
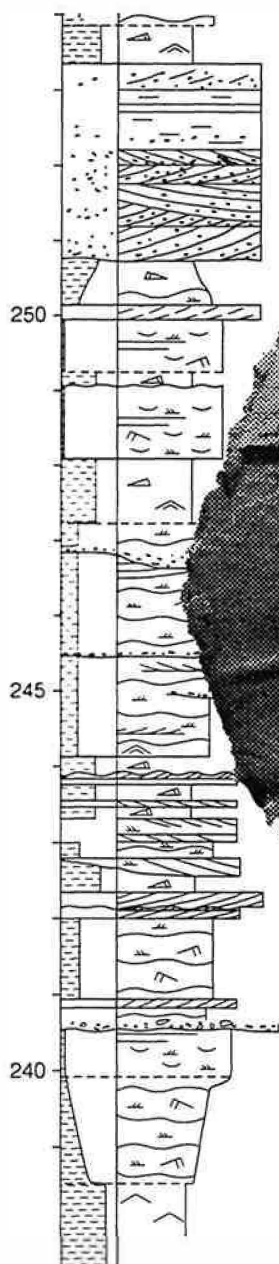


Boreal dinoflagellate cyst stratigraphy of Middle to Upper Jurassic sediments of Milne Land, East Greenland

By Stefan Piasecki



**Formation of Source and Reservoir Rocks in a Sequence Stratigraphic Framework,
Jameson Land, East Greenland
Havniveau-kontrolleret dannelse af Kilde- og Reservoirbjergarter**

**Energy Research Programme 1993, Projects No. 1313/0010 & 0017
Completion Report, Appendix No. 13**

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**Geological Survey of Denmark and Greenland
February 1997**

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East Greenland is geographically located between the North Sea region and the Arctic region and the Jurassic dinoflagellate flora of East Greenland is correspondingly related both to the Submediterranean/Sub-boreal flora of the North Sea region and to the Boreal flora of the Arctic region. The dinoflagellate cyst stratigraphy of the North Sea region is calibrated to the Sub-boreal ammonite zonation of especially UK. However, diversity and density of the dinoflagellate cyst floras decrease northwards and the range of stratigraphical important species is clearly changing with latitudes. Stratigraphical correlation and dating of Jurassic strata in the North Atlantic on the basis of dinoflagellate cysts are therefore hampered by the lack of an ammonite calibrated dinoflagellate zonation in this area. The further north in the region, the worse.

The purpose of this work is to establish a dinoflagellate stratigraphy calibrated with the Boreal ammonite zonation and to bring precision and reliability of the dinoflagellate stratigraphy a step further northwards in the North Atlantic. The standard Boreal ammonite zonation has been established based on studies in East Greenland since the 1950'ies (Callomon, 1993) and provides the frame for this dinoflagellate cyst stratigraphy.

History

Since the earliest expeditions to East Greenland, ammonites from the Jurassic succession have been brought back for palaeontological and stratigraphical studies (Madsen, 1904). The rich faunas and the abundance of ammonite material lying on the ground in Jameson Land were noted by Rosenkrantz (1929). Many of the ammonites from the earliest

collections were from loose blocks in ravines and from the scree below steep sections. The stratigraphical position and evolution of ammonites were therefore riddled with uncertainties (Aldinger, 1935; Spath, 1935, 1936). Extensive studies of Jurassic and Cretaceous invertebrates (including ammonites) in East Greenland were performed under the leadership of D. T. Donovan (1949, 1955, 1957).

Fieldwork especially by T. Birkelund, J. H. Callomon and F. Surlyk from the 1950's until recently, documented more precisely the stratigraphic occurrences of ammonites and combined with a better understanding of the lithostratigraphy (Surlyk *et al.*, 1973), the ammonite stratigraphy improved considerably. Through a number of publications, Birkelund and Callomon refined and formalised a very detailed ammonite stratigraphy for Boreal Bathonian to Middle Volgian in central East Greenland. The Middle Jurassic stratigraphy (Bajocian to Callovian) is based on ammonites from the Vardekløft and Olympen Formations on Jameson Land (Callomon, 1959, 1993; Birkelund, Håkansson & Surlyk, 1971). In the Upper Jurassic, the Boreal Oxfordian ammonite stratigraphy is based partly on faunas from Northeast and East Greenland and partly on material from Scotland (Sykes and Surlyk, 1976; Sykes and Callomon, 1979). The Boreal Kimmeridgian to Middle Volgian stratigraphy is based on ammonites from the Kap Leslie Formation on Milne Land (Callomon & Birkelund, 1980, 1982; Birkelund, Callomon & Fürsich, 1984; Birkelund & Callomon, 1985). The ammonite stratigraphy of central East Greenland is probably the most complete and best known succession in the Boreal Province and has been used as a standard of reference for time correlation in the Arctic (Callomon, 1993).

Ammonite stratigraphy

The Jurassic ammonites in East Greenland are generally concentrated in certain horizons separated by barren intervals. The assemblages are of low diversity typical for the Boreal realm and the stratigraphy is based on evolutionary lineages of a few ammonite taxa (Callomon, 1993). Although the ammonite faunas are taphonomically distorted (locally 90 to 99% adult females or 100% juveniles; Callomon, 1993) and discontinuously represented in the sections, collections from Svalbard (Rawson, 1982) and from the North Sea (Callomon, 1976, 1979) have not revealed faunas missing in East Greenland. Boreal faunas that differ

from those in East Greenland are present in Yukon, Canada (Poulton, 1987) and in Arctic Siberia (Meledina, 1971). Whether these represent contemporaneous faunas in another bioprovince or represent time gaps in the East Greenland sequence cannot be properly determined.

The oldest Middle Jurassic ammonites in East Greenland belong to the Borealis Zone - Fauna 1 of Callomon (1993). They appear after an interval barren of ammonites and overly ammonites of Aalenian/Early Bajocian age. Callomon (1993) suggests a minimum age of Late Bajocian for the Borealis horizon based on the close morphological relationship of *Cranocephalites borealis* and the Early Bajocian genus *Chondroceras* and the estimated evolution-time for ammonites. The "Boreal Bathonian" cannot be directly correlated to the Bajocian - Bathonian in the Submediterranean fauna province of the North Sea region (UK) as there are no species in common. The earliest stratigraphical level with common ammonites is the basal Callovian, the Apertum Zone, although Boreal Early Callovian fauna still has little in common with faunas from the North Sea region. During the Middle Callovian to Early Oxfordian the Boreal fauna migrates southwards into the North Sea region and consequently the two regions have a common ammonite zonation. Faunas of the Callovian Coronatum and Lamberti Zones have not been documented in East Greenland. However, the fauna recovery is generally poor in the Middle-Upper Callovian and sediment intervals may be present although the ammonites have not yet been found. Renewed separation of the ammonite faunas occurred during the mid Oxfordian and provincialism is most marked in the Upper Oxfordian, whereas the segregation becomes less distinct in the Kimmeridgian and is absent in the Lower Volgian (Middle and lower Upper Kimmeridgian *sensu anglico*). The Early Volgian Scitulus Zone has not been documented in East Greenland. Fauna separation increases again in the Middle Volgian. Consequently a Boreal standard ammonite zonation has been erected for Middle-Upper Oxfordian (Sykes & Surlyk, 1976; Sykes & Callomon, 1979) and the Middle Volgian (Callomon & Birkelund, 1982). Correlation of the Oxfordian and Middle Volgian Boreal ammonite standard zones with the corresponding Sub-boreal / sub-Mediterranean standard zones is based on the presence of several specific taxa that are traceable from one fauna to the other. The fauna separation is therefore less distinct than in the Boreal Bathonian but

the faunas in East Greenland are anyway of clear Boreal affinity with few taxa and high abundance in certain horizons.

A succession of 48 ammonite faunas has been identified on Milne Land (Callomon & Birkelund, 1980; Birkelund, Callomon & Fürsich, 1984; Birkelund & Callomon, 1985): 46 of these (faunas 2-47) occur in the Kap Leslie Formation; they are the basis for this dinoflagellate cyst study. The oldest ammonite fauna to be numbered (fauna 2; Athleta Zone) occurs 30 metres above basis of the Kap Leslie Formation but a few ammonites also from the Athleta Zone have been collected from another horizon only 12 metres above the basis (Callomon & Birkelund, 1980; p. 218). The earliest sediments analysed in this study occur below the Late Callovian, Athleta Zone. Although not dated by ammonites, these sediments may approximate at oldest, to the Middle Callovian "Coronatum" Zone as they contain no dinoflagellate cysts that indicate an older age.

Previous studies of Jurassic dinoflagellate cysts in East Greenland

Dinoflagellates were first reported from East Greenland (Jameson Land) by Sarjeant (1972). His study was based upon two samples that survived a fire in the palynological laboratories of University of Nottingham. The samples are without precise litho- and biostratigraphical control and the palynomorphs are poorly preserved. Sarjeant (1972) established a number of new species but the work has very little stratigraphical importance to day due to the uncertainties. However, Pocock and Sarjeant (1972) described the stratigraphically important species *Mendicodinium groenlandicum* from one of Sarjeant's preparations mentioned above. Later, Fensome (1979) studied a stratigraphically and geographically scattered collection of samples from the Middle to Upper Jurassic and Lower Cretaceous of Jameson Land. His work is an excellent taxonomic study and many of his new species are stratigraphically important. The stratigraphical details are limited due to the stratigraphical scattering of samples and because only some samples were dated by ammonites. However, the study clearly showed the stratigraphical potential of the Jurassic dinoflagellate flora in East Greenland.

Piasecki (1981) studied the dinoflagellate cysts of the Jurassic succession on Milne Land. A formal (but unpublished) dinoflagellate zonation was suggested for the Upper

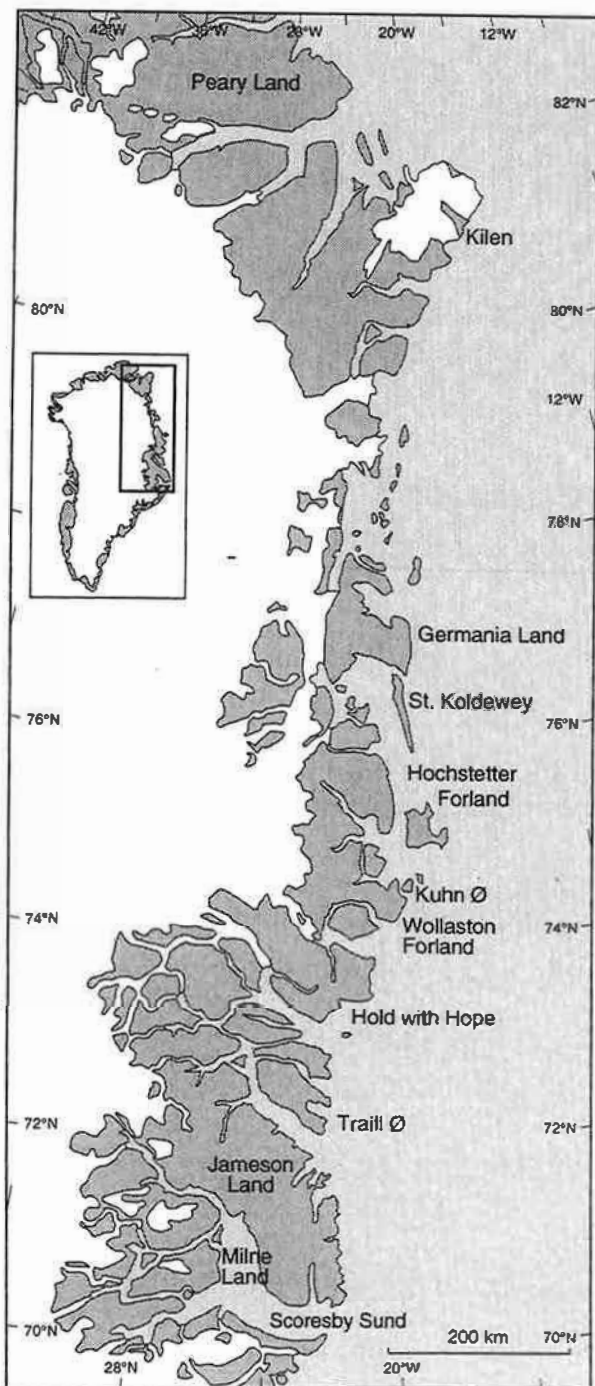


Figure 1. Map of East and Northeast Greenland with localities.

Callovian to Middle Volgian Kap Leslie Formation. The zonation was closely calibrated to the ammonite stratigraphy of Birkelund and Callomon (Callomon & Birkelund, 1980; Birkelund, Callomon & Fürsich, 1984; Birkelund & Callomon, 1985). Piasecki (1981) included some data from Jameson Land in order to correlate the Upper Jurassic lithostratigraphical units to the Milne Land units.

An extended abstract by Poulsen (1985) gives a short summary of dinoflagellate cysts occurrences at the boundary between the Vardekløft and Hareelv Formations at Ugleelv in Jameson Land with very few data and without any ammonite control on the palynological data. Poulsen (1985) is extensively cited by Riding & Thomas (1992) in their summary of Jurassic dinoflagellate stratigraphy for stratigraphical data that do not occur in his paper. This is probably due to misunderstanding of figure 2 in Poulsen (1985) that shows Callovian to Kimmeridgian data from the North Sea region, which were used for dating of the investigated Oxfordian sediments at Ugleelv in East Greenland.

Based on first appearance/extinction criteria Smelror (1988) erected a Middle Jurassic palynozonation of Bathonian to Lower Oxfordian dinoflagellate cysts from Jameson Land. The oldest analysed material is from the Variable Zone and the zonation was calibrated to the Boreal ammonite zonation. Smelror (1988) included data from the lowermost part of Kap Leslie Formation.

In a study of the mid-Cimmerian unconformities of the North Sea, Underhill & Partington (1994) include dinoflagellate data from three sections through the Vardekløft and lower Hareelv Formations in Jameson Land. These samples are not calibrated with ammonite stratigraphy.

Geological Setting

Milne Land is situated along the western margin of the Upper Palaeozoic-Mesozoic system of sedimentary basins in East Greenland (Fig. 1). The island is located west of the main fault zone controlling sedimentation from the Devonian and onwards (Friend *et al.*, 1983), and Jurassic sediments are directly overlying Caledonian affected basement. East of this fault zone post Caledonian sedimentary basins started to form in the Devonian where more than 7 km of Middle and Upper Devonian continental sediments and volcanic rocks

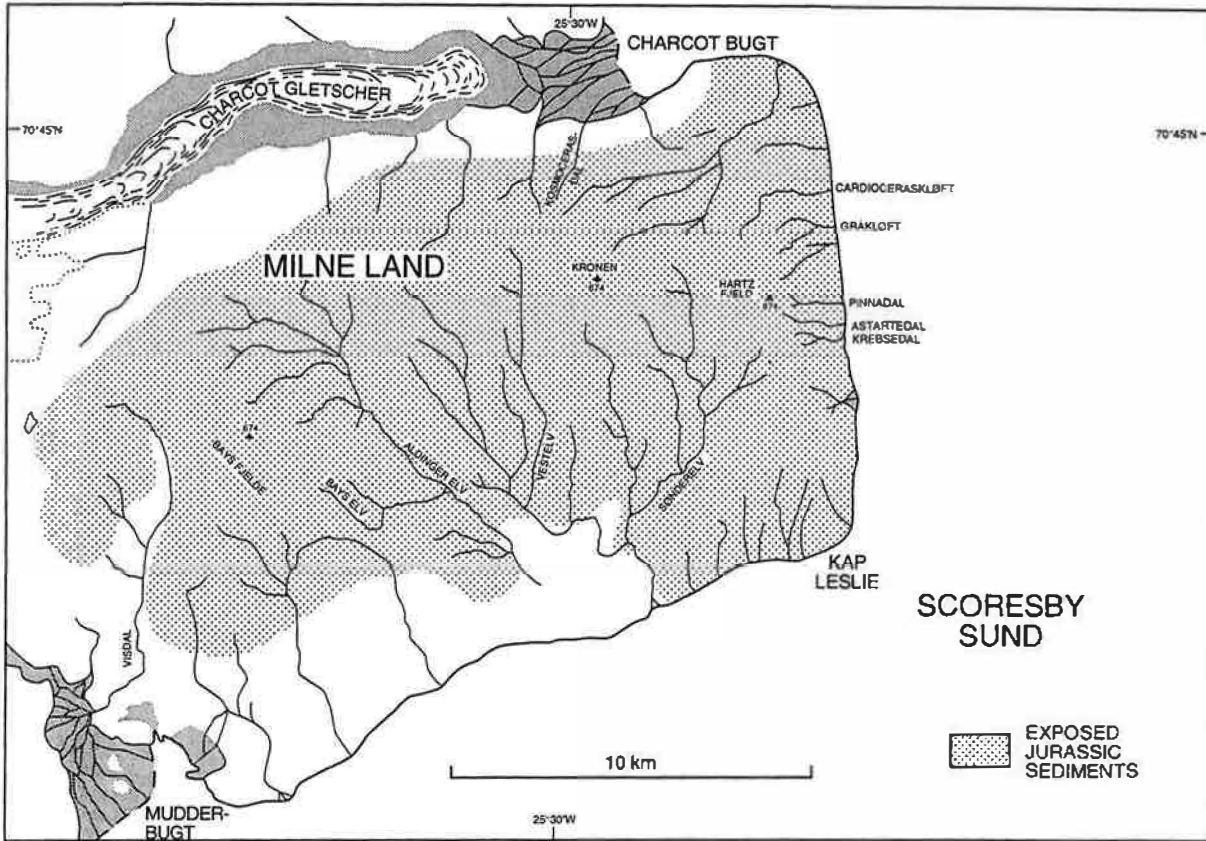
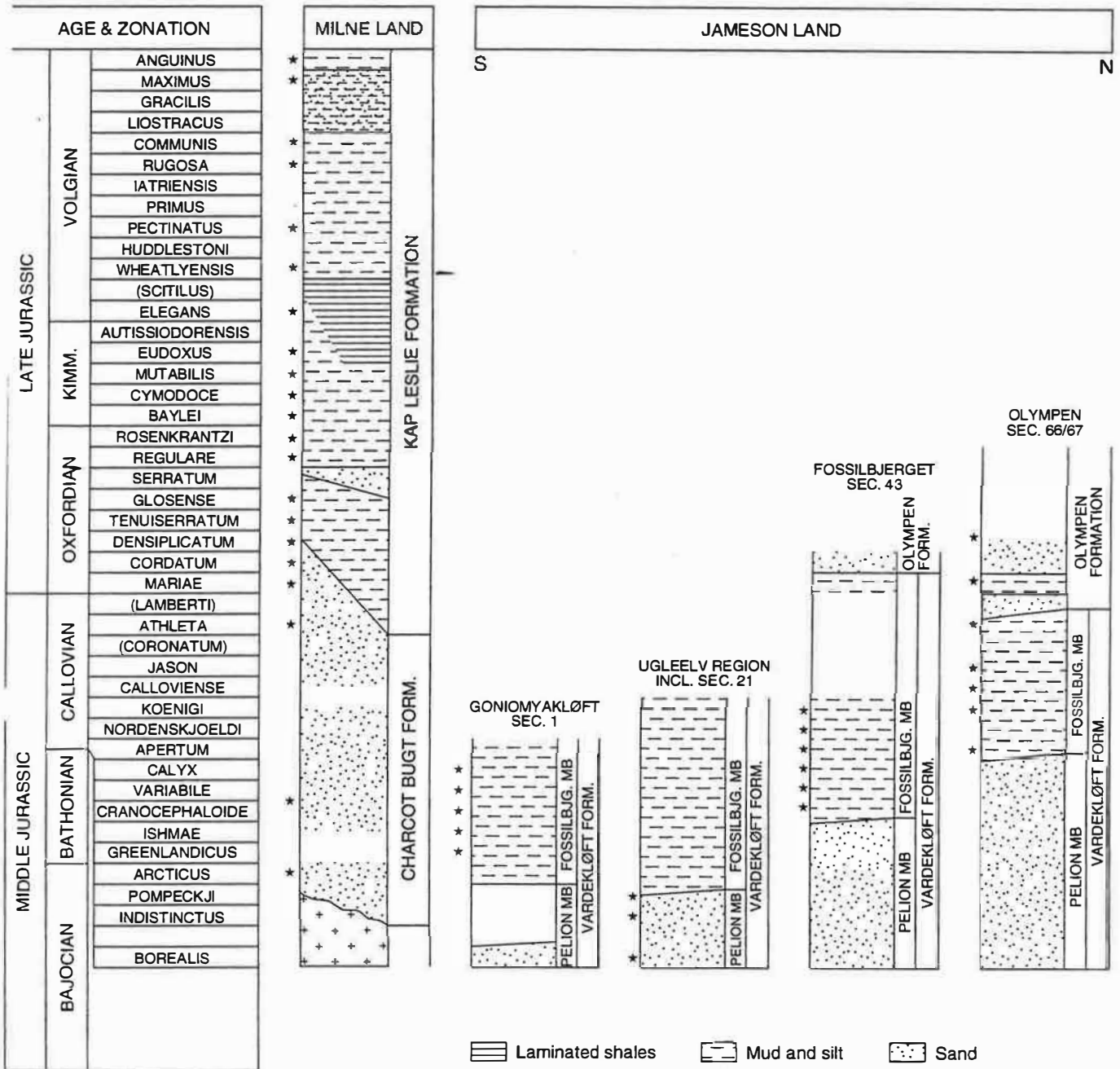


Figure 2. Map of Southeast Milne Land with exposed Jurassic sediments and main geographical localities marked.

JURASSIC STRATIGRAPHY



* AMMONITE ZONE IDENTIFIED BY FAUNA HORIZONS AND USED FOR CORRELATION IN THIS STUDY

Figure 3. Stratigraphy of analysed sections on Milne Land and Jameson Land, East Greenland

MILNE LAND

AMMONITES		DINOFLAGELLATE CYSTS			
ZONES	& FAUNAS	FAD	LAD		
VOLGIAN	ANGUINUS	(45)-46	<i>K. porosispinum</i> , <i>Muderongia</i> sp. A, <i>E. expiratum</i> , <i>T. hystrix</i>		
	PSEUDAPERTUM	41-44	<i>Cribroperidinium</i> sp. A	<i>A. cumula</i> <i>G. mutabilis</i> <i>S. irritabile</i>	
	GRACILIS	38-40			
	LIOSTRACUS	36-37	<i>C. cf. longicome</i>		
	COMMUNIS	34-35			
	RUGOSA	33	<i>K. cf. corrugatum</i>		
	IATRIENSIS			<i>K. telaspinosum</i>	
	PRIMUS		<i>Tanyosphaeridium</i> sp. <i>C. cf. compta</i>		
	PECTINATUS	29			
	HUDLESTONI		<i>C. downii</i> , <i>P. insolitum</i> <i>T. cf. ciliatum</i> , <i>S. jurassica</i> <i>G. mutabilis</i> , <i>S. janei</i>	<i>K. telaspinosum</i> <i>E. polyplacophorum</i> <i>R. thula</i> , <i>R. pennata</i> <i>R. pennata</i>	<i>R. pennata</i> , <i>P. granulata</i> <i>T. aff. ciliatum</i>
	WHEATLEYENSIS	25			<i>O. patulum</i>
(SCITULUS)		<i>R. "machaera"</i>			
ELEGANS	24	<i>Valensiella</i> sp.			
KIMMERIDGIAN	AUTISSIODORENSIS	23		<i>O. patulum</i>	
		22		<i>P. pannosum</i>	
	EUDOXUS	21		<i>cf. N. similis</i> <i>P. pannosum</i>	
		20	<i>A. cf. falcificum</i> <i>P. pannosum</i>		
	MUTABILIS	19		<i>P. capillosa</i>	
		17-18	<i>C. distinctum</i>		
	CYMODECE	16	<i>O. cf. monoheuriskos</i>		
		15			
	BAYLEI	14		<i>P. saturnalis</i> , <i>H. petilum</i> <i>P. borealis</i> , <i>A. hartzii</i>	
	ROSENKRANTZI	13		<i>S. irregulare</i>	
OXFORDIAN	REGULARE	12	<i>T. cf. iunctispina</i> <i>G. dimorphum</i>		
	SERRATUM	11		<i>D. jurassica</i>	
	GLOSENSE	10	<i>D. jurassicum</i>	<i>P. osmingtonense</i> <i>A. utera</i> , <i>S. irritabile</i> <i>Systematophora</i> spp.	<i>S. crystallinum</i> <i>C. polonicum</i>
	TENUISERRATUM	9	<i>C. cerastes</i> , <i>E. luridum</i> <i>L. subtile</i> , <i>L. mirabile</i>		
		8			
		7	<i>Stephanelytron</i> spp.	<i>P. stegasta</i>	
	DENSIPLICATUM	6			<i>R. aemula</i> <i>L. scarburghensis</i>
		5		<i>S. crystallinum</i>	
	CORDATUM	4	<i>R. aemula</i>		<i>W. digitata</i> , <i>T. dangeardii</i> <i>W. fimbriata</i> , <i>W. thysanota</i> , <i>N. pellucida</i>
	MARIAE	3		<i>W. dictydia</i> <i>W. digitata</i> <i>L. scarburghensis</i>	<i>M. groenlandicum</i>
(LAMBERTI)		<i>W. thysanota</i>			
CALLOVIAN	ATHLETA	2	<i>C. polonicum</i>	<i>C. dictydia</i> <i>G. pectinifera</i>	

★abundant ● acme

Figure 4. Stratigraphically significant dinoflagellate cyst events in the Upper Jurassic of Milne Land

filled strike-slip dominated basins (Friend *et al.*, 1976a & b; Larsen & Bengaard, 1991). Continental deposition continued in tilted halfgrabens during the Carboniferous where two major extensional pulses occurred in Early and Late Carboniferous respectively (Stemmerik *et al.*, 1991).

A change from east-west extension to passive, thermally controlled subduction occurred in Jameson Land during the Permian and is marked by marine transgression in the Late Permian (Surlyk *et al.*, 1986). Steady subsidence continued in the Jameson Land area resulting in the accumulation of a relatively complete Mesozoic succession. Sedimentation on Milne Land started during the Middle Jurassic as a result of an overall Jurassic sea-level rise that progressively led to onlapping of the basin margins (Surlyk, 1990). Further to the North, rifting continued during the Late Permian and Mesozoic resulting in the absence of Middle Triassic to Lower Jurassic sediments (Stemmerik *et al.*, 1993). In this northern region, an important new rift-phase occurred in the Late Jurassic - Early Cretaceous with marine deposition in rotated half-grabens (Surlyk, 1978).

The North Atlantic seafloor spreading between Greenland and Norway began in the Early Palaeocene and was accompanied by extrusion of extensive plateau basalts particular south of Jameson Land, on Wollaston Forland and on Hold with Hope. The entire region was uplifted in the range of 1-2 km during the Tertiary (Christiansen *et al.*, 1992) and the Jurassic sediments were exposed over large parts of East Greenland including Milne Land and Jameson Land (Fig. 1).

Lithostratigraphy of Milne Land and depositional model

The Jurassic - Lower Cretaceous succession on Milne Land (Fig.2) was deposited along the western margin of the Jameson Land basin in a more marginal setting than most of the time equivalent sediments in Jameson Land. The sedimentary succession onlaps the crystalline basement and the thickness increases rapidly eastwards towards Scoresby Sund fjord and Jameson Land. The top of the succession is capped by Lower Tertiary plateau basalts in the western outcrops.

The sedimentary succession is clearly tripartite which is also reflected in the local lithostratigraphy (Fig. 3). A basal coarse sandstone unit, the Charcot Bugt Formation, is

overlain by mudstones, shales, siltstones and fine-grained sandstones of the Kap Leslie Formation, and the top part of the succession is another coarse sandstone unit, the Hartz Fjeld Formation. The Kap Leslie Formation, which is the subject of this study, ranges in age from Callovian to Middle Volgian based on ammonites. It is subdivided into 8 members, in some cases on the basis of subtle lithological differences that make some boundaries difficult to pinpoint in the field (Callomon & Birkelund, 1980; Birkelund & Callomon, 1984).

Three of the members are completely uniform in lithology, sedimentological features and types of concretions and could not be distinguished in the field if they were not separated by distinct lithological marker beds. The basal Kosmocerasdal Member, the Cardioceraskløft Member and the upper Krebsedal Member all comprise micaceous, bioturbated mudstones and silt-rich shales with horizons of large yellow concretions. Laminated shales or sandstones with primary sedimentary structures occur locally in the Oxfordian Cordatum to Tenuiserratum ammonite zones of the Kosmocerasdal Member. The Kosmocerasdal Member is coarsening upwards with a gradual transition within the Glosense Zone to the Aldinger Elv Member which is a medium to coarse-grained sandstone unit with primary sedimentary structures, abundant trace fossils and shell lag beds (Fürsich & Heinberg, 1983). This succession is viewed as being essentially stratigraphically complete; ammonites of the Serratum Zone is not sampled in the study section but documented in other sections in the region. A sharp lithological break marks the base of the overlying Bays Elv Member, which consists of micaceous, bioturbated mud alternating with glauconitic fine-grained sand beds. This member contains ammonites of the Regulare to Baylei Zones. The disappearance of glauconitic sand beds marks the transition to the Cardioceraskløft Member (Cymodoce to Mutabilis Zones), whereas a facies shift to laminated claystones and shales marks the Gråkløft Member (Eudoxus to Elegans Zones). Higher up, above the Lower Volgian Elegans Zone lamination disappears and slightly coarser and bioturbated mud to siltstone facies of the Krebsedal Member was deposited from the Wheatlyensis Zone to the Communis Zone. The lower boundary of this member is sharp and there is possibly a hiatus between the Gråkløft and Krebsedal members as the Scitulus Zone has not been identified. Beds of glauconitic sand with abundant mollusc assemblages appear in the Middle Volgian Liostracus Zone and characterise the Pernaryggen Member. They are overlain by monotonous micaceous fine-

grained sandstones of the Astartedal Member, equivalent to the Anguinus Zone. A sharp boundary marks the top of the Kap Leslie Formation and separates it from the overlying the coarse-grained white sandstone of the Hartz Fjeld Formation.

The Kap Leslie Formation is envisaged to have been deposited on an open marine, muddy shelf (Kosmocerasdal Member) which is invaded by offshore bar sandstones of the Aldinger Elv Member (Birkelund *et al.*, 1984). The Aldinger Elv Member thickens towards the east away from the palaeocoastline. Slowly rising sea level (Bays Elv - Cardioceraskløft Member) ultimately results in deposition of organic rich, laminated shales of the Gråkløft Member. Progradation or falling sea level terminates deposition of anaerobic shales and the slightly coarser, siltstone facies of the Krebsedal Member was deposited. This coarsening upward trend continues with the deposition of shallow marine sandstones attributable to the Pernaryggen Member. The shallow marine, fine-grained Astartedal Member is followed by the progradation of fan deltas attributed to the Hartz Fjeld Formation.

Sections analysed from Milne Land

Only the fine-grained Kap Leslie Formation has been included in this study. Piasecki (1981) measured and sampled sections of the Kap Leslie Formation throughout the Jurassic exposures in Milne Land in close co-operation with T. Birkelund and J. H. Callomon (see the localities in Birkelund *et al.* 1984; Fig. 2). The most complete and well dated sections from Kosmocerasdal / Cardioceraskløft, Gråkløft and Krebseryggen respectively have been compiled into a composite section representing the complete Kap Leslie Formation from the Upper Callovian to the Middle Volgian (except for the very coarse-grained Aldinger Elv Member of the Upper Glosense to Serratum Zones). A few samples from ammonite dated levels which are missing in the composite section have been supplied from e.g. section 14 (Birkelund *et al.* 1984) close to Visdal

PALYNOSTRATIGRAPHY

The Kap Leslie Formation is studied in three main sections and the results from each section are presented separately in distribution-charts with data arranged after first occurrences (Enclosures 1 - 3). In this report, the charts present basic data without too much editing and some identifications and names may therefore reflect some of the uncertainties that normally have been removed in publications.

The stratigraphically most important dinoflagellate cyst data are presented in a conclusive event scheme where first stratigraphical appearance datum (FAD) and last stratigraphical occurrence datum (LOD) are presented together with FAD and LOD of abundant occurrences and together with maximum abundance horizons (acme) (Fig. 4). These events are calibrated with ammonite fauna horizons and with the standard ammonite zonation.

The sedimentary intervals between ammonite fauna horizons are calibrated to an ammonite zone if the fauna of two neighbour horizons belong to the same zone. In most cases, the succession between two fauna horizons is dated most precisely within the range of two ammonite zones (each represented by a fauna horizon) accentuating that an event in the dinoflagellate flora may occur in anyone of these two zones.

The dinoflagellate stratigraphy is discussed in the frame of ammonite provincialism e.g. in units of ammonite stratigraphy common (or not common) with the North Sea region as these stratigraphical units seem to be relevant for the dinoflagellate cyst assemblages as well. The events are compared with the corresponding events reported from North Sea region and summarised by Riding & Thomas (1992).

All data are recorded in the image-database, MicroImage, at GEUS and can be studied there on request.

Upper Callovian - Middle Oxfordian

Athleta - Cordatum Zones

Ammonite fauna 2- 4

Provincialism: In this time interval some similarities between the dinoflagellate cyst assemblages in East Greenland and in the North Sea region should be expected due to the

similarities in the ammonite faunas and a common ammonite stratigraphy in these two areas. However, though there are similarities, the significant differences are evident.

Dinoflagellate cyst assemblages: The dinoflagellate cyst flora in the lowermost Kap Leslie Formation is dominated by a *Valensiella dictydia* assemblage below the Athleta Zone, a *Mendicodinium groenlandicum* / *Liesbergia scarburghensis* / *Rhynchodiniopsis cladophora* assemblage in the Athleta - Lamberti Zones and a *Rigaudella aemula* / *Liesbergia scarburghensis* / *Scriniodinium crystallinum* assemblage in the Mariae - Cordatum Zones. The maximum abundance and diversity of the dinoflagellate cyst assemblages occur in the Cordatum Zone.

Dinoflagellate cyst stratigraphy: The stratigraphical important events are listed in figure 4 and their significance is discussed below: *Compositosphaeridium polonicum* appears below fauna 2, Athleta Zone. It is present throughout the Callovian in the North Sea region. *Liesbergia scarburghensis* appears at the basis of Athleta Zone in accordance with the North Sea standards but *Wanaea digitata* appears higher in the zone as the first species of the *Wanaea*-group *sensu lato*. *Energlynia (Wanaea) acollaris* is not recorded from East Greenland. *Wanaea thysanota* appears late, between fauna 2 (Athleta Zone) and fauna 3 (Mariae Zone) in presumed Lamberti Zone and *Wanaea fimbriata* slightly later just below fauna 3. The absence of one important species and delayed occurrence of another species of the *Wanaea*-group in East Greenland in relation to the North Sea region clearly mark difference, at times when the two regions should be expected to be similar.

All three species of *Wanaea* disappear between fauna horizon 4 and 5 (Cordatum and Densiplicatum Zones) but *Wanaea digitata* and *fimbriata* earlier than *Wanaea thysanota*. This is in accordance with data from the North Sea region (*Wanaea fimbriata* disappears in mid-Cordatum Zone and *Wanaea thysanota* at the basis of Densiplicatum Zone (Riding & Thomas, 1992)).

Valensiella dictydia has an acme in the Athleta Zone and *Mendicodinium groenlandicum* occurs abundant in the Athleta - "Lamberti" Zone but becomes infrequent just below fauna 3 (Mariae Zone). *Rigaudella aemula* and morphologically related species as *Rigaudella paucispina* and *Rigaudella filamentosa* appear for the first time in the Cordatum Zone (fauna 4) much later than in the North Sea region where they are present in the Middle

and Upper Callovian (Riding & Thomas, 1992). *Rigaudella aemula* becomes rapidly abundant in the Cordatum Zone.

Scriniodinium crystallinum appears between fauna 4 and 5 (Cordatum and Densiplicatum Zones) again much later than in the North Sea region (Upper Callovian, Riding & Thomas, 1992). Continuously occurring *Nannoceratopsis pellucida* disappears between fauna 4 and 5 (Cordatum and Densiplicatum Zones) but scattered *N. pellucida* occurs far up into the Volgian.

A number of species have clear last occurrences within this time interval: *Gonyaulacysta pectinigera* disappears just below fauna 2 (Athleta Zone), *Gonyaulacysta eisenackii* between fauna 2 and 3 in presumed Lamberti Zone, *Lithodinia jurassica* in fauna 4 (Cordatum Zone) and *Tubotuberella dangeardii* between fauna 4 and 5 (Cordatum and Densiplicatum Zones).

The above mentioned species reflect very well the occurrence of dinoflagellate cysts in East Greenland in relation to the North Sea region. In this time interval, the abundant and characteristic North Sea species appear (significantly) later in East Greenland whereas they disappear approximately at the same time in both regions.

Middle - Upper Oxfordian

Densiplicatum - Rosenkrantzi Zones

Ammonite fauna 5 - 13

Provincialism: In this period, the Boreal ammonite fauna withdrew from the North Sea region to East Greenland and further north and there is a strong fauna separation between the two regions. A similar situation should be expected for the dinoflagellate floras. The diversity and density of the dinoflagellate cyst flora decreases rapidly upwards in this succession but abundant and diverse floras reappear in the uppermost Oxfordian, Serratum to Rosenkrantzi Zones.

Dinoflagellate cyst assemblages: The *Rigaudella aemula* / *Rhychodiniopsis cladophora* / *Gonyaulacysta jurassica* assemblage dominates in the Densiplicatum -

Tenuiserratum Zones, followed by a *Gonyaulacysta jurassica* / *Adnathosphaeridium hartzi* assemblage in the Regulare to Rosenkrantzi Zones.

Dinoflagellate cyst stratigraphy: *Stephanelytron* spp. appears between fauna 6 and 7 in the Densiplicatum Zone but otherwise no new species appear in the lower part of this interval. *Pareodinia stegasta*, which occurs consistently from the Athleta Zone, has an acme between fauna 6 and 7 in the Densiplicatum Zone in association with the disappearance of *Liesbergia scarburghense* (The latter is in accordance with Partington et al. 1993 but one ammonite zone earlier than indicated by Riding & Thomas, 1992). Abundant *Rigaudella aemula* has a top between fauna 6 and 7 in the Densiplicatum Zone and this species disappears in fauna 8, the Tenuiserratum Zone. Both events are in accordance with data from the North Sea region (Riding & Thomas, 1992; Partington et al. 1993).

Leptodinium mirabile (see later), *Leptodinium subtile*, *Chytroeisphaeridia cerastes* and *Endoscrinium luridum* appear in fauna 8 (Tenuiserratum Zone) much later than in the North Sea region where they appear in the Cordatum and Tenuiserratum Zones respectively (Riding & Thomas, 1992). *Systematophora* spp., *Scriniodinium inritibulum*, *Ambonosphaera calloviana* and later *Pareodinia osmingtonense*, *Prolixosphaeridium granulosum* and *Acanthaulax granuligera* appear between fauna 8 and 9 (Tenuiserratum and Glosense Zones) and *Dingodinium jurassicum* appears in fauna 10 (Glosense Zone). The significance of several of these occurrences are debatable. Some are occurring late as mentioned above, some could be the result of reworking and in general the species are not abundant. E.g. *Leptodinium mirabile* has been recorded in a dinoflagellate assemblage (Densiplicatum Zone) from another locality at Milne Land and supporting an earlier occurrence for *L. mirabile/subtile*? as suggested by Partington et al. 1993. *Ambonosphaera calloviana* is described from the Calloviense Zone in Jameson Land but has an effectively re-occurrence in the Glosense Zone and an acme in the Baylei Zone. However, the occurrence of these species seem to be stratigraphical significant also in other sections in East Greenland.

Scriniodinium crystallinum has maximum abundance just below fauna 9 of the Glosense Zone, much earlier than in the North Sea (In the Rosenkrantzi Zone; Partington et al., 1993)

The Serratum Zone is not represented in this study because it occurs in very coarse-grained facies. Most species that occur above the Serratum Zone appeared earlier in the underlying Glosense Zone. In the North Sea region the Serratum Zone is not well marked in dinoflagellate cysts stratigraphy (Riding & Thomas, 1992; Partington *et al.*, 1993).

Glossodinium dimorphum and *Taeniophora cf. iunctispina* occur earliest below fauna 12 (Regulare Zone) and *Dingodinium jurassicum* does not occur above fauna 12. *Scriniodinium irregulare* appears below fauna 13 (Rosenkrantzi Zone). *Glossodinium dimorphum* is reported to appear much earlier in the North Sea region, respectively in the Densiplicatum Zone (Partington *et al.*, 1993) and the Tenuiserratum Zone (Riding & Thomas, 1992). *Compositosphaeridium polonicum* disappears between fauna 8 and 9 (Tenuiserratum and Glosense Zones) only slightly earlier than in the North Sea Region (Glosense Zone, Thomas & Riding, 1992; Partington *et al.*, 1993).

The Serratum, Rosenkrantzi and Baylei Zones are characterised by abundant *Gonyaulacysta jurassica sensu lato* which is stratigraphically significant both in the North Sea region (Riding & Thomas, 1992) and in the Boreal flora from the Arctic region (Brideaux & Fisher, 1976; Davies, 1983; Piasecki, 1994). *Rhynchodiniopsis cladophora* is abundant in the Serratum Zone whereas *Adnathosphaeridium hartzi*, *Taeniophora cf. iunctispina* and *Ambonosphaera calloviana* are abundant in the Baylei Zone.

Between fauna 13 (Rosenkrantzi Zone) and fauna 14 (Baylei Zone) *Paragonyaulacysta borealis* and *Pandadinium saturnalis* of the Arctic Borealis Flora (Brideaux & Fisher, 1976; Davies, 1983) appear in East Greenland together with *Adnathosphaeridium hartzi* and *Hystriospheridium petilum*. *A. hartzi* occurs in the Jurassic of the Wandel Sea Basin (Piasecki, 1994) whereas *H. petilum* is occurs in the basal Kimmeridgian in the North Sea region from where it is described (Gitmez, 1970). The *Scriniodinium crystallinum* acme reported in the Rosenkrantzi Zone from the North Sea (Partington *et al.*, 1993) is not recognised in East Greenland where this species is recorded scattered throughout the Kimmeridgian.

The dinoflagellate cyst flora in this strictly Boreal Densiplicatum - Rosenkrantzi interval does not show a similar distinct Boreal affinity as the ammonites. The flora has low diversity and density compared to the flora of North Sea region giving the impression of it being an impoverished North Sea flora instead of an independent Boreal flora. The abundance

of dinoflagellate cysts increases in the Serratum to Baylei Zones and the dinoflagellate flora show similarities in composition to contemporaneous floras both in the Wandel Sea Basin where *Gonyaulacysta jurassica/longicornuta/dualis* also is abundant (Piasecki, 1994) and to the North Sea region. Late appearances and early disappearances of many species that are stratigraphical important in the North Sea region, seem to be a general rule in these northern regions. The appearance of species described from the Borealis Flora (Brideaux & Fisher, 1976; Davies, 1983) emphasises the position of East Greenland intermediate between the present Arctic regions and the North Sea region. It is interesting that the Boreal dinoflagellate cysts migrated down to East Greenland exactly at the time when parts of the Sub-boreal ammonite family, Perisphintaceae, migrated northwards to East Greenland (Birkelund & Callomon, 1985) and create the basis for common ammonite zonation in both regions. This may simply reflect better circulation between the basins through the Jurassic Seaway. Smelror (1983) reports that both *P. borealis* and *P. capillosa* occurs south of East Greenland much earlier but he does not report these species from the Bathonian to Early Oxfordian in East Greenland (Smelror, 1988) in accordance with the present data set.

Kimmeridgian *sensu gallico*

Baylei - Autissiodorensis Zones

Ammonite fauna 14 - 23

Provincialism: Despite the common ammonite zonation in the Sub-Boreal and the Boreal provinces, ammonites of the Cardioceratidae are still completely dominating the fauna in East Greenland and provincialism was predominant also in the Kimmeridgian (Birkelund & Callomon, 1985).

Dinoflagellate cyst assemblages: Three main dinoflagellate cyst assemblages occur in the Kimmeridgian. *Taeniophora cf. iunctispina*, *Taeniophora hartzi*, *Gonyaulacysta jurassica* or *Sirmiodinium grossii* dominates the Baylei, Cymodoce and Mutabilis Zones. *Perrisseiasphaeridium pannosum* dominates completely in the Eudoxus Zones followed by an *Oligosphaeridium patulum* dominated assemblage in the Autissiodorensis and Elegans Zones.

Dinoflagellate cyst stratigraphy: Abundant *Gonyaulacysta jurassica sensu lato*, *Taeniophora* cf. *iunctispina*, *Adnathosphaeridium hartzi*, *Sentusidinium pelionense* in the flora from the Baylei Zone (fauna 14) and the acme of both *Escharisphaeridium pocockii* and *Sirmiodinium grossii* in the Cymodoce Zone (fauna 17) can be correlated with corresponding events in the dinoflagellate cyst flora in the Jurassic Ladegårdsåen Formation in the Wandel Sea Basin, North Greenland (Piasecki, 1994). This indicates some Boreal affinity of the assemblage.

Occissucysta cf. *monoheuriskos* appears abundantly in fauna 16 and *Circulodinium distinctum* appears in fauna 17 both of the Cymodoce Zone. *Paragonyaulacysta capillosa* appears below fauna 19 and *Perisseiasphaeridium pannosum* appears within fauna 19 (Mutabilis Zone) and becomes abundant in fauna 20 (basal Eudoxus Zone). *Avellodinium* cf. *falcificum* appears in fauna 19 (Mutabilis Zone). All these species are excellent stratigraphical markers in these two ammonite zones.

Occissucysta monoheuriskos is described on the basis of one specimen from the Cymodoce Zone in Scotland (Gitmez & Sarjeant, 1972) and has not been mentioned further as potentially stratigraphically important species. *Circulodinium distinctum* is a systematic garbage can for unidentified *Circulodinium* types but is very useful here. *Paragonyaulacysta capillosa* is the third main member of the Borealis Flora reaching southwards into East Greenland and again indicating some Boreal affinity of the assemblage. In contrast *Perisseiasphaeridium pannosum* is well known from the North Sea region where it appears in the Mutabilis Zone (Nøhr-Hansen, 1986). *Avellodinium* cf. *falcificum* is not reported earlier.

Some stratigraphical significant marker species from the corresponding interval in the North Sea region are absent in East Greenland or appear much later. *Subtilisphaera paeminosa*, *Subtilisphaera inaffecta* and *Cribroperidinium longicorne* are absent, although forms partly similar to the latter appear stratigraphically higher. *Oligosphaeridium patulum/pulcherrimum* has not been recorded in this interval in East Greenland but appears higher in the succession and much later than reported from the North Sea region (Cymodoce Zone; Riding & Thomas, 1992; Partington et al. 1993).

The Eudoxus Zone is monotonously dominated by *Perisseiasphaeridium pannosum* until above fauna 22 (top Eudoxus Zone) where *Oligosphaeridium patulum* appears and then

dominates of the flora approximately from the boundary between the Eudoxus and Autissiodorensis Zones. In contrast, Partington *et al.* (1993) interpret the *Perisseiasphaeridium pannosum* acme to be equivalent to both the Eudoxus and Autissiodorensis Zones in the North Sea region. An *Oligosphaeridium patulum* dominated flora in the Autissiodorensis Zone as in East Greenland apparently do not occur in the North Sea region (Partington *et al.*, 1993; Riding & Thomas, 1992). Neither of these abundant species have been recorded from the Arctic region (Brideaux, 1976; Håkansson *et al.* 1981; Davies, 1983; Piasecki, 1994) and they may be regarded as southerly species. Their stratigraphical ranges are already significantly reduced in East Greenland compared to the North Sea region and their occurrences apparently wedges out further towards the north in the Boreal realm. Apparently *Subtilispaera paeminosa* and *S. inaffecta* follows the same pattern but already disappears at latitudes south of East Greenland.

The characteristically, *Cyclopsiella*-like species cf. *Nummus similis* appears in fauna 20 (lower Eudoxus Zone) but otherwise no significant floristic events have been recorded in this zone.

The apparent closer relationship between the floras of the North Sea and East Greenland region and the stability of the flora (hardly any new events) may be related to the high sea-level during the Eudoxus and Autissiodorensis Zones.

Lower Volgian

Elegans - Pectinatus Zones

Ammonite fauna 24 - 29

Provincialism: The stratigraphical distance between horizons with ammonites become larger in this part of the section and abundance of ammonites is low. The result is decreasing precision in correlation and the Scitulus Zone has not been recorded. The ammonites of this interval in East Greenland are almost identical with those in England (Callomon & Birkelund, 1982).

Dinoflagellate cyst assemblages: The *Oligosphaeridium patulum* assemblage includes the Elegans Zone but is replaced by a diverse and rich assemblage with many species

appearing for the first time in the transition from the Elegans to the Wheatlyensis Zone, where the Scitulus Zone should have been recorded. *Circulodinium downei*, *Trichodinium* aff. *ciliatum*, *Senoniasphaera jurassica*, *Senoniasphaera janei* and several others (Fig. 4).

Dinoflagellate cyst stratigraphy: Fauna 24 (Elegans Zone) occurs within the range of abundant *Oligosphaeridium patulum*. *Valensiella* sp. appears below fauna 24 in presumed Autissiodorensis Zone and *Rhynchodiniopsis "machaera"* appears above fauna 24.

A markedly increase in flora diversity and abundance occur below fauna 25 (Wheatlyensis Zone) in the interval of assumed "Scitulus Zone" associated with the appearances of *Gochteodinium mutabilis*, *Trichodinium* aff. *ciliatum*, *Senoniasphaera jurassica*, *Senoniasphaera janei*, *Circulodinium downei* and *Perisseiasphaeridium insolitum*. Again most of these species appear late to very late compared to the North Sea region. According to Riding & Thomas (1992) *Gochteodinium mutabilis* occurs already at the Eudoxus/Autissiodorensis boundary whereas Partington *et al.* (1993) favour a first occurrence at the Elegans/Scitulus boundary. *Senoniasphaera jurassica* is claimed to be present from the Baylei Zone in the North Sea (Riding & Thomas, 1992; Partington *et al.* 1993). *Circulodinium downei* is reported from the Wheatlyensis Zone in England (Ioannides *et al.*, 1976). *Perisseiasphaeridium insolitum* is reported from much younger strata (Davey, 1982) but a similar type *Perisseiasphaeridium* sp. A Ioannides *et al.* (1976) is reported from the Wheatlyensis Zone in England

Rotosphaeropsis thula, *Rhynchodiniopsis pennata*, *Egmontodinium polyplachophorum* and *Kleithriasphaeridium telaspinosum* appears higher but still below fauna 25 (Wheatlyensis Zones). These appearances are coincident with the top of abundant *Oligosphaeridium patulum*. In the North Sea region these species appear more scattered from the Elegans to the Scitulus Zone. The contemporaneous first occurrences of these species could indicate a hiatus in the section which also could explain the apparent absence of ammonites from the Scitulus Zone.

Rotosphaeropsis thula is a case of an early appearance in East Greenland as it is recorded to appear approximately on ammonite zone later in the North Sea region (at the boundary of Wheatlyensis/Huddlestoni Zones; Riding & Thomas, 1992; Partington *et al.*, 1993). Fisher & Riley (1980) dates the first appearance of *Rhynchodiniopsis pennata* in the North Sea as later than the Pectinatus Zone e.i. much later than in East Greenland. Both

Kleitriasphaeridium telaspinosum and *Egmontodinium polyplachophorum* occur as early as the basis of the Elegans Zone in the North Sea region (Riding & Thomas, 1992; Partington *et al.*, 1993) and appears therefore later in East Greenland.

Rhynchodiniopsis pennata and *Pyxidiniopsis granulata* have an acme of abundance and *Trichodinium cf. ciliatum* occurs for the last time between fauna 25 and 29, Wheatlyensis to Pectinatus Zones. *Canningia cf. compta* occurs only in fauna 29, Pectinatus Zone, and *Tanyosphaeridium* sp. appears at the same level. Abundance and diversity of dinoflagellate cysts drop drastically above fauna 29 apparently associated with reinforcement of the provincialistic separation between the North Sea region and East Greenland.

Middle Volgian

Primus - Gracilis Zones

Ammonite fauna 31 - 40

Provincialism: The ammonites of this stratigraphical interval in East Greenland have little in common with the more southern North Sea faunas and correlation is restricted to certain levels e.g. from the Communis Zone to the Rotunda Zone (Callomon & Birkelund, 1982). The poor abundance and diversity of dinoflagellate cysts in this interval may reflect depositional facies of a prograding succession. But it also coincides with significant ammonite provincialism and therefore with some physical separation from the corresponding North Sea floras. Many species, that are not recorded in this interval, are abundantly present below and above this interval, where more North Sea related floras occur. Consequently, the few events that do occur among the few present species could more important for the Boreal dinoflagellate cyst stratigraphy.

Dinoflagellate cyst assemblages: No characteristic assemblages occurs in this interval. The assemblages appear strongly diluted as most records are here and there occurrences of species known lower or higher in the section.

Dinoflagellate cyst stratigraphy: In spite of the poor flora, a second short appearance of *Perisseiasphaeridium pannosum* and *Oligosphaeridium patulum* is recorded approximately at the level where Riding & Thomas (1992) indicate their last appearance in

the North Sea region ; Pallasioides and Pectinatus Zone respectively. Stratigraphically significant first occurrences are neither common in the North Sea region (Riding & Thomas, 1992) nor in East Greenland. *Kleithriasphaeridium telaspinosum* apparently disappears and *Kleithriasphaeridium* cf. *corrugatum* appears below fauna 33, Rugosa Zone. The latter is much earlier than *K. corrugatum* appears in the North Sea region; Albani/Glaucolithus Zone (Riding and Thomas, 1992). *Cribroperidinium* cf. *longicorne* appears between fauna 34 and 37, Communis and Liostracus Zones.

Middle Volgian

Pseudapertum - Anguinus Zones

Ammonite fauna 41 - 46

Provincialism: In fauna 41 - 46 the ammonites from East Greenland again have taxonomic counterparts in the North Sea region and correlation becomes possible (Callomon & Birkelund, 1982).

Dinoflagellate assemblages: Diversity and density increases rapidly upwards and becomes very high in the middle of Anguinus Zone followed by a decrease (Fig. 5). Assemblages in the lower part of the interval are characterised by frequent *Cribroperidinium* sp. and *Rhynchodiniopsis* sp. whereas *Valensiella* sp., *Avellodinium culmula*, *Mendicodinium groelandicum* and *Tenua hystrix* are abundant in the upper part.

Dinoflagellate cyst stratigraphy: *Cribroperidinium* sp. A Davey appears between faunas 40 and 41 (Gracilis and Pseudapertum Zones), and *Avellodinium cumula* appears within faunas 41 - 45 (Pseudapertum Zone). *Kleithriasphaeridium porosispinum*, *Muderongia* sp. A. Davey, *Egmontodinium expiratum* and *Tenua hystrix* appear in fauna 46 (Anguinus Zone).

The appearance of *Egmontodinium expiratum*, *Kleithriasphaeridium porosispinum* and *Muderongia* sp. A. Davey are delayed compared to the North Sea ranges (Riding & Thomas, 1992). In contrast *Cribroperidinium* sp. A. Davey and *Avellodinium cumula* appear at the same time in both regions.

At the top of the studied section, the significance of last occurrences are difficult to evaluate but *Scriniodinium inritibile* and *Gochteodinia mutabilis* may have their last occurrence in fauna 46 (Anguinus Zone) a little early for the last one but otherwise in accordance with the ranges in the North Sea region.

DISCUSSION

Diversity and abundance

The diversity is recorded simply as number of recorded species in each sample (Fig. 5). The overall pattern is clear though there are local variations. The diversity varies between 15 and 25 species pr. sample in most of the Milne Land succession. Top Callovian, Middle/Upper Oxfordian and Middle Volgian successions have generally low diversity from 15 to 20 species in contrast to the uppermost Oxfordian/Kimmeridgian - Lower Volgian succession which mostly has 20 to 25 species pr. sample. Maximum diversity occurs at 4 levels. The two earliest peaks occur in the *Mariae* and *Cordatum* Zones (Lower - Middle Oxfordian) and in the *Cymodoce* Zone (Kimmeridgian) and they are not very significant. In contrast, very distinctive maxima occur in the in the “*Scitilus*” /*Wheatlyensis* Zones (Lower Volgian) and in the *Groenlandicus* Zone (Middle Volgian).

High abundance of dinoflagellate cysts occur in the *Cordatum* Zone, the *Rosenkrantzi* Zone, *Eudoxus* Zone, the *Wheatlyensis* Zone and the *Groenlandicus* Zone (Fig. 5). The high abundance in the *Cordatum* Zone, the *Wheatlyensis* Zone and the *Groenlandicus* Zone coincide with diversity maxima.

Provincialism

Smelror (1993) analysed and discussed the distribution and variations of the Bathonian to Oxfordian dinoflagellate floras from the Jurassic Boreal regions (now Arctic regions) to the Tethys realm (now Mediterranean regions) based on data from the Sverdrup Basin, Svalbard/Barents Sea, East Greenland/offshore Norway to Northwest Europe and further into the Tethyan region to Israel/Egypt. He concludes that there was a clear trend from Bathonian to Early Oxfordian of decreasing provincialism in the dinoflagellate floras and he relates the provincialism to tectonically disruption of seaways from Tethys to Northwest Europe and to

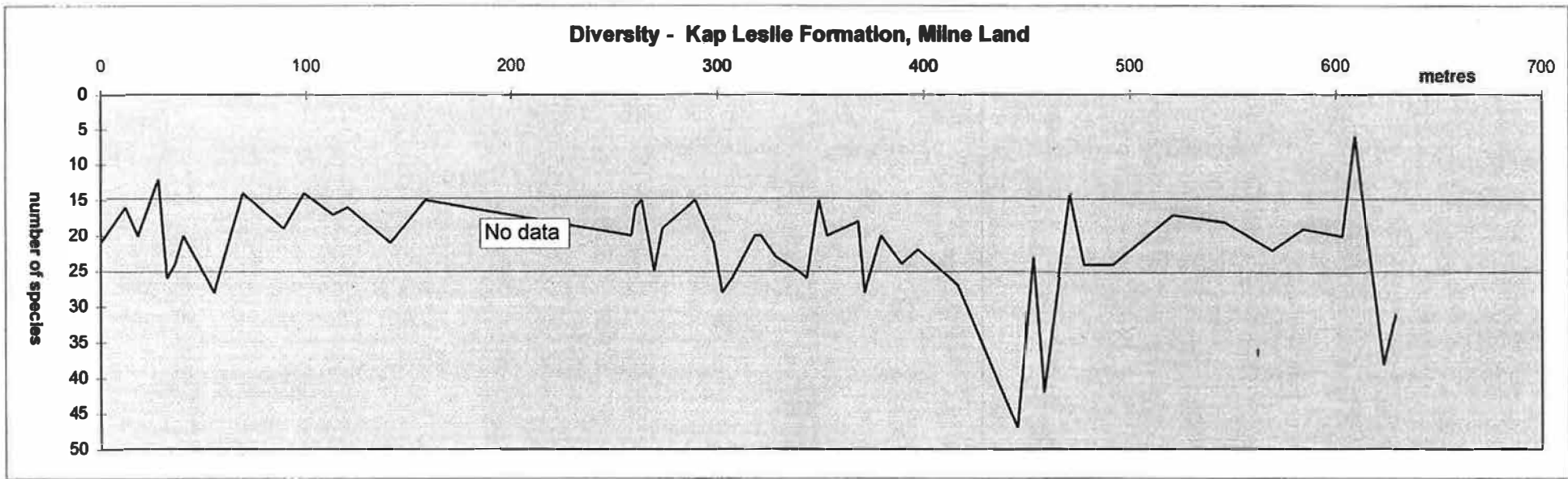


Figure 5: Diversity of dinocyst assemblages in the Kap Leslie Formation, Milne Land.

the Arctic region. Smelror (1993) also concludes that very few species are endemic to one flora-province and that Boreal diversity increases from Bathonian to Lower Oxfordian (e.i. stratigraphically towards less strict provincialism both in the dinoflagellate floras and the ammonite faunas). He suggests that the variations in distribution and composition of the dinoflagellate floras largely follow the pattern from the ammonites of the same time (Smelror, 1993).

In the present study of mainly Upper Jurassic dinoflagellate cysts, the stratigraphical data are most easily compared with the well documented data set from Northwest Europe i.e. UK / the North Sea region where the recorded dinoflagellate cyst distribution also is closely correlated to ammonite stratigraphy. Another important area for correlation and comparison are the Arctic / North Atlantic area but unfortunately, most dinoflagellate data from these regions suffer from lack of precise correlation to ammonite stratigraphy. There are a few exceptions in Peary Land, North Greenland (Piasecki, 1994) and at Svalbard (Bjærke, 1980; Århus, 1988).

The Late Callovian - Early Oxfordian dinoflagellate assemblages in UK and East Greenland become statistically more similar in composition and more diverse than they have been since the separation in flora provinces in the Bathonian (Smelror, 1993). Despite of this, the effects of provincialism are still clearly reflected in the divergent stratigraphical occurrences of many species in these two regions; mainly as a delayed appearance in East Greenland but also in the absence of characteristic species. The most common assemblage for the two regions occurs in the following *Cordatum* Zone, of lowermost Middle Oxfordian.

Above the *Cordatum* Zone, upwards decreasing abundance of dinoflagellate cysts and delayed appearances of species compared to the Northwest Europe standard dinoflagellate zonation characterise the dinoflagellate assemblages in the strictly Boreal Middle and Upper Oxfordian of Milne Land. The average diversity is constant and low but in contrast, abundant and relatively diverse assemblages reappear in the strictly Boreal, uppermost Oxfordian (and in the less Boreal lowermost Kimmeridgian) *Rosenkrantzi*, *Baylei* and *Cymodoce* Zones. A contemporaneous bloom in abundance and diversity occurs in Peary Land, North Greenland (Piasecki, 1994).

The average diversity of the Kimmeridgian and Lower Volgian dinoflagellate cyst assemblages in Milne Land are generally high compared to the diversity in the Oxfordian and Middle Volgian strata of the studied section. But these Kimmeridgian assemblages are clearly intermediate in diversity and abundance compared to the rich NW-Europe assemblages and the poor North Greenland/Svalbard/Barents Sea assemblages (Århus, 1988; Piasecki, 1994). Despite restricted provincialism of the ammonite faunas in this period reflected in the common stratigraphy of these areas, the faunas have distinct Boreal affinities (Birkelund & Callomon, 1985). This is also clearly reflected in the dinoflagellate cyst assemblages. The stratigraphical range of several species becomes restricted from the North Sea towards East Greenland and further restricted towards the North. Especially in the Kimmeridgian, there are good examples of abundant and stratigraphically important species in the North Sea region that do not occur in East Greenland (e.g. *Subtilisphaera inaffectum*, *S. paeminosa*) or occur with limited ranges (e.g. *Perisseiasphaeridium pannosum* and *Oligosphaeridium patulum*). The latter species can be followed further north e.g. to Wollaston Forland or Hochstetter Forland but they do not occur in North Greenland and on Svalbard (Piasecki, 1994; Århus, 1988). Middle Volgian assemblages in Milne Land is again dominantly of low diversity and especially of low abundance and again appear intermediate to rich assemblages in NW-Europe and very poor assemblages in North Greenland and in Svalbard (Håkansson et al. 1981; Århus, 1988; Piasecki, 1994)

TAXONOMY

The Upper Jurassic dinoflagellate cyst flora in East Greenland clearly demands a detailed taxonomic work to get the abundant species in a satisfactory systematic frame for further stratigraphical work. However, this will be the subject of another paper. The dinoflagellate floras are thoroughly illustrated and arranged stratigraphically in this report. Three new species are described because they are stratigraphically important and because they have been used informally in the unpublished part of the stratigraphical literature for some time. The formal publication of these species will be done separately in a proper way following the rules of botanical nomenclature and therefore some of the numbers in the text of this report are replaced with an asterisk.

Taeniophora hartzi sp. nov.

Pl. 17, Fig. 1.

Diagnosis: Chorate cysts having apical archaeopyle. Taeniate processes are arranged into annular or soleate intratabulate complexes. The complexes indicate paratabulation and no paracingular complexes or processes occur. The massive and vesiculate processes are broad or slender, but are fan-shaped distally, expanding slightly in width proximally. Distal trabeculae connect the processes within a complex or between the complexes. The paratabulation formula is (1-4', 1-6", ?, ?"', 1''').

Derivation of name: Named after the Danish phytopalaeontologist Dr. N. Hartz, who joined the East Greenland Expedition (1891-92) as a student and was one of the first, who reported the occurrence of Mesozoic sediments on Milne Land.

Description: The central body of these dinoflagellate cysts is ovoidal to subspherical. The surface is covered by complexes of processes, which are of approximately the same length on any one specimen, but otherwise are very variable. The wall of the main body is formed of one layer, autophragm.

The *processes* are taeniate, but the width varies considerably, even within one specimen. However, each specimen is generally characterised by having either slender or broad processes. The processes are massive, hyaline and densely vesiculate. The distal part of the processes are fan-shaped, and in some cases the processes may be bi- or trifurcate and fenestrate, especially when they are very broad. Short processes are generally broad, long ones narrow. The processes are arranged into annulate and soleate complexes and are connected proximally by low membranes or thickenings on the surface of the main body. The complexes vary from fully annulate to soleate or are more fragmentarily developed, but are generally rather uniform on any one specimen. The complexes are generally well separated, although coalescence may occur. Distal trabeculae may occur between processes within a complex or between different complexes, and short spines may occur on the distal margin of the trabeculae.

The *archaeopyle* is apical, of type tA. Four apical paraplates are reflected on the polygonal operculum by the occurrence of four process-complexes. Accessory archaeopyle sutures may occur between the precingular paraplates. The *auto-phragma* is approximately 1 micron thick and lacks internal structures. The surface is smooth to granular and lacks parasutural structures.

The *paratabulation* is indicated by the complexes of processes and partly by the archaeopyle sutures. The operculum has 4 complexes of very different sizes, which indicate 4 apical paraplates. The accessory archaeopyle sutures may split the rim of the archaeopyle into 6 precingular paraplates, each of which is occupied by one complex. However, no paracingular processes have been recognised and the precise number of postcingular process-complexes has not been determined. One large complex appears to occur on the antapex and is interpreted as antapical paraplate 1^{'''}. The paratabulation formula is therefore (1-4', 1-6'', ?c, ?''', 1''''') and the process formula is (4', 6'', 0c, 4-5?''', 1''''').

Remarks: Despite the large number of specimens, which have been observed, the paratabulation has not been fully determined. The large number of processes and the variation in the development of the complexes makes it difficult to determine the paratabulation.

Taeniophora hartzi is very characteristic when all characters are fully developed, especially the broad, solid, vesiculate processes with trabeculae and arranged in intratabular complexes are characteristic. However, apparently *T. hartzi* grades morphologically into *Taeniophora iunctispina* and *T. cf. iunctispina*. Morphological intermediate specimens cannot be classified with certainty. Superficially the Eocene *Adnathosphaeridium vittatum* looks very similar to *T. hartzi* but the absence of cingular processes exclude *T. hartzi* from the genus *Adnathosphaeridium*.

Occurrence: *T. hartzi* is only reported from the Upper Jurassic of Greenland; i.e. Milne Land and Peary Land (Piasecki, 1994).

Dimensions: 22 specimens with detached operculum were measured. The diameter of the central body varied from 40 to 69 μm , average 56 μm . The maximum length of the processes varied from 17 to 30 μm , average 20 μm .

Holotype: Pl. *, Fig. *. The diameter of the central body is 54 μm and the maximum length of the processes is 18 μm .

Paratypes: Pl. *, Fig. *. The diameter of the central body is 63 μm and the maximum length of the processes is 17 μm . Pl. *, Fig. *. The diameter of the central body is 60 μm and the length of the processes is 18 μm .

Type locality and type stratum: Cardioceraskløft on Milne Land; Bays Elv Member from 3 m above the lower boundary to the top.

Age: The range of *Taeniophora hartzi* sp. nov. is equivalent to the Regulare, Rosenkrantzi, Baylei and Cymodoce Zones. The age is Late Oxfordian to Early Kimmeridge.

Ambonosphaera calloviana Fensome 1979

Pl. 7, Figs 1-2; Pl. 10, Figs 1-5.

Ambonosphaera calloviana is described from a very specific sandstone bed with Calloviense ammonite fauna in Jameson Land (Fensome 1979). The species is rare outside this bed. Piasecki (1981) described a similar species from the uppermost Oxfordian of Milne Land based on some apparent morphological differences from the type material. A restudy of

the type material leads to the consideration that all morphological variations occur in both stratigraphical levels and that the same species apparently have two acmes at stratigraphical levels separated by approximately 10 million years.

Ambonosphaera calloviana has a clear, smooth 3-shaped flagellar mark in the parasulcus between the ends of the paracingulum. A granular or verrucate thickening marks the position of each flagella-pore. An irregular area of the ventral wall around the flagella marks is thick and hyaline. This area is resistant to degradation and is often the last morphological character to disappear on degraded specimens.

Dimensions of the Upper Oxfordian specimens: 22 specimens with detached operculum were measured. The length of the pericysts varies from 35 to 52 microns averaging 43 microns, and the width varies from 36 to 52 μm averaging 43 μm . The length of the endocysts varies from 33 to 45 μm averaging 39 μm , and the width varied from 31 to 46 μm averaging 38 μm . Two specimens having the operculum *in situ* has been measured. The length of the pericysts were 38 to 50 μm and the length of the endocysts were 31 to 43 μm .

Senoniasphaera janei sp. nov.

Pl. 10, Figs 10-11.

Diagnosis: Proximate to hypocavate cysts with a long apical horn formed by two wall layers. The cavity of the apical horn and the cavity of the hypocyst vary in size. The hypocyst is rounded to polygonal and may have indications of lateral and antapical protrusions. The endocyst is ovoidal and protruding into the apical horn. The paracingulum is indicated, but there is no other parasutural structure. The archaeopyle is apical and the shape of the suture is significantly zigzag. The wall layers lack sculpture and structure.

Derivation of name: Named after my wife Jane Piasecki.

Description: These dinoflagellate cysts have an ovoidal to polygonal main body and a well developed apical horn. The cyst wall is formed of two wall layers, which are separated in the posterior region, the hypocyst, and in the apical horn, but closely connected in the anterior

part of the main body, the epicyst. The size of the cavities varies. The epicoel may be restricted to the distal part of the apical horn, but may reach down to the base of the horn. The distal part of the horn, which is formed by the periphragm, may be broken along an irregular suture. When unbroken, the apical horn appears to terminate distally in a round to ovoidal platform. The size and shape of the hypocoel are often obscured by folding of the periphragm. Equatorial folds are especially common. Lateral and antapical protrusions similar to indication lateral and antapical horns may occur.

The *archaeopyle* is apical and there is only one operculum: type tA. The operculum may be attached along the dorsal margin. The shape of the archaeopyle margin is significantly zigzag in dorsal-ventral view.

The *periphragm* is thin, less than 1 mm, and lacks both sculpture and structure. Thin parasutural thickenings indicate the paracingulum, but there are no other parasutural structures on the periphragm.

The *endophragm* is thicker than the periphragm, approximately 1 mm, and also lacks sculpture and structure. There are no parasutural structures.

The *paratabulation* is only indicated by the shape of the archaeopyle and by the paracingulum. There are apparently 6 precingular paraplates and a small sulcal flap. The truncated apex of the apical horn may indicate a preapical paraplate. A gonyaulacoid tabulation pattern is possible.

The general folding of these cysts and the limited material makes it difficult to determine whether or not the delicate thickenings of the periphragm at the paracingulum extend into the surface to form further parasutures.

Remarks: These cysts differ from most of the species belonging to the genus *Senoniasphaera* by not having structural elements between peri- and endophragm. But the general morphology and the shape of the archaeopyle are very similar to *Senoniasphaera*. *Hexagonifera jurassica* Gitmez & Sarjeant, 1972, which has been transferred to *Senoniasphaera* by Lentin & Williams (1976) and to *Ambonosphaera* by Fenton (1979), is closely related to the present species and occurs in the same sediments. *Senoniasphaera janei* sp. nov. appears to be morphologically intermediate between *H. jurassica* and the species of

Senoniasphaera and may therefore support the transfer of *H. jurassica* to *Senoniasphaera*. *Senoniasphaera janei* differs from *S. jurassica* (Gitmez & Sarjeant) Lentin & Williams, 1976 in the well developed apical horn, which is formed both by the endo- and periphragm, and in the zigzag shaped archaeopyle margin.

Occurrence: *S. janei* is reported only from East Greenland

Dimensions: 8 specimens were measured; two of these had lost the operculum. The total length of the cysts varies from 85 to 124 μm , average 104 μm . The width varies from 54 to 67 μm , average 61 μm . The length of the apical horn is difficult to define on these specimens and therefore has not been measured.

Holotype: Pl. *, Fig. *. The length of the pericyst is 112 μm and the width is 67 μm . The length of the endocyst is 85 μm and the breadth is 65 μm .

Type locality and type stratum: Krebsedal on Milne land; Krebsedal Member, from the lower boundary to 25 m above the lower boundary.

Age: *S. janei* sp. nov. range from the Wheatlyensis Zone to the Anguinus Zone. The age is Early Volgian to Middle Volgian.

Trichodinium surlyki sp. nov.

Pl. 24, Figs 10-12

Trichodinium cf. *T. ciliatum*; Fensome 1979, Pl. 6, Figs 9,12; Pl. 7, Fig. 2

Diagnosis: Broad ovoidal, proximate cysts characterised by a densely foveolate surface, covered by regularly distributed short, conical to slender, pointed spines. An apical horn is formed by a tuft of spines or by coalesced longer spines. Plate equivalent structures are only indicated by the preangular archaeopyle of type P.

Derivation of name: Named after Dr. Prof. Finn Surlyk, University of Copenhagen, who has worked with the Jurassic of East Greenland since 1968, and who has been "the driving force" behind much of the geological work done in East Greenland especially in the 1980's and 1990's.

Description: Broad, ovoidal dinoflagellate cysts having rounded antapex and rounded to slightly pointed apex. An apical horn may be formed by the extension and coalescence of the apical spines. The occurrence and length of the apical horn vary.

The *archaeopyle* is rounded trapezoid, and the position of one side along the equatorial line of the cyst combined with the shape of the archaeopyle indicate equivalence to the third precingular paraplate. The archaeopyle is type P.

The *autophragm*, which is the only layer in the wall, is approximately 1 μm thick. The surface of the wall is densely foveolate, in some cases spongy to fibrous. The surface is covered by short spines, which are conical or simple. The broad base of the spines may be hollow or penetrated, and the spines are pointed distally. The distribution of the spines on the surface is very uniform and regular.

Paratabulation is not indicated by structure or sculpture.

Remarks: This species differs from *T. ciliatum* (Gocht) Davey, 1974 by the presence of a well developed apical horn and by the larger dimensions. *T. castanea* (Deflandre) Clarke & Verdie, 1967 and *T. speetonensis* Davey, 1974 differ from this species by structural indications of paratabulation. The genus *Trichodinium* is primarily known from the Early Cretaceous, but Fensome (1979) indicated two specimens from the Late Kimmeridgian - Early Portlandian of Jameson Land, East Greenland, and Vozzhennikova (1967) described *T. castanea* from the Jurassic in Siberia. *T. surlyki* occurs in the lower part of the Subcrassum Zone of Northern Siberia, which is equivalent to the Wheatleyensis Zone (pers. obs.). *Circulodinium* sp. 2 (pl. 20, Figs 6-8) in this report has wall structure and surface sculpture similar to *T. surlyki* but has an apical archaeopyle. Both species occur in Lower Volgian strata and folded or crushed specimens may be easy to recognise but difficult identify with certainty.

Occurrence: *T. surlyki* is reported previously only from East Greenland (Fensome, 1979).

Dimensions: 9 specimens were measured. The length of the cysts varies from 77 to 110 μm , average 97 μm . The width of the cysts varies from 60 to 90 μm , average 82 μm . The

length of the apical horn is up to 10 μm , and the length of the spines is from 2 to 5 μm , average 3 μm .

Holotype: Pl. *, Fig. *. The length of the cyst is * μm , including a * μm long apical horn. The width of the cyst is * μm . The spines are * μm long.

Type locality and type stratum:

Age: The range of *Trichodinium surlyki* is equivalent to the upper Elegans/"Scitulus", Wheatlyensis and possibly lower Huddlestoni . The age is Early Volgian.

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Enclosure 1

FOSSIL RANGE CHART

KOSMOCERAS DAL

TOP OF CHART: 360.00m

SCALE : 1: 500

CLIENT :

PREP. BY:

DATE : 03/04/97

ANALYSTS: 09 1994 SP 10 07

COMMENT: KOSMOCERASDAL MEMBER



- S.I.S 3.0 -

LEGEND :

FOSSIL OCCURRENCE:

DCS SMC CCD SUS BAR

□	△	◇	○		rare
▣	▲	◆	◊	■	common
▤	▲	◆	◊	■	abundant
▥	▲	◆	◊	■	dominant

R reworked
 C caved or contamination
 ? uncertain identification

GY	grey	LY	light gr.
DY	dark gr.	GN	green
LN	light gr.	DN	dark gr.
BK	black	RD	red
DD	dark red	BW	brown
LW	light br.	DW	dark br.
WE	white	OE	orange
PK	pink		
P	pyrite		
G	glauconite		
M	mica		
K	kaolin		
S	siderite		
D	dolomite/ancerite		
A	additives		
O	other (see text)		



Claystone
 Shale
 Mudstone
 Siltstone
 Sandstone, very fine
 Sandstone, fine
 Sandstone, medium
 Sandstone, coarse
 Pebbles/Congl.
 Limest./Chalk
 Dolom./Ancerite
 Marl
 Gypsum/Anhydr.
 Salt
 Tuff/Volcanics
 Coal
 Basement
 Additives
 Ditch Cuttings (DCS)
 Sidewall cores (SMC)
 Convention cores (CCD)
 Surface samples (SUS)

LOCALITY DATA

Locality : KOSMOCERAS DAL
 Operator : SP
 Rig :
 Coordin. :
 Client :
 Status :
 Confide. :
 Started :
 Ended :

Ref horizon :
 Datum adjust: 0
 Water depth : 0
 Direction : ASCENDING
 Top/TD : 360.00- 185.00
 Top sample : 360.00
 Base sample : 185.00
 Samples : 34
 Lithology : 29
 Palynology : 15
 Mikropaleont: 0
 Nannoplankt : 0
 Makrofossils: 0
 Other foss. : 0
 Kerogen : 0

Comments:

PLOTTING DATE: 03/04/97

- 77 *Acanthaulax granulifera*
 68 *Adnetosphaeridium* spp.
 63 *Ambonosphaera calloviense*
 40 *Atopodinium* cf. *haromense*
 25 *Atopodinium* spp.
 41 *Barbatocysta baculata*
 62 *Barbatocysta creberbarbata* (ERKHAN & SARJEANT) COURTINAT, 1989
 35 *Barbatocysta verrucosa*
 47 *Chlamydotheca ectotabulata* str. STRATLAB (internal species)
 65 *Chytroisphaeridia cerastes*
 43 *Chytroisphaeridia chytroscoides*
 39 *Chytroisphaeridia grossa* Smelror
 14 *Compositosphaeridi polonicum*
 33 *Ctenidodinium continuum*
 80 *Dingodinium jurassicum*
 2 *Dissilidinium giganteum* Feist-Buchart
 49 *Dissilidinium hocneratum* (FENTON & al.) LENTIN & WILLIAMS, 1
 8 *Durotrigia* aff. *deveyi*
 82 *Durotrigia deveyi* BAILEY, 1987
 44 *Endoscrinium geleritum*
 69 *Endoscrinium luridum*
 81 *Epilophaena bireticulata* KLEMENT, 1980
 21 *Escharisphaeria laevigata* Smelror 1990
 27 *Escharisphaeridia pocockii*
 32 *Escharisphaeridia* spp.
 59 *Evansia evittii*
 1 *Fromea tornalis*
 20 *Gonyaulacysta* cf. *helicoides*
 34 *Gonyaulacysta eisenschkii*
 19 *Gonyaulacysta jurassica*
 3 *Gonyaulacysta pectinifera*
 23 *Hystriochodinium* spp.
 75 *Kalyptea dicerae*
 65 *Leptodinium mirabile*
 67 *Leptodinium subtile*
 26 *Liesbergia scarburghensis*
 24 *Lithodinia jurassica*
 31 *Mendicodinium "granulatum"* Milner
 11 *Mendicodinium groenlandicum*
 13 *Nannoceratopsis pellucida*
 10 *Parasvensia brachytheta*
 54 *Paroedinia "granulata"* Piasecki
 52 *Paroedinia "reticulata"* Piasecki
 15 *Paroedinia ceratophora*
 5 *Paroedinia groenlandicum*
 29 *Paroedinia halosa* (FILATOFF) LENTIN & WILLIAMS, 1981
 74 *Paroedinia osmingtonense*
 8 *Paroedinia prolongata*
 78 *Paroedinia scopaeus*
 70 *Paroedinia* spp.
 28 *Paroedinia stegasta*
 50 *Plurilavium osmingtonense* SARJEANT, 1962
 73 *Prolixosphaeridium granulosa*
 60 *Protobeticolodinium* spp.
 17 *Rhynchodiniopsis cladophora*
 55 *Rigaudella acmula*
 53 *Rigaudella filamentosa*
 51 *Rigaudella paucispina*
 4 *SENTUSIDINIUM* SP. O FENSOME FENSOME, 1980
 61 *Scriniodinium crystallinum*
 72 *Scriniodinium inritibulum*
 56 *Sentusidinium* cf. *erythrocomum*
 18 *Sentusidinium pelionense* Fensome 1980
 7 *Sentusidinium rioulti*
 22 *Sentusidinium sparsibarbatum*
 12 *Sentusidinium villerense*
 46 *Sirmiodinium* aff. *grossii*
 16 *Sirmiodinium grossii*
 79 *Stephanelytron redcliffense*
 64 *Stephanelytron scarburghense*
 45 *Surculosphaeridium* spp.
 57 *Surculosphaeridium vestitum*
 71 *Systemetophora penicillata*
 58 *Taeniophora* cf. *unctispina*
 76 *Taeniophora* spp.
 38 *Tubotuberella apetele*
 9 *Tubotuberella dmngardii*
 30 *Valensella dictydia*
 37 *Varyhachium* spp.
 36 *Wanea digitata*
 48 *Wanea fimbriata*
 42 *Wanea thysanota*

Enclosure 2

FOSSIL RANGE CHART

GRAAKLOEFT

TOP OF CHART: 295.00m

SCALE : 1: 500

CLIENT :

PREP. BY:

DATE : 03/04/97

ANALYSTS: 10 1994 SP 09

COMMENT: BAYS ELV/GRAAKLOEFT



- S.I.S 3.0 -

LEGEND :

FOSSIL OCCURRENCE:

DCS	SMC	CCO	SUS	BAR	
□	△	◇	○		rare
▣	▲	◆	◉	■	common
▤	▴	◇	◉	■	abundant
▥	▴	◇	◉	■	dominant

R reworked
C caved or contamination
? uncertain identification

GY grey	LY light gr.
DY dark gr.	GN green
LN light gr.	DN dark gr.
BK black	RD red
DD dark red	BW brown
LW light br.	DW dark br.
WE white	OE orange
PK pink	
P pyrite	
G glauconite	
M mica	
K kaolin	
S siderite	
D dolomite/ancerite	
A additives	
O other (see text)	

	Claystone
	Shale
	Mudstone
	Siltstone
	Sandstone, very fine
	Sandstone, fine
	Sandstone, medium
	Sandstone, coarse
	Pebbles/Congl.
	Limest./Chalk
	Dolom./Ancerite
	Marl
	Gypsum/Anhydr.
	Salt
	Tuff/Volcanics
	Coal
	Basement
	Additives
	Ditch Cuttings (DCS)
	Sidewall cores (SWC)
	Convention cores (CCO)
	Surface samples (SUS)

LOCALITY DATA

Locality : GRAAKLOEFT
Operator : SP
Rig :
Coordin. :
Client :
Status :
Confide. :
Started :
Ended :

Ref horizon :
Datum adjust: 0
Water depth : 0
Direction : ASCENDING
Top/TD : 600.00- 70.00
Top sample : 295.00
Base sample : 70.00
Samples : 43
Lithology : 43
Palynology : 25
Mikropaleont: 0
Nannoplankt : 0
Makrofossils: 0
Other foss. : 0
Kerogen : 0

Comments:

PLOTTING DATE: 03/04/97

44	<i>Acanthaulax granuligera</i>	
56	<i>Acanthaulax granuligera</i>	
14	<i>Ambonosphaera calloviense</i>	
87	<i>Apteodinium "reticulatum"</i>	
83	<i>Apteodinium nuciforme</i>	
108	<i>Apteodinium</i> spp.	
38	<i>Atopodinium</i> cf. <i>harowense</i>	
27	<i>Atopodinium</i> spp.	
72	<i>Avellodinium</i> spp.	
70	<i>Chlaesydophorella</i> 2 <i>Piasecki</i>	<i>Piasecki</i>
120	<i>Chlaesydophorella</i> spp.	
122	<i>Chlaesydophorella</i> spp.	
78	<i>Chytroisphaeridia chytrocoidea</i>	
54	<i>Circulodinium distinctum</i>	
130	<i>Circulodinium downiei</i>	
124	<i>Cleistosphaeridium</i> 1 <i>Piasecki</i>	<i>Piasecki</i>
71	<i>Cleistosphaeridium</i> 2 <i>Piasecki</i>	<i>Piasecki</i>
96	<i>Cribroperidinium</i> cf. <i>perforans</i>	
138	<i>Ctenidodinium continuum</i>	
115	<i>Ctenidodinium panneum</i>	
85	<i>Cyclopsiella</i> 2 <i>Piasecki</i>	<i>Piasecki</i>
62	<i>Cyclopsiella</i> spp.	
88	<i>Cyclopsiella</i> spp.	
135	<i>Dichadogonyaulax</i> cf. <i>irregularis</i>	
2	<i>Dingodinium jurassicum</i>	
57	<i>Dingodinium tuberosum</i>	
415	<i>Egmontodinium polyplochophorum</i>	
113	<i>Ellipsodictyum</i> spp.	
39	<i>Endoscrinium luridum</i>	
29	<i>Endoscrinium luridum</i> s.l.	
80	<i>Episphaera areolata</i>	
17	<i>Episphaera bireticulata</i>	KLEMENT, 1960
137	<i>Episphaera</i> cf. <i>gochtzi</i>	
65	<i>Episphaera</i> spp.	
3	<i>Escherisphaeria laevigata</i>	Šmejral 1990
53	<i>Escherisphaeria pocockii</i>	
6	<i>E. jurassica sphaerica</i>	<i>Piasecki</i>
121	<i>E. mutab</i> var. <i>Piasecki</i>	<i>Piasecki</i>
63	<i>Geiselodinium</i> spp.	
9	<i>Glossodinium dimorphum</i>	
126	<i>Gochteodinia</i> cf. <i>mutabilis</i>	
126	<i>Gochteodinia mutabilis</i>	
105	<i>Gochteodinium antennata</i>	
86	<i>Gonyaulacysta</i> cf. <i>helicoides</i>	
40	<i>Gonyaulacysta dualis</i>	
5	<i>Gonyaulacysta helicoides</i>	
12	<i>Gonyaulacysta jurassica</i>	
116	<i>Healertonia</i> spp.	
31	<i>Hyatrachodinium</i> spp.	
42	<i>Hyatrachosphaeridium patulum</i>	
151	<i>Hyatrachosporites</i> spp. <i>Piasecki</i>	<i>Piasecki</i>
101	<i>Kalyptea diceras</i>	
136	<i>Kalyptea</i> spp.	
90	<i>Kleithrisphaeridium teleosporium</i>	
75	<i>Leiosphaeridia</i> spp.	
99	<i>Leiosphaeridia</i> spp.	
102	<i>Leptodinium scruatum</i>	
123	<i>Leptodinium antigonium</i>	
111	<i>Leptodinium</i> cf. <i>subtile</i>	
81	<i>Leptodinium freakii</i>	
73	<i>Leptodinium semilifera</i>	
143	<i>Leptodinium milliodii</i>	
110	<i>Leptodinium</i> spp.	
16	<i>Leptodinium subtile</i>	
140	<i>Liesbergia scarburghensis</i>	
117	<i>Lithodinia</i> spp.	
150	<i>Lycospora isoperialis</i>	Jansonius
147	<i>Maculatasporites</i> spp.	
1	<i>Mendicodinium "granulatum"</i>	Milner
92	<i>Mendicodinium groenlandicum</i>	
104	<i>Mendicodinium</i> spp.	
69	<i>Michryatridium</i> 1 <i>Piasecki</i>	<i>Piasecki</i>
106	<i>Occisucycta</i> cf. <i>tentoria</i>	
49	<i>Occisucycta</i> spp.	
82	<i>Oligosphaeridium</i> aff. <i>pulcherrimum</i>	
107	<i>Oligosphaeridium pulcherrimum</i>	
84	<i>Oligosphaeridium</i> spp.	
35	<i>Pandodinium saturnalis</i>	
141	<i>Paraeovansia brachythelis</i>	
60	<i>Paragonyaulacysta capillosa</i>	
41	<i>Parodinia "granulata"</i>	<i>Piasecki</i>
43	<i>Parodinia borealis</i>	
59	<i>Parodinia caratophora</i>	
98	<i>Parodinia</i> cf. <i>prolongata</i>	
33	<i>Parodinia</i> cf. <i>verrucosa</i>	
48	<i>Parodinia groenlandicum</i>	
24	<i>Parodinia halosa</i>	(FILATOFF) LENTIN & WILLIAMS, 1981
77	<i>Parodinia nuda</i>	
36	<i>Parodinia prolongata</i>	
22	<i>Parodinia scopaeus</i>	
94	<i>Parodinia</i> spp.	
57	<i>Parodinia stegasta</i>	
129	<i>Perisseiasphaeridium inaeclitum</i>	
64	<i>Perisseiasphaeridium pennosum</i>	
21	<i>Plurivervalium osmingtonense</i>	SARJEANT, 1962
18	<i>Prolixosphaeridium granulatum</i>	
46	<i>Protobatuladinium</i> spp.	
93	<i>Pteropermella</i> spp.	
74	<i>Pyxidiniopsis granulata</i>	
7	<i>Rhynchodiniopsis cladophora</i>	
119	<i>Rhynchodiniopsis machaera</i>	
65	<i>Rhynchodiniopsis pennata</i>	
30	<i>Rhynchodiniopsis</i> spp.	
134	<i>Retosphaeropsis thula</i>	
133	<i>S. galeritum fornicatum</i>	
114	<i>S. grossi</i> var. <i>Piasecki</i>	<i>Piasecki</i>
95	<i>S. luridum</i> var. <i>Piasecki</i>	<i>Piasecki</i>
34	<i>Scriniodinium</i> cf. <i>oxfordianum</i>	
15	<i>Scriniodinium crystallinum</i>	
25	<i>Scriniodinium inritabile</i>	

32	Scriniodinium irregulare	
142	Scriniodinium oxfordianum	
148	Scutisporites spp.	
125	Senoniasphaera "jensei"	Pisasecki
132	Senoniasphaera jurassica	
118	Sentusidinium cf. riouliti	
50	Sentusidinium cf. sparsibarbatum	
19	Sentusidinium pelionense	Fensholt 1980
28	Sentusidinium riouliti	
76	Sentusidinium sp D FENSOLT	FENSOLT, 1980
98	Sentusidinium sparsibarbatum	
79	Sentusidinium spp.	
144	Siraoidiniopsis orbis	
20	Siraoidinium grossii	
51	Siraoidinium spp.	
10	Stephanelytron redcliffense	
85	Stephanelytron scorburchense	
61	Systematophora areolata	
8	Systematophora penicillata	
47	Systematophora valensii	
149	Taeniasporites novieulensis	
146	Taeniasporites spp.	
29	Taeniophora cf. iunctispina	Pisasecki
37	Taeniophora hartzi	
67	Taeniophora iunctispina	KLEMENT, 1960
139	Taeniophora spp.	
91	Taenianites spp.	
103	Taenianites spp.	
109	Trichodinium cf. ciliatum	
127	Trichodinium surlyki	Pisasecki
131	Tubotuberella "sphaerocephala"	Vozzhannikova/Pisasecki
11	Tubotuberella spatula	
13	Tubotuberella spemni	
4	Valensiella dictydia	
112	Valensiella spp.	
68	Veryhachium cf. sortehatense	
100	Veryhachium sortehatense	
26	Veryhachium spp.	
89	Veryhachium 2 Pisasecki	Pisasecki
52	Veryhachium 3 Pisasecki	Pisasecki
145	Vittatina spp.	

-GGU-

SHEET: 2
SCALE: 1: 500

UPPER ORFORDIAN		KIMBERLIAN		KIMBERLIAN		LOWER VOLCANIC		SYSTEM	
ALDHUKE ELY MBR	CHADOCENSIAN MBR	CHADOCENSIAN MBR	CHADOCENSIAN MBR	GRAAKLOEFT MBR	GRAAKLOEFT MBR	GRAAKLOEFT MBR	GRAAKLOEFT MBR	STAGE	MEMBER
GLSEN./FESOL. ZONE	BOSSAK. ZONE	BAVLEY. ZONE	GLSEN./FESOL. ZONE	BOSSAK. ZONE	BAVLEY. ZONE	GLSEN./FESOL. ZONE	BOSSAK. ZONE	ZONE	MEMBER
75	100	125	150	175	200	225	250	DEPTH	LITHOLOGY
245830	245827	245826	245824	245824	245824	245824	245824	275	234121
245827	245826	245824	245824	245824	245824	245824	245824	234123	234127
245824	245824	245824	245824	245824	245824	245824	245824	234119	234115
245824	245824	245824	245824	245824	245824	245824	245824	234115	234111
245824	245824	245824	245824	245824	245824	245824	245824	234106	234102
245824	245824	245824	245824	245824	245824	245824	245824	234101	245896
245824	245824	245824	245824	245824	245824	245824	245824	245889	245884
245824	245824	245824	245824	245824	245824	245824	245824	245881	245867
245824	245824	245824	245824	245824	245824	245824	245824	245862	245860
245824	245824	245824	245824	245824	245824	245824	245824	245876	245874
245824	245824	245824	245824	245824	245824	245824	245824	245873	245869
245824	245824	245824	245824	245824	245824	245824	245824	245840	245830

SAMPLES
1 <i>Hemitelia "granulata"</i>
2 <i>Dipodolum jurassicum</i>
3 <i>Exochopora turrita</i>
4 <i>Palaeolitea dicycla</i>
5 <i>Goniatites halictoides</i>
6 <i>Jurva spinosa</i>
7 <i>Rhynchonella ciliophora</i>
8 <i>Systemophora penicillata</i>
9 <i>Glossidium distichum</i>
10 <i>Strophomena rectifrons</i>
11 <i>Tuberculata sp.</i>
12 <i>Rhynchonella jurassica</i>
13 <i>Tuberculata sp.</i>
14 <i>Atrypa ciliata</i>
15 <i>Scrinidium crystallinum</i>
16 <i>Leptodonta subtile</i>
17 <i>Epilasma birticula</i>
18 <i>Protrichopora granulosum</i>
19 <i>Scrinidium molle</i>
20 <i>Strophomena sp.</i>
21 <i>Plectambonites ocellatus</i>
22 <i>Rhynchonella spinosa</i>
23 <i>Trematophora cf. lucifera</i>
24 <i>Rhynchonella sp.</i>
25 <i>Scrinidium irritabile</i>
26 <i>Rhynchonella sp.</i>
27 <i>Strophomena sp.</i>
28 <i>Scrinidium foudii</i>
29 <i>Strophomena turrita s.l.</i>
30 <i>Rhynchonella sp.</i>
31 <i>Hemitelia sp.</i>
32 <i>Scrinidium irregularis</i>
33 <i>Rhynchonella cf. verrucosa</i>
34 <i>Scrinidium cf. arcaforme</i>
35 <i>Rhynchonella elongata</i>
36 <i>Rhynchonella sp.</i>
37 <i>Trematophora sp.</i>
38 <i>Strophomena cf. hirsuta</i>
39 <i>Strophomena sp.</i>
40 <i>Strophomena sp.</i>
41 <i>Rhynchonella sp.</i>
42 <i>Hemitelia "granulata"</i>
43 <i>Rhynchonella sp.</i>
44 <i>Atrypa sp.</i>
45 <i>Strophomena polychaeta</i>
46 <i>Protrichopora sp.</i>
47 <i>Systemophora velinae</i>
48 <i>Rhynchonella granulosum</i>
49 <i>Ocellularia sp.</i>
50 <i>Scrinidium cf. sparsibarbatum</i>
51 <i>Rhynchonella sp.</i>
52 <i>Rhynchonella sp.</i>
53 <i>Exochopora sp.</i>
54 <i>Crinidium distinctum</i>
55 <i>Strophomena scaberrima</i>
56 <i>Atrypa sp.</i>
57 <i>Rhynchonella sp.</i>
58 <i>Scrinidium sparsibarbatum</i>
59 <i>Rhynchonella sp.</i>
60 <i>Strophomena sp.</i>
61 <i>Systemophora sp.</i>
62 <i>Crinidium sp.</i>
63 <i>Strophomena sp.</i>
64 <i>Rhynchonella sp.</i>
65 <i>Rhynchonella sp.</i>
66 <i>Strophomena sp.</i>

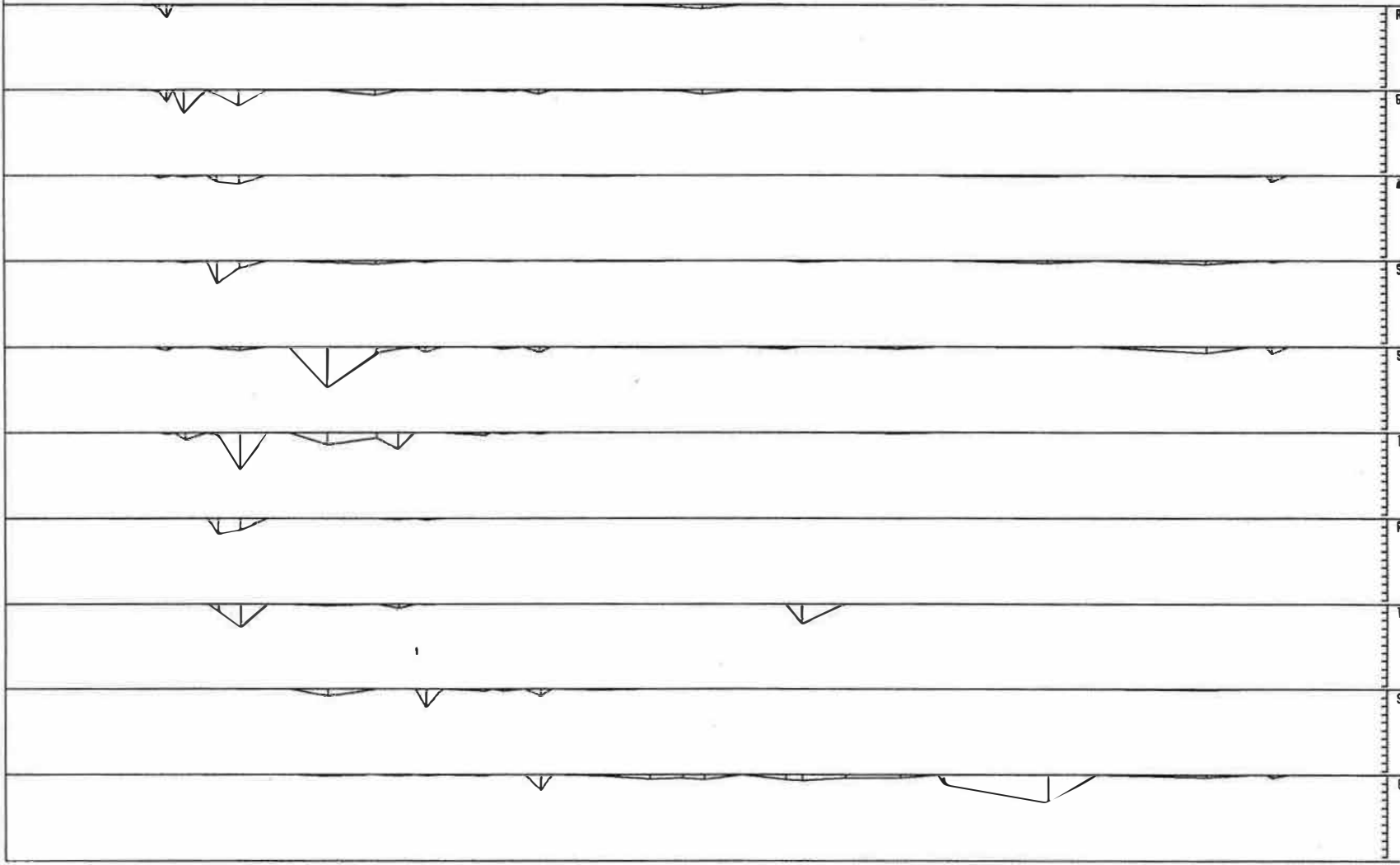
Enclosure 2
 SHEET: 7
 SCALE: 1: 500
 GRAAKLOEFT (295 - 70m)

UPPER OXFORDIAN		KIMMERIDGIAN			KIMMERIDGIAN		LOWER VOLGIAN		SYSTEM
ALDINGER ELY. MBR.	BAYS ELY. MEMBER	CARDIOCERASIAL MEMBER	GRAAKLOEFT MEMBER			GRAAKLOEFT MEMBER	KIERSDAL MEMBER	STAGE	
GLOSEN / REGUL. ZONE	ROSENAU ZONE	BAVLEY ZONE	CYNODICE ZONE	MUTABRILLIS ZONE	ELDDIOS ZONE	AUTISSIODRENSIS ZONE	ELEGANS ZONE	WHEATLYENSIS ZONE	ZONE
75	100	125	150	175	200	225	250	275	DEPTH



REF.:
 DATUM 0

SAMPLES
 COUNTED ABUNDANCE



Enclosure 3

FOSSIL RANGE CHART

KRABBERYGGEN

TOP OF CHART: 320.00m

SCALE : 1: 500

CLIENT :

PREP. BY:

DATE : 03/04/97

ANALYSTS: 10 1994 SP 1992 11

COMMENT:



-S.I.S 3.0-

LEGEND :

FOSSIL OCCURRENCE:
DCS SMC CCD SUS BAR

□	△	◇	○		rare
▣	▲	◆	◊	■	common
▤	▴	▥	◈	■	abundant
▦	▸	▧	◉	■	dominant

R reworked
C caved or contamination
? uncertain identification

GY grey	LY light gr.
DY dark gr.	GN green
LN light gr.	DN dark gr.
BK black	RD red
DD dark red	BW brown
LW light br.	DW dark br.
WE white	OE orange
PK pink	
P pyrite	
G glauconite	
M mica	
K kaolin	
S siderite	
D dolomite/ancerite	
A additives	
O other (see text)	



Claystone
Shale
Mudstone
Siltstone
Sandstone, very fine
Sandstone, fine
Sandstone, medium
Sandstone, coarse
Pebbles/Congl.
Limest./Chalk
Dolom./Ancerite
Marl
Gypsum/Anhydr.
Salt
Tuff/Volcanics
Coal
Basement
Additives
Ditch Cuttings (DCS)
Sidewall cores (SMC)
Convention. cores (CCD)
Surface samples (SUS)

LOCALITY DATA

Locality : KRABBERYGGEN
Operator : SP
Rig :
Coordin. :
Client :
Status :
Confide. :
Started :
Ended :

Ref horizon :
Datum adjust: 0
Water depth : 0
Direction : ASCENDING
Top/TD : 310.00- 100.00
Top sample : 320.00
Base sample : 90.00
Samples : 35
Lithology : 31
Palynology : 12
Mikropaleont: 0
Nannoplankt : 0
Makrofossils: 0
Other foss. : 0
Kerogen : 0

Comments:

PLOTTING DATE: 03/04/97

- 38 Acanthaulax granulata
- 43 Acanthaulax granuligera
- 7 Ambonosphaera calloviense
- 17 Atopodinium cf. haromense
- 28 Atopodinium spp.
- 30 Avellodinium cf. falsificum
- 76 Avellodinium culmulum
- 9 Chlamydomorphella 2 Piasecki Piasecki
- 67 Chlamydomorphella spp.
- 52 Circulodinium cf. compta
- 33 Circulodinium distinctum
- 20 Circulodinium downiei
- 45 Cosmophaeridium capillatum
- 74 Cribroperidinium a devey DAVEY, 1982
- 70 Cribroperidinium cf. longicornis
- 51 Cribroperidinium cf. perforans
- 31 Cribroperidinium perforans
- 8 Cribroperidinium spp.
- 6 D. sp. A Ioannides et al.
- 102 Densicoprites spp.
- 91 Dichodogonyaulax pannea
- 75 Dichodogonyaulax spp.
- 5 Dingodinium minutum
- 77 Dingodinium spinosum
- 40 Dingodinium spp.
- 63 Egmontodinium expiretum
- 32 Egmontodinium polyplachophorum
- 69 Endoscrinium galeritum
- 3 Epipiosphaera bireticulata KLEMENT, 1960
- 62 Escherisphaeria laevigata Smolror 1990
- 11 Escherisphaeridia pocockii
- 104 Fungal hyphae
- 64 Gloeodinium disorphum
- 23 Gochtheadinia mutabilis
- 35 Gonyaulacysta dualis
- 97 Gonyaulacysta pectinifera
- 68 Healertonia spp.
- 1 Hystrichodinium 1 Piasecki
- 84 Hystrichodinium cf. pulchrum
- 54 Hystrichosphaeridium petilum
- 66 Kleithrisphaeridium cf. corrugatum
- 90 Kleithrisphaeridium porosipinum
- 18 Kleithrisphaeridium telepinosum
- 72 Lecaniella spp.
- 15 Leiosphaeridia spp.
- 42 Leptodinium antigonium
- 21 Leptodinium subtile
- 93 Liesbergia scarburghensis
- 92 Lithodinia spp.
- 61 Mendicodinium "granulatum" Milner
- 39 Mendicodinium groenlandicum
- 82 Michrystridium 1 Piasecki Piasecki
- 86 Muderongia a devey 1979 DAVEY, 1979
- 95 Nannoceratopsis pellucida
- 94 Nannoceratopsis spp.
- 46 Occisucycta "arcua"
- 44 Occisucycta cf. tentoria
- 65 Oligosphaeridium aff. pulcherrimum
- 19 Oligosphaeridium pulcherrimum
- 29 Paragonyaulacysta capillosa
- 10 Pareodinia "granulata" Piasecki
- 22 Pareodinia borealis (FILATOFF) LENTIN & WILLIAMS, 1961
- 24 Pareodinia halosa
- 47 Pareodinia scopaeus
- 78 Pareodinia spp.
- 60 Perissisphaeridium danneum
- 79 Perissisphaeridium spp.
- 48 Prolixosphaeridium granulatum
- 60 Protobatioladinium imbatodiniense
- 49 Protobatioladinium spp.
- 103 Protohaploxypinus spp.
- 41 Pyxidiniopsis granulata
- 16 Rhynchodiniopsis cladophora
- 25 Rhynchodiniopsis machera
- 36 Rhynchodiniopsis pennata
- 87 Rotosphaeropsis thula
- 96 Scriniodinium crystallinum
- 63 Scriniodinium inritabile
- 99 Scutasporites spp.
- 27 Senoniasphaera "jamei" Piasecki
- 37 Senoniasphaera jurasica
- 58 Sentuoidinium pelionense Fensome 1980
- 34 Sirmiodinium grossii
- 2 Stephanelytron redcliffense
- 57 Surculosphaeridium spp.
- 89 Systematophora areolata
- 81 Systematophora orbifera
- 85 Systematophora palmula
- 73 Systematophora penicillata
- 4 Systematophora spp.
- 101 Taeniasporites spp.
- 53 Taeniphora junctispina KLEMENT, 1960
- 96 Teniosphaeridium spp.
- 88 Tenus hystrix Piasecki
- 12 Trichodinium surlyki
- 35 Tubotuberella apetela
- 13 Tubotuberella egemeni
- 50 Valensiella magna
- 26 Valensiella spp.
- 71 Valensiella spp.
- 14 Veryhachium spp.
- 59 Veryhachium 2 Piasecki Piasecki
- 100 Vittatina spp.
- 98 Wences-digitata



Plate 1

Figs 1-3. *Wanaea thysanota* Woollam, 1982. **Fig. 1:** (probably Lamberti ammonite zone), GGU 245 973, L191/8, LVR 1.4531, MI 3407. **Fig. 2:** Cordatum ammonite zone, GGU 245 980, L152/8, LVR 1.4747, MI 3607. **Fig. 3:** Athleta ammonite zone, GGU 245 964, L89/9, LVR 1.4682, MI 3545.

Figs 4-6. *Wanaea fimbriata* Sarjeant, 1961. **Fig. 4:** (probably Lamberti ammonite zone) GGU 245 974, L92/3, LVR 1.4588, MI 3456. **Figs 5-6:** (Lamberti / Mariae ammonite zones) GGU 245974, L92/8, LVR 1.4560-59, MI 3430. Magnification reduced approximately x 0.6 in Figs 4-5.

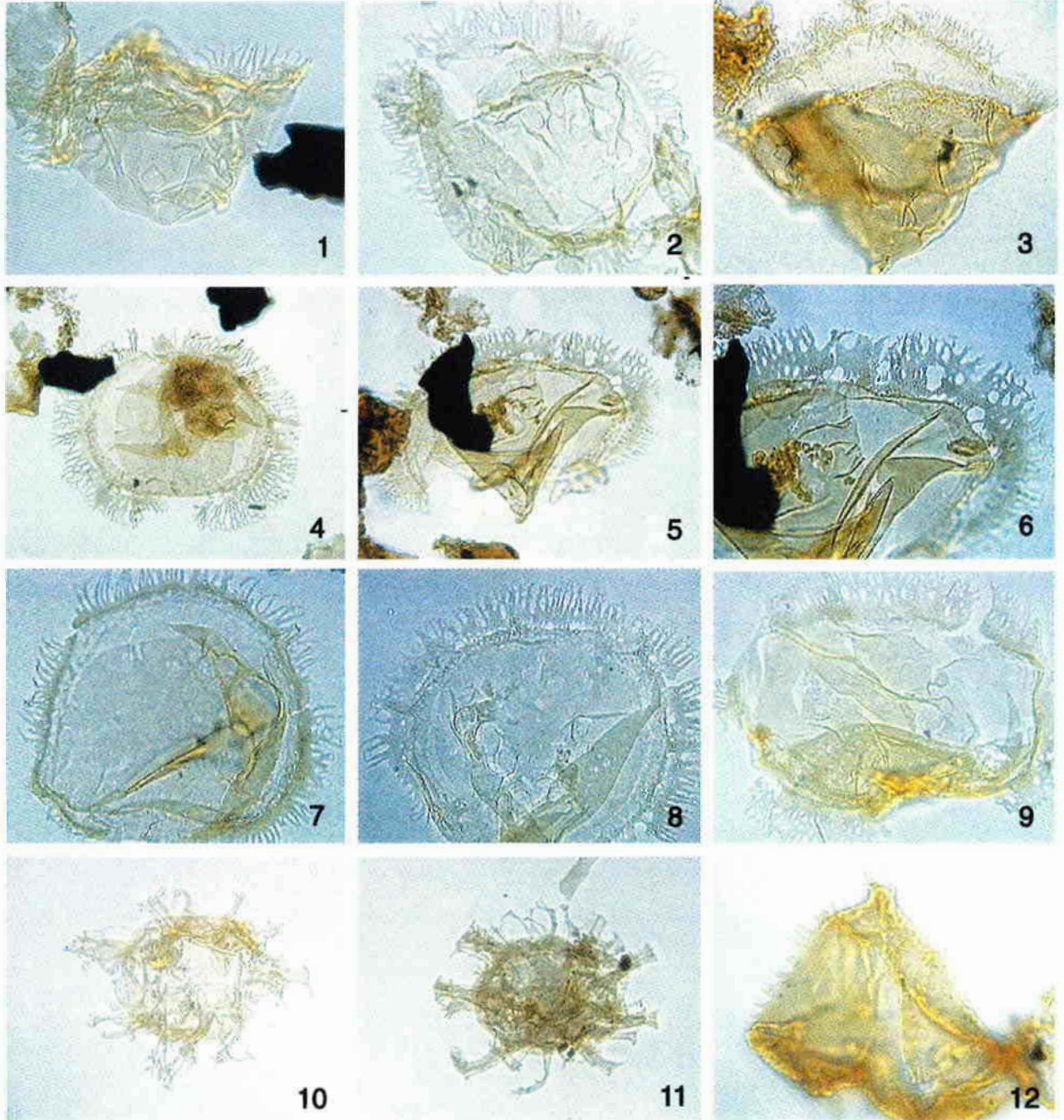
Fig. 7. *Wanaea digitata* Cookson & Eisenack, 1958; Cordatum ammonite zone, GGU 245 980, L152/7, LVR 1.4734, MI 3594.

Figs 8-9. *Wanaea thysanota?* Woollam, 1982, morphological transition to *W. digitata* and *W. fimbriata* respectively. **Fig. 8:** (probably Lamberti ammonite zone) GGU 245 973, L191, LVR 1.4546, MI 3420. **Fig. 9:** Cordatum ammonite zone, GGU 245 977, L193/8, LVR 1.4703, MI 3564.

Figs 10-11. *Compositosphaeridium polonicum* (Gorka, 1965) Erkmen & Sarjeant, 1980. **Fig. 10:** Tenuiserratum ammonite zone, GGU 234 159, K59/4, LVR 1.4909, MI 3752. **Fig. 11:** Densiplicatum ammonite zone, GGU 234 239, L135/4, LVR 1.4804, MI 3660.

Fig. 12. *Gonyaulacysta pectinigera* (Gocht, 1970) Fensome, 1979, (pre-Athleta ammonite zone?) GGU 245 953, K48/3, LVR 1.4418, MI 3316.

Callovian - Oxfordian Milne Land



20 μ m

Figs 1-2. *Scriniodinium crystallium* (Deflandre, 1938) Klement, 1960, Glosense ammonite zone. Fig. 1; GGU 234 168, L96/6, LVR 1.4929, MI 3772. Fig. 2; GGU 234 168, L96/3, LVR 1.4944, MI 3786.

Figs 3-4. *Scriniodinium inritibile* Fisher & Riley, 1980, Tenuiserratum ammonite zone. Fig. 3: GGU 234 159, K59/4, LVR 1.4913, MI 3756. Fig. 4: GGU 234 159, K59/4, LVR 1.4907, MI 3750.

Fig. 5. *Endoscrinium galeritium* (Deflandre, 1938) Vozzhennikova, 1967, Tenuiserratum ammonite zone, GGU 234 159, K59/7, LVR 1.4895, MI 3738.

Fig. 6. *Endoscrinium luridum* (Deflandre, 1938) Gocht, 1970, Tenuiserratum ammonite zone, GGU 234 155, K58/7, LVR 1.4850, MI 3703.

Figs 7-9. *Tubotuberella dangeardii* (Sarjeant, 1968) Stover & Evitt, 1978, Athleta ammonite zone. Fig. 7: GGU 245 964, L89/8, LVR 1.4510, MI 3389. Fig. 8: GGU 245 964, L89/8, LVR 1.4516, MI 3395. Fig. 9: GGU 245 964, L89/9, LVR 1.4686, MI 3549.

Fig. 10. *Tubotuberella apatela* (Cookson & Eisenack, 1960) Ioannides *et al.* 1977, (Lamberti / Mariae ammonite zones), GGU 245 974, L92/8, LVR 1.4575, MI 3444.

Fig. 11. *Goryaulacysta eisenackii* (Deflandre, 1938) Lentin & Williams, 1989, Athleta ammonite zone, GGU 245 964, L89/8, LVR 1.4513, MI 3392.

Fig. 12. *Dingodinium jurassicum* Cookson & Eisenack, 1958, Glosense ammonite zone, GGU 234 177, K64/10, LVR 1.4953, MI 3794.

Callovian - Oxfordian Milne Land

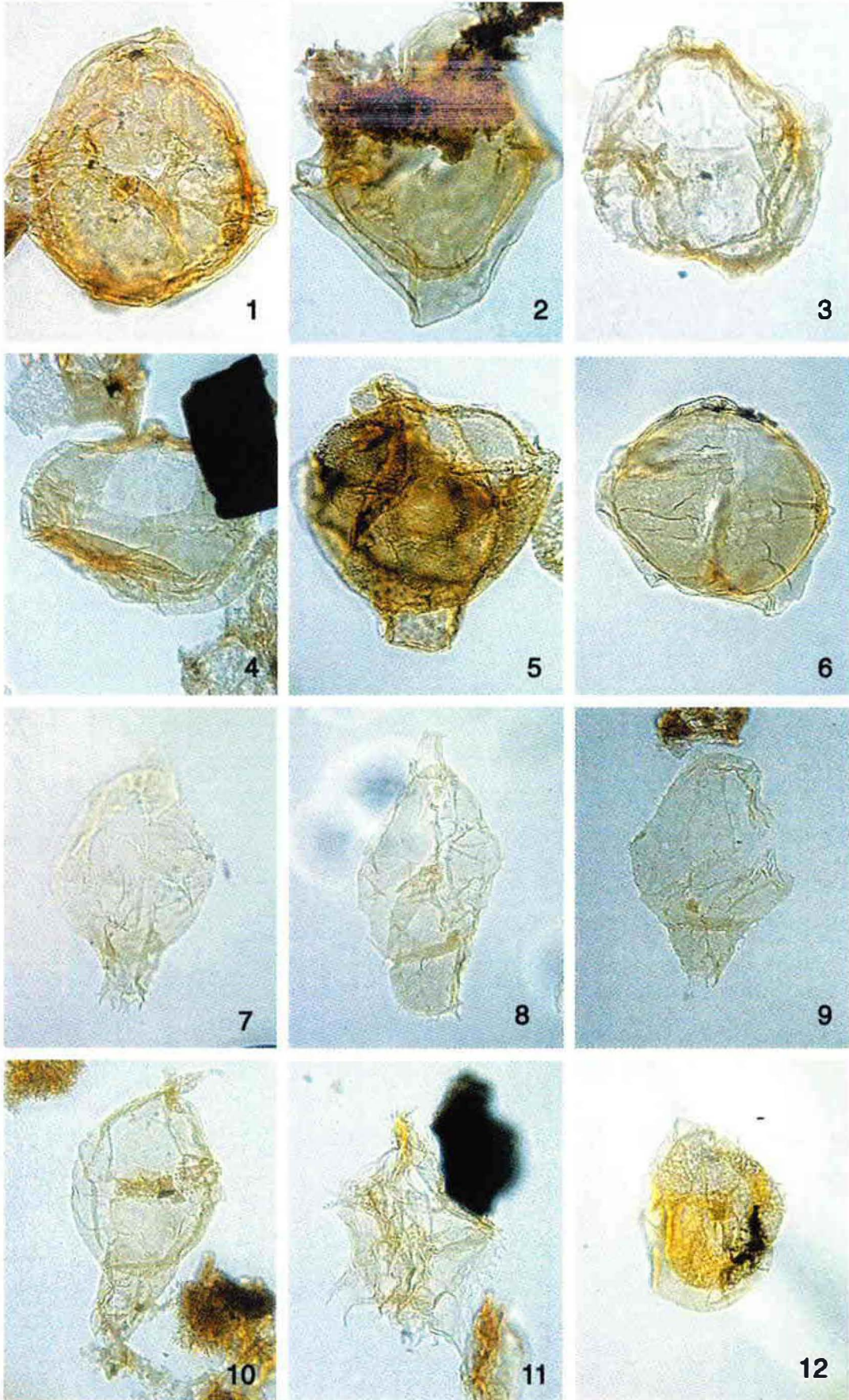


Plate 3

Figs 1-3. *Rigaudella aemula* (Deflandre, 1938) Below, 1982. **Fig. 1:** Cordatum ammonite zone, GGU 245 980, L152/9, LVR 1.4743, MI 3603. **Fig. 2:** Densiplicatum Zone, GGU 234 241, L113/3, LVR 1.4837, MI 3692. **Fig. 3:** Cordatum ammonite zone, GGU 245 977, L193/4, LVR 1.4724, MI 3585.

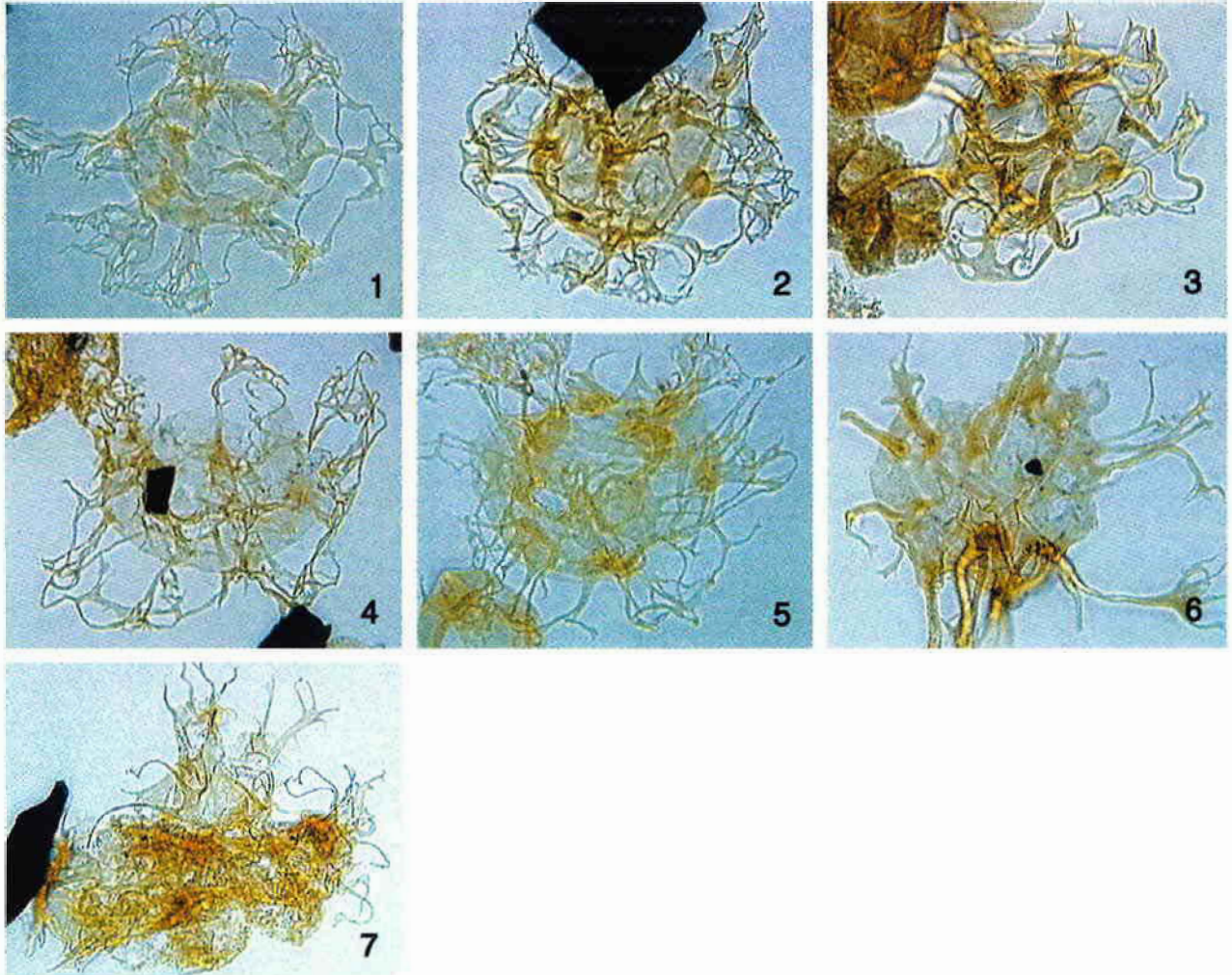
Fig. 4. *Rigaudella filamentosa* (Cookson & Eisenack 1958). Below, 1982, Cordatum ammonite zone, GGU 245 980, L152/4, LVR 1.4755, MI 3614.

Fig. 5. *Taeniophora iunctispina* Klement, 1960 emend. Sarjeant & Göcht, 1984, Cordatum ammonite zone, GGU 245 980, L152/7, LVR 1.4736, MI 3596.

Fig. 6. *Surculosphaeridium vestitum* (Deflandre, 1938) Davey *et al.*, 1966, Cordatum ammonite zone, GGU 245 980, L152/4, LVR 1.4764, MI 3623.

Fig. 7. *Systematophora "scapula"*, Glosense ammonite zone, GGU 234 177, K64, LVR 1.4978, MI 3819.

Callovian - Oxfordian Milne Land



20µm

Plate 4

Figs 1-2. *Rhyncodiniopsis cladophora* (Deflandre, 1938) Below, 1981. **Fig. 1:** Tenuiserratum ammonite zone, GGU 234 155, K58/7, LVR 1.4854, MI 3705. **Fig. 2:** Glosense ammonite zone, GGU 234 177, K64/6, LVR 1.4976, MI 3817.

Figs 4-5. *Liesbergia scarburghense* (Sarjeant, 1964) Berger, 1986. **Fig. 4:** probably Lamberti ammonite zone, GGU 245 973, L191/8, LVR 1.4533, MI 3408. **Fig. 5:** Athleta ammonite zone, GGU 245 969; L151/3, LVR 1.4526, MI 3403.

Figs 3 & 6. *Gonyaulacysta cf. helicoidea* (Eisenack & Cookson) Sarjeant, 1966, Glosense ammonite zone. **Fig. 3:** GGU 234 177, K64/6, LVR 1.4985, MI 3825. **Fig. 6:** GGU 234 177, K64/9, LVR 1.4964, MI 3805.

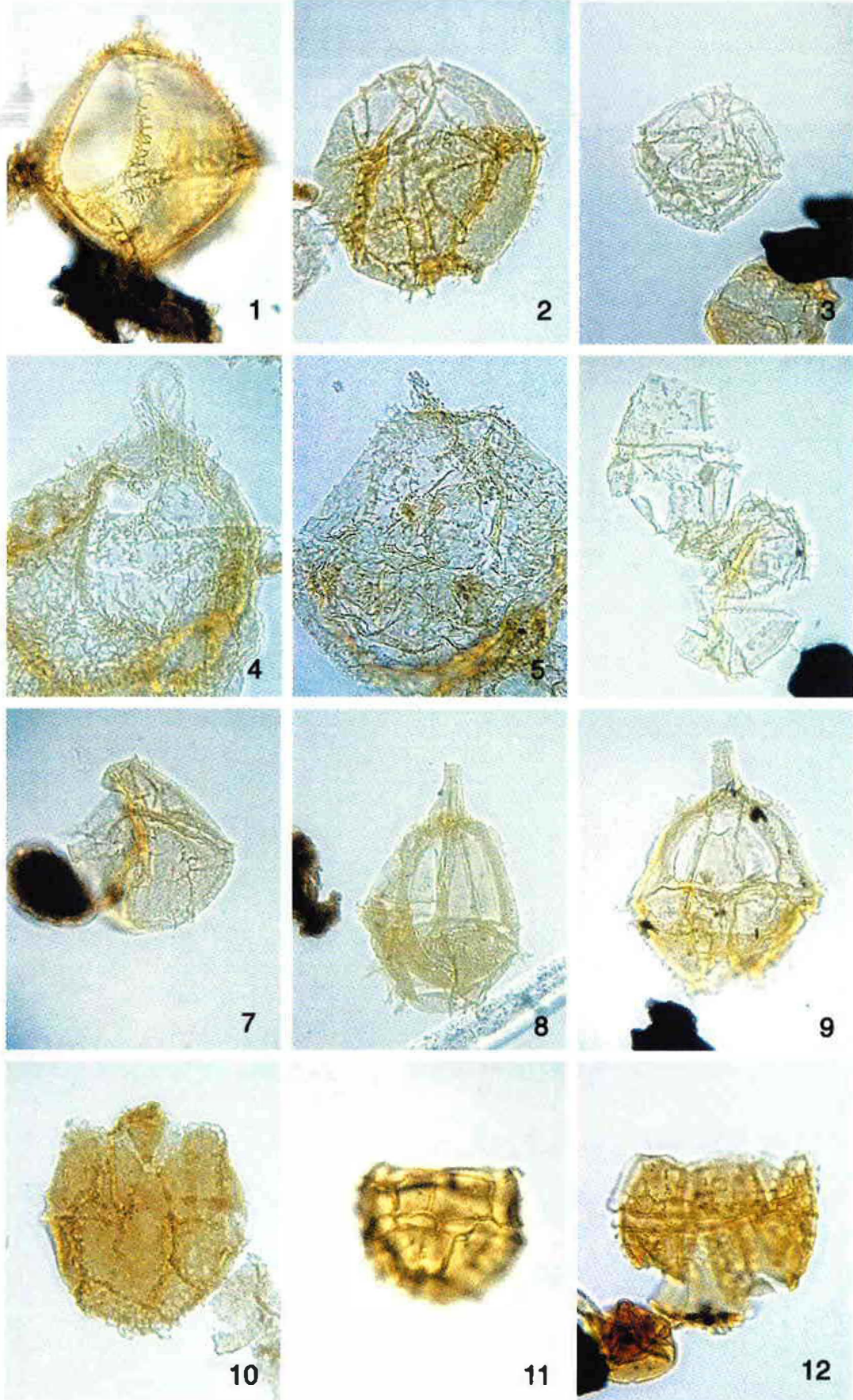
Fig. 7. *Acanthaulax granuligera* (Klement) Brenner, 1988, Glosense Zone, GGU 234 177, K64/6, LVR 1.4972, MI 3813.

Figs 8-9. *Gonyaulacysta jurassica* (Deflandre) Sarjeant, 1982. **Fig. 8:** Densiplicatum ammonite zone, GGU 234 241, L113/3, LVR 1.4825, MI 3680. **Fig. 9:** Tenuiserratum ammonite zone, GGU 234 155, K58/7, LVR 1.4836, MI 3706.

Fig. 10. *Lithodinia jurassica* (Eisenack) Gocht, 1975, Lamberti / Mariae ammonite zones, GGU 245 974, L92/8, LVR 1.4551, MI 3424.

Figs 11-12. *Meiurogoyaulax cf. planoseptata* Riding, 1987, Tenuiserratum ammonite zone. **Fig. 11:** GGU 234 155, K58/7, LVR 1.4853, MI 3704. **Fig. 12:** GGU 234 155, K58/7, LVR 1.4864, MI 3713.

Callovian - Oxfordian Milne Land



20μm

Plate 5

Figs 1-2. *Nannoceratopsis pellucida* (Deflandre) Evitt, 1961. **Fig. 1:** Athleta ammonite zone, GGU 245 969, L151/3, LVR 1.4524, MI 3401. **Fig. 2:** Tenuiserratum ammonite zone, GGU 234 159, K59/8, LVR 1.4894, MI 3737.

Figs 3-4. *Mendicodinium groenlandicum* (Pocock & Sarjeant) Davey, 1979. Lamberti ammonite zone; GGU 245 973, L191/8, LVR 1.4534, MI 3409. **Fig. 4:** Cordatum ammonite zone, GGU 245 977, L193/4, LVR 1.4726, MI 3587.

Fig. 5. *Chytroeisphaeridia chytroeides* (Sarjeant, 1962) Downie & Sarjeant, 1965 emend. Davey, 1979, Tenuiserratum ammonite zone, GGU 234 159, K59/4, LVR 1.4911, MI 3754.

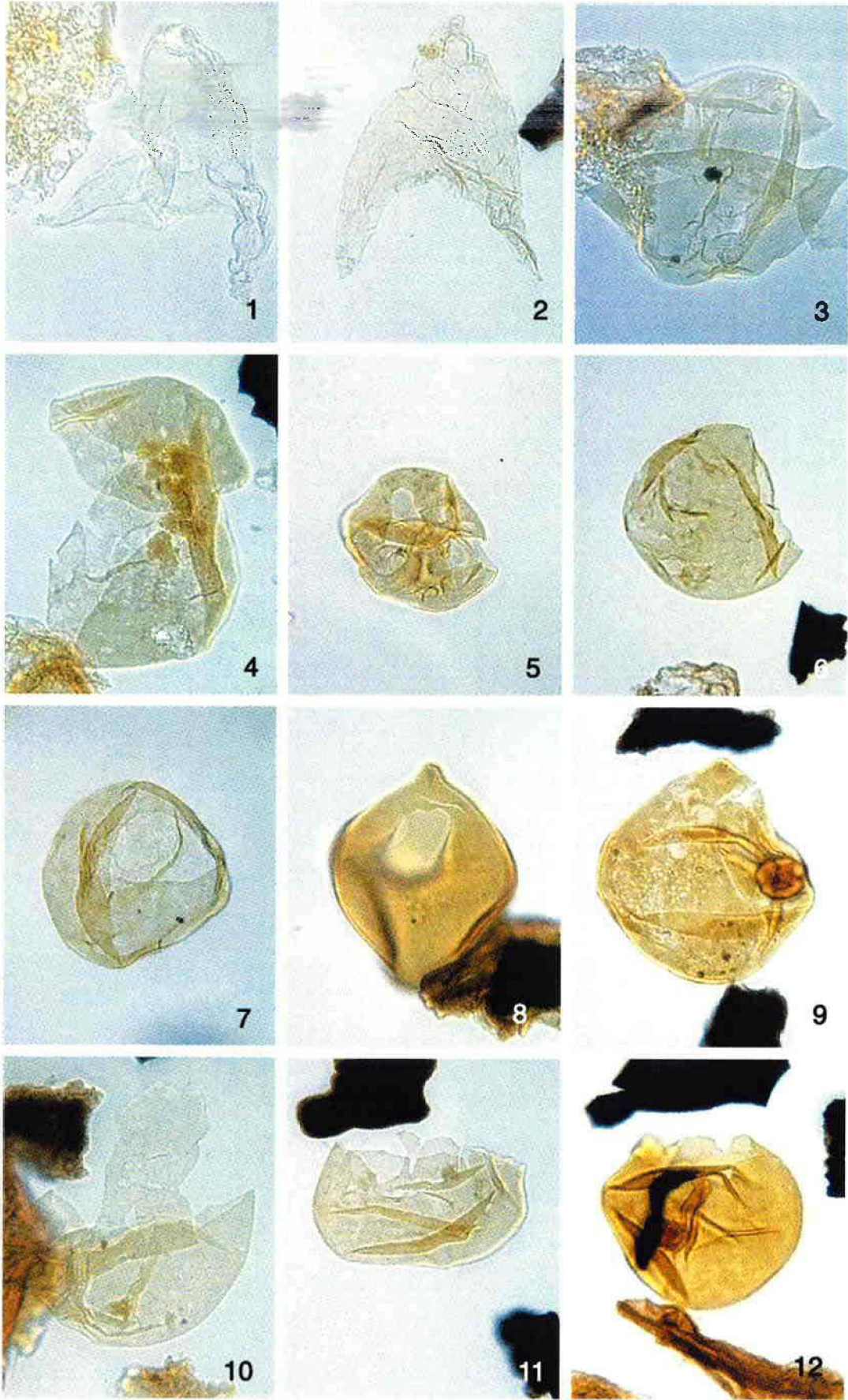
Figs 6-7. *Chytroeisphaeridia hyalina* Raynaud, 1978, pre-Athleta ammonite zone, **Fig. 6:** GGU 245 953, L107/4, LVR 1.4500, MI 3379. **Fig. 7:** GGU 245 953, L107/6, LVR 1.4491, MI 3372.

Figs 8-9. *Chytroeisphaeridia cerastes* Davey, 1979, Tenuiserratum ammonite zone. **Fig. 8:** GGU 234 155, K58/7, LVR 1.4845, MI 3699. **Fig. 9:** GGU 234 155, K58/7, LVR 1.4860, MI 3710.

Fig. 10. *Dissiliodinium hocneratum* (Fenton *et al.*) Lentin & Williams, 1993, Lamberti/Mariae ammonite zones) GGU 245 974, L92/8, LVR 1.4567, MI 3436.

Figs 11-12. *Escharisphaeridia laevigata* Smelror, 1988. **Fig. 11:** Glosense ammonite zone, GGU 234 177, K64/6, LVR 1.4981, MI 3822. **Fig. 12:** Densiplicatum ammonite zone, GGU 234 241, L113/3, LVR 1.4820, MI 3675.

Callovian = Oxfordian Milne Land



20µm

Plate 6

Figs 1-2. *Pareodinia stegasta* (Sarjeant) Below, 1990. Fig. 1: Tenuiserratum ammonite zone, GGU 234 159, K59/8, LVR 1.4892, MI 3735. Fig. 2: Densiplicatum Zone, GGU 234 239, L135/8, LVR 1.4810, MI 3665.

Fig. 3. *Kalyptea diceras* (Cookson & Eisenack) Fisher & Riley, 1980, Glosense ammonite zone, GGU 234 168, L96/3, LVR 1.4945, MI 3787.

Fig. 4. *Paraevansia brachytelis* (Fensome) Below, 1990, (pre-Athleta ammonite zone) GGU 245 953, L107/4, LVR 1.4496, MI 3377.

Fig. 5. *Evasia evittii* (Pocock) Jansonius, 1986, Cordatum / Densiplicatum ammonite zones, GGU 245 980, L152/7, LVR 1.4739, MI 3599.

Fig. 6. *Pareodinia groenlandica*, Sarjeant, 1972, Cordatum ammonite zone, GGU 245 977, L193/4, LVR 1.4731, MI 3592.

Fig. 7. *Protobatioladinium* sp., Tenuiserratum ammonite zone, GGU 234 159, K59/8, LVR 1.4893, MI 3736.

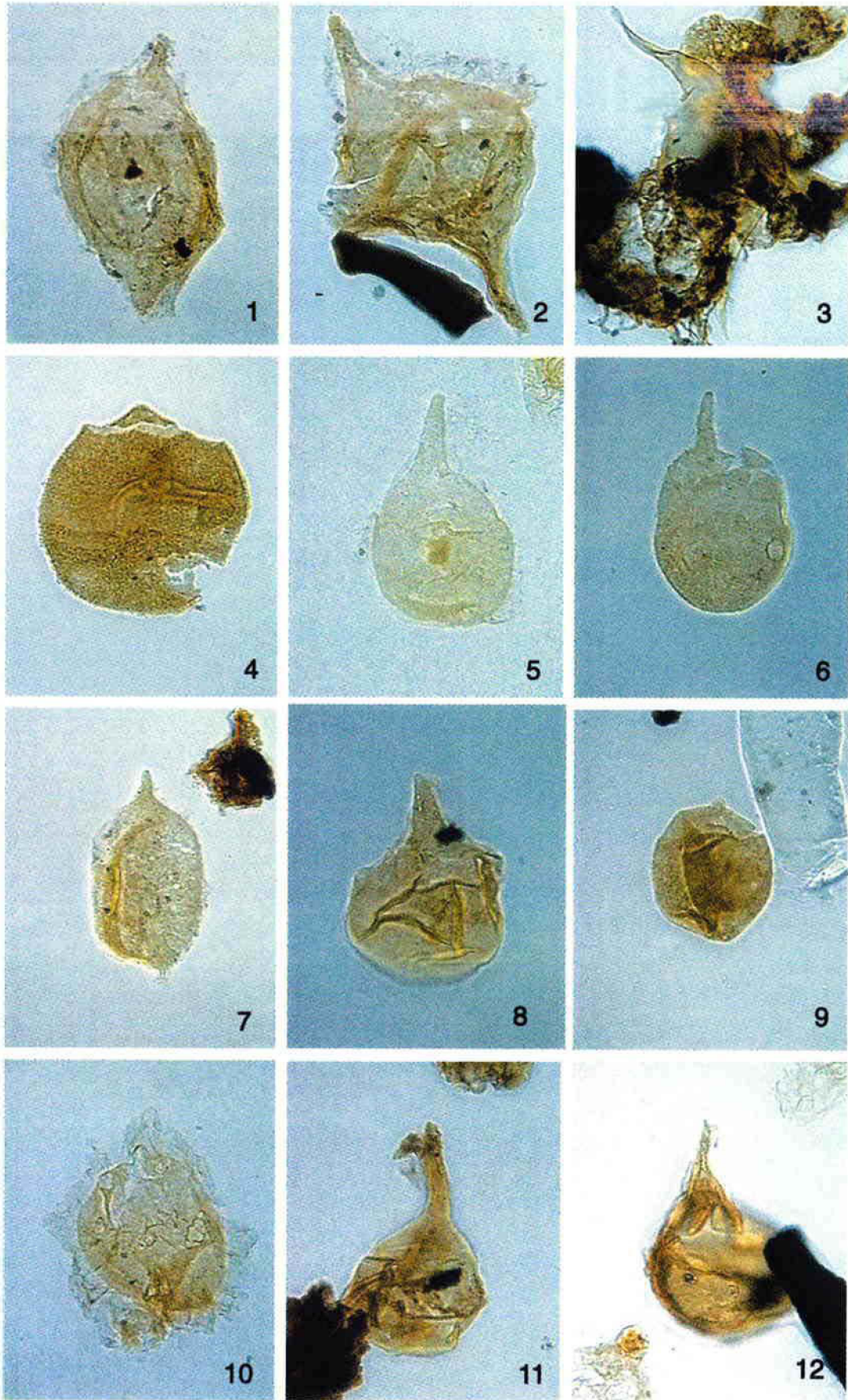
Fig. 8. *Pareodinia ceratophora* Deflandre, 1947, (pre-Athleta Zone) GGU 245 953, L107/3, LVR 1.4664, MI 3530.

Fig. 9. *Pareodinia ceratophora scopaeus* (Sarjeant) Below, 1990, Athleta ammonite zone, GGU 245 969, L151/2, LVR 1.4622, MI 3489.

Fig. 10. *Pareodinia halosa* (Filatoff) Prauss, 1989, Athleta ammonite zone, GGU 245 961, L87/6, LVR 1.4650, MI 3516.

Figs 11-12. *Pareodinia prolongata* Sarjeant, 1959. Fig. 11: Lamberti / Mariae zones GGU 245 974, L92/3, LVR 1.4596, MI 3464. Fig. 12: (pre-Athleta Zone) GGU 245 953, L107/5, LVR 1.4477, MI 3359.

Callovian - Oxfordian Milne Land



20 μ m

Plate 7

Figs 1-2. *Ambonosphaera calloviana* Fensome, 1979, Glosense ammonite zone. **Fig. 1:** GGU 234 177, K64/9, LVR 1.4967, MI 3808. **Fig. 2:** GGU 234 168, L96/8, LVR 1.4920, MI 3763.

Fig. 3. *Chlamydophorella ectotabulata* Smelror, 1989, Cordatum ammonite zone, GGU 245 977, L193/4, LVR 1.4721, MI 3582.

Fig. 4. *Cassiculosphaeridia dictydia* (Sarjeant, 1972) Riley and Fenton, 1982, Tenuiserratum ammonite zone, GGU 234 155, K58/7, LVR 1.4861, MI 3711.

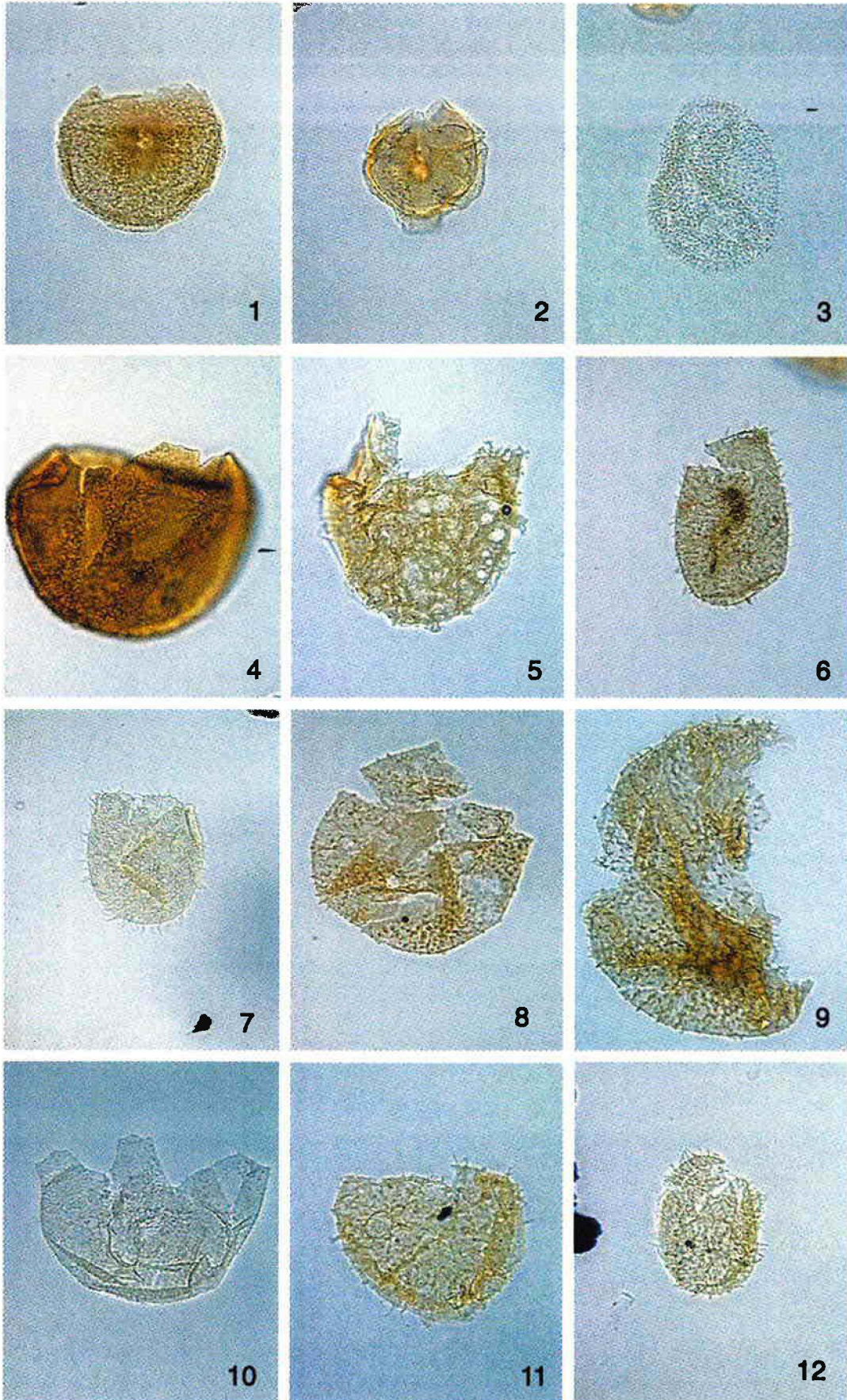
Fig. 5. *Epiplosphaera bireticulata* Klement, 1960, Glosense ammonite zone, GGU 234 177, K64, LVR 1.4987, MI 3827.


Figs 6-10. *Sentusidinium* spp. **Fig. 6:** Note apical archaeopyle with operculum (and apex) *in situ*, Cordatum / Densiplicatum ammonite zones, GGU 245 980, L152/4, LVR 1.4770, MI 3627. **Fig. 7:** Cordatum / Densiplicatum ammonite zones, GGU 245 980, L152/9, LVR 1.4744, MI 3604. **Fig. 8:** probably Lamberti ammonite zone GGU 245 973, L191/4, LVR 1.4602, MI 3471. **Fig. 9:** Lamberti / Mariae ammonite zones GGU 245 974, L92, LVR 1.4582, MI 3450. **Fig. 10:** Glosense ammonite zone, GGU 234 177, K64/9, LVR 1.4965, MI 3806.

Fig. 11. *Sentusidinium rioultii* (Sarjeant, 1968) Courtinat, 1989, Athleta ammonite zone, GGU 245 964, L89/8, LVR 1.4509, MI 3388.

Fig. 12. *Sentusidinium* cf. *erythrocomum* Erkmen & Sarjeant, 1980, Tenuiserratum ammonite zone, GGU 234 159, K59/4, LVR 1.4916, MI 3759.

Callovian - Oxfordian Milne Land



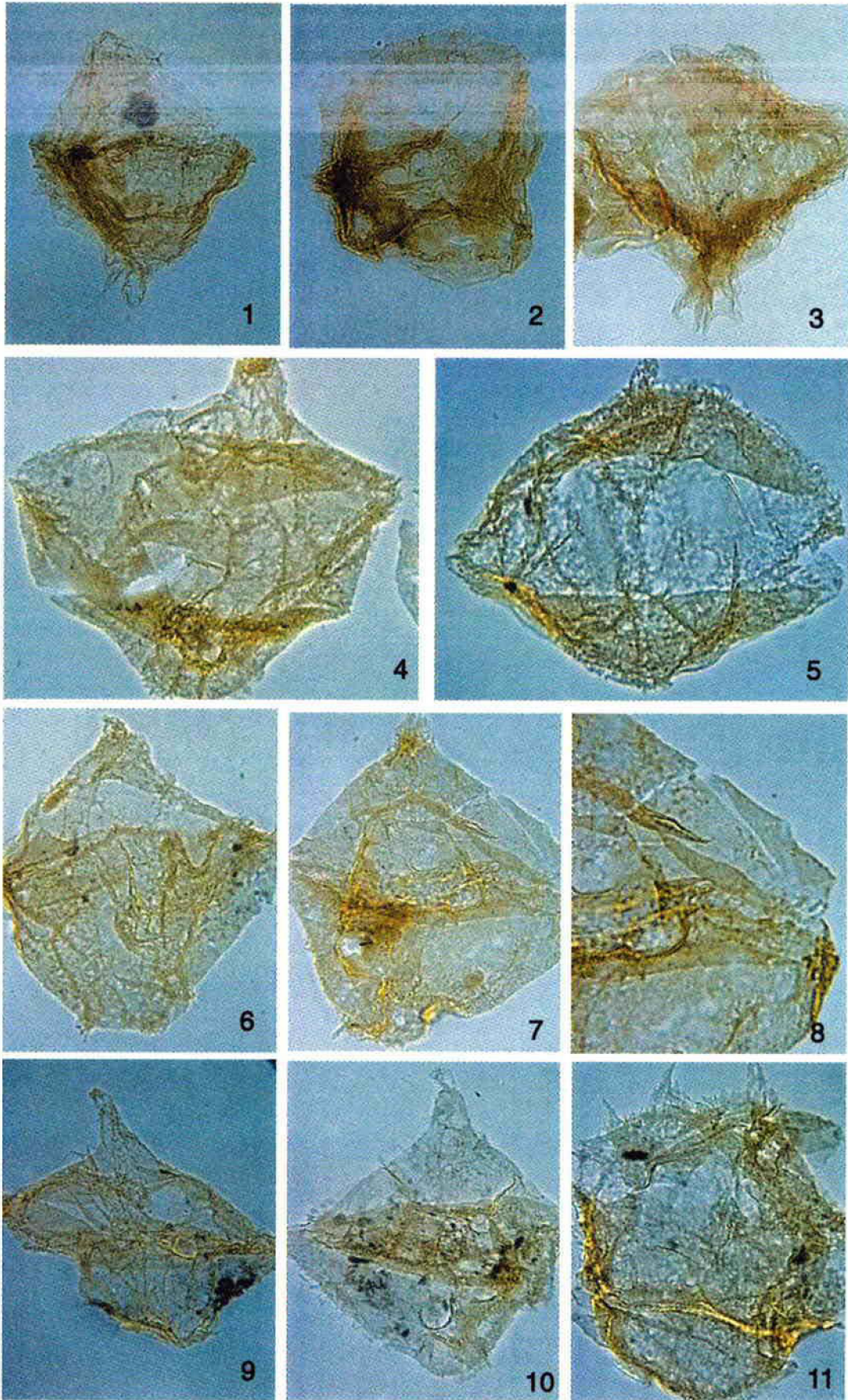


Figs 1-3. *Glossodinium dimorphum* (Ioannides *et al.*) Courtinat & Gaillard, 1980. **Fig. 1:** Autissiodorensis ammonite zone GGU 234 105, K37/3, LVR 1.2350, MI 1685. **Fig. 2:** (Autissiodorensis Zone) GGU 234 106, K34/4, LVR 1.2316, MI 1656. **Fig. 3:** Eudoxus Zone, GGU 245 889, K101/6, LVR 1.2115, MI 1503.

Figs 4-10. *Occisucysta* aff. *monoheuriskos* (Gitmez & Sarjeant) Jan du Chene *et al.*, 1986. **Figs 4, 6, 7-8:** Autissiodorensis ammonite zone GGU 234 106, K34/4, LVR 1.2314, MI 1654; LVR 1.2600, MI 1658 & LVR 1.2321-22, MI 1659. **Fig. 5:** Elegans/Wheatlyensis ammonite zones GGU 234 123, K37/3, LVR 1.2355, MI 1689. **Fig. 9:** Elegans/Wheatlyensis ammonite zones GGU 234123, K185/8, LVR 1.2419, MI 1744. **Fig. 10:** Eudoxus ammonite zone GGU 234102, K32/8, LVR 1.2600, MI 1907.

Fig. 11. *Rhynchodiniopsis "machaera"*, Scitulus ammonite zone GGU 234 123, K185/8, LVR 1.2456, MI 1780.

Kimmeridgian - Milne Land



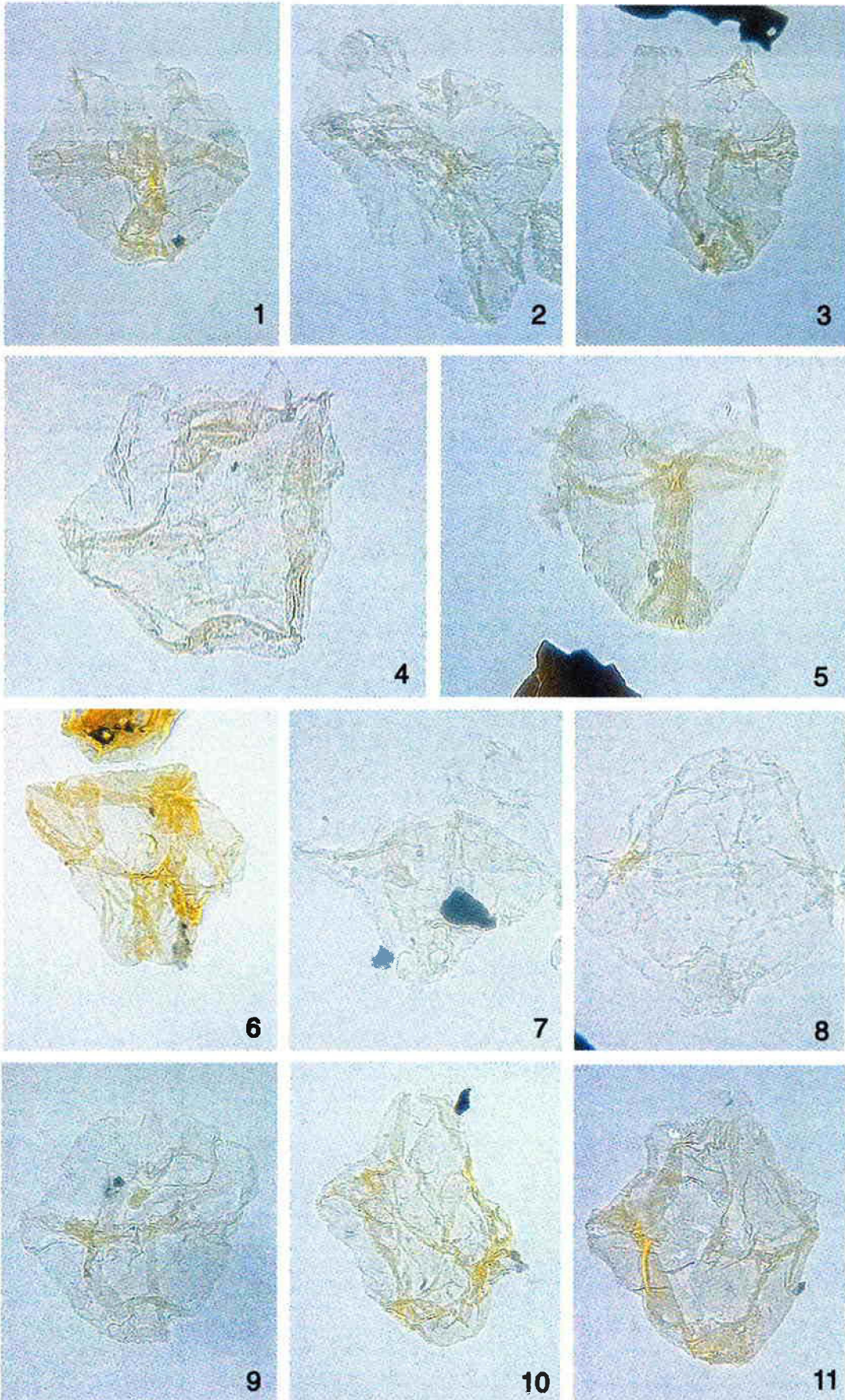
20 μm

Plate 9

Figs 1-6. *Atopodinium haromense* Thomas & Cox, 1988, Eudoxus/Autissiodorensis ammonite zones. **Fig. 1:** GGU 234 102, K32/8, LVR 1.2596, MI 1902. **Figs 2-3:** GGU 234 105, K37/2, LVR 1.2370, MI 1702 & LVR 1.2341, MI 1676. **Fig. 4:** GGU 234 105, K37/2, LVR 1.2371, MI 1703. **Figs 5-6:** GGU 234 106, K34/4, LVR 1.2329, MI 1665.

Figs 7-11. *Atopodinium* sp. **Fig. 7:** Eudoxus ammonite zone, GGU 245 894, K102/6, LVR 1.2175, MI 1545. **Figs 8-11;** Eudoxus/Autissiodorensis ammonite zones. **Fig. 8:** GGU 234 121, K173/4, LVR 1.2523, MI 1836. **Fig. 9:** GGU 234 102, K32/8, LVR 1.2589, MI 1895. **Fig. 10:** GGU 234 106, K34/4, LVR 1.2311, MI 1652. **Fig. 11:** GGU 234 101, K31/4, LVR 1.2294, MI 1637. **Fig. 12:** GGU 234 101, K31/4, LVR 1.2294, MI 1637.

Kimmeridgian - Milne Land



20 μm

Plate 10

Figs 1-5. *Ambonosphaera calloviana* Fensome, 1979 with antapical flange in figs 1,2 & 5 and with latero-antapical invaginations / perforations in figs 3 & 4. **Fig. 1:** Elegans zone, GGU 234 119, L128/3, LVR 1.2406, MI 1734. **Fig. 2:** Wheatlyensis ammonite zone, GGU 234 121, K173/4, LVR 1.2521, MI 1834. **Figs 3-4:** Autissiodorensis ammonite zone GGU 234105, K37/3, LVR 1.2344, MI 1679. & LVR 1.2361, MI 1693. **Fig. 5:** Wheatlyensis ammoniote zone, GGU 234 121, K173/11, LVR 1.2473, MI 1796.

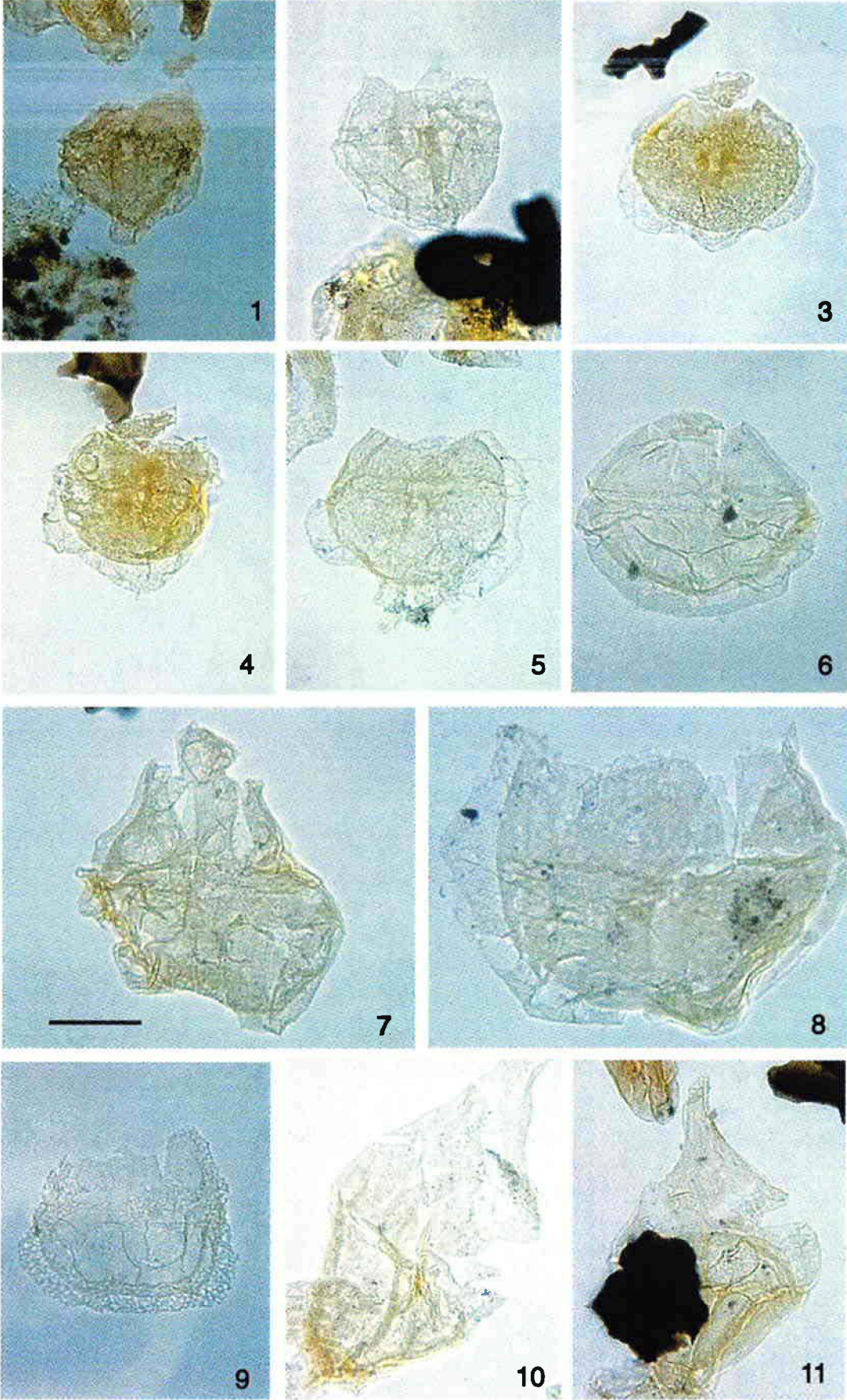
Figs 6-7. *Sirmiodinium grossii* (Alberti) Warren, 1973 with round outline in fig. 6 and angular (pentagonal) outline in fig. 7. **Fig. 6:** Eudoxus ammonite zone, GGU 245 896, L148/9, LVR 1.2256, MI 1606. **Fig. 7:** GGU 245 873, K97/7, LVR 1.2077, MI 1472.

Fig. 8. *Senoniasphaera jurassica* (Gitmez & Sarjeant) Lentin & Williams, 1976, Wheatlyensis ammonite zone, GGU 234 121, K173/4, LVR 1.2529, MI 1842.

Fig. 9. *Sirmiodinium grossii* var.?, Eudoxus ammonite zone, GGU 245 896, L148/9, LVR 1.2260, MI 1609.

Figs 10-11. *Senoniasphaera "janei"*. **Fig. 10:** Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2478, MI 1801. **Fig. 11:** Scitulus ammonite zone GGU 234 123, K185/4, LVR 1.2435, MI 1759.

Kimmeridgian - Milne Land



20 μ m

Plate 11

Figs 1-2. *Apteodinium* sp. Fig. 1: Coarse and thickwalled, Eudoxus ammonite zone, GGU 234 106, K34/4, LVR 1.2304, MI1647. **Fig. 2:** Thinwalled and shorter apical horn, Elegans/Wheatlyensis ammonite zones, GGU 234 121, K173/11, LVR 1.2469, MI 1791.

Fig. 3. Cf. *Apteodinium* sp., partly hyaline and with weak parasutures, no sculpture, Elegans/Wheatlyensis ammonite zones, GGU 234 121, K173/11, LVR 1.2516, MI 1830.

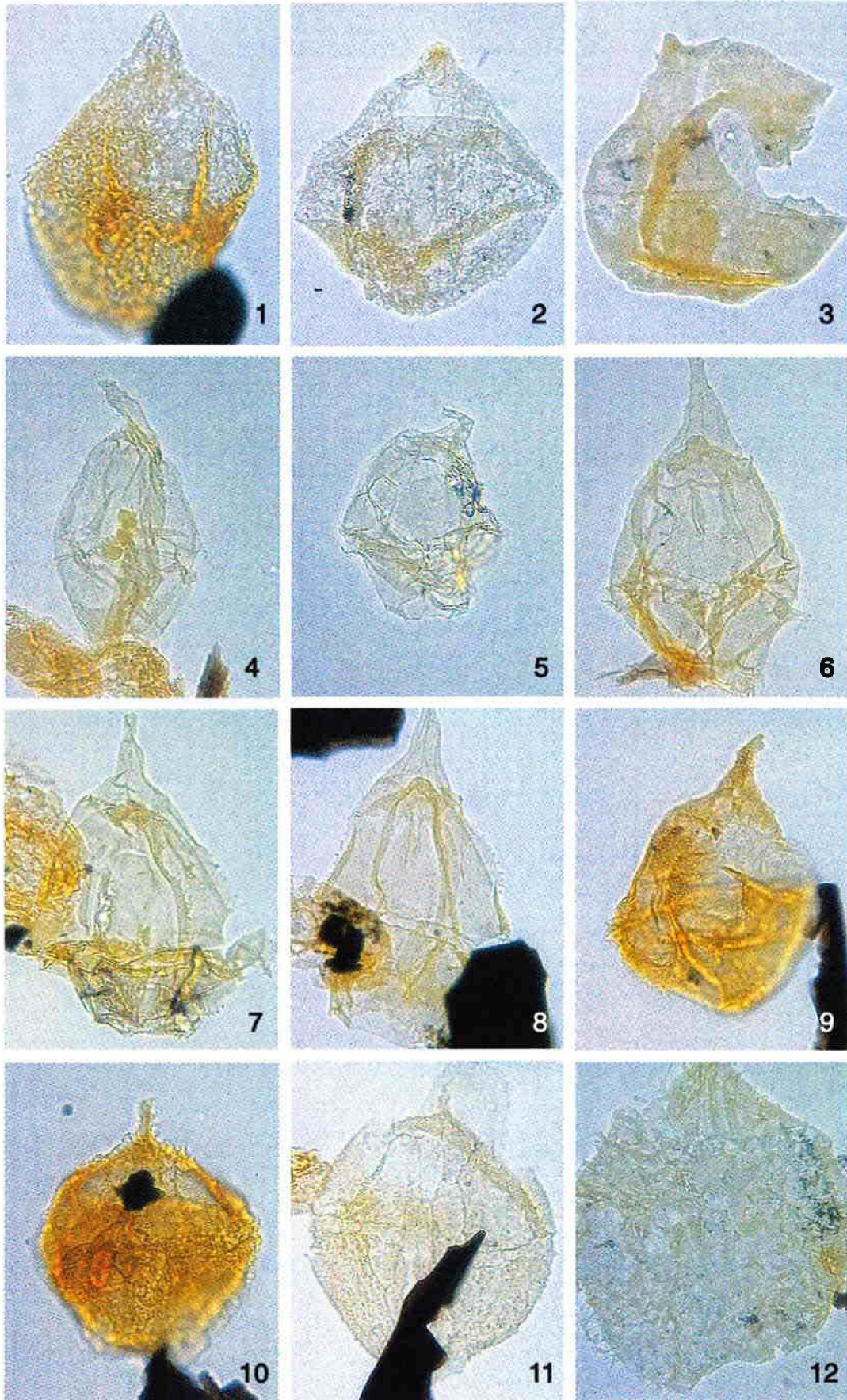
Figs 4-5. *Gonyaulacyst* "dualis". Fig. 4: Elegans/Wheatlyensis ammonite zones, GGU 243 101, K31/4, LVR 1.2293, MI 1636. **Fig. 5:** Eudoxus ammonite zone, GGU 245 896 L148/9, LVR 1.2257, MI 1607.

Figs 6-8. *Gonyaulacysta jurassica* Fig. 6: Eudoxus ammonite zone, GGU 245 896 L148/9, LVR 1.2249, MI 1596. **Fig. 7:** Eudoxus ammonite zone, GGU 245 896 L148/9, LVR 1.2248, MI 1599. **Fig. 8:** Eudoxus ammonite zone, GGU 234 102, K32/8, LVR 1.2602, MI 1909.

Figs 9-11. *Acanthaulax granuligera*. Fig. 9: Eudoxus ammonite zone, GGU 234 101, K31/4, LVR 1.2292, MI 1635. **Fig. 10:** Elegans/Wheatlyensis ammonite zones, GGU 234 121, K173/11, LVR 1.2292, MI 1635. **Fig. 11:** Elegans/Wheatlyensis ammonite zones, GGU 234 121, K173/11, LVR 1.2492, MI 1812.

Fig. 12: *Circulodinium distinctum*, Elegans/Wheatlyensis ammonite zones, GGU 234 121, K173/11, LVR 1.2475, MI 1599.

Kimmeridgian - Milne Land



20 μm

Plate 12

Figs 1-3. "*Endoscrinium*" *irregularis* (Cookson & Eisenack) Stover & Evitt, 1978. **Fig. 1:** *Eudoxus* ammonite zone, GGU 245 896, L148/9, LVR 1.2253, MI 1603. **Figs 2-3:** *Eudoxus* ammonite zone, GGU 234 101, K31/7, LVR 1.2262, MI 1611 & LVR 1.2265, MI 1612.

Figs 4-5. *Scriniodinium luridum* (Deflandre) Klement, 1960, Autissiodorensis ammonite zone) GGU 234 105, K37/3, LVR 1.2348, MI 1683 & LVR 1.2364, MI 1696.

Figs 7. *Scriniodinium luridum* var.?, Scitulus ammonite zone GGU 234 111, K170/3, LVR 1.2574, MI 1882.

Figs 6 & 8. *Scriniodinium* cf. *crystallinum* (Deflandre) Klement, 1960, Scitulus ammonite zone). **Fig. 6:** GGU 234 111, K170/3, LVR 1.2570, MI 1878. **Fig. 8:** GGU 234 123, K185/4, LVR 1.2422, MI 1747.

Figs 9-10. *Scriniodinium galeritum* (subsp. *fornicatum*?) (Deflandre) Klement, 1960 Scitulus ammonite zone GGU 234 123, K185/4, LVR 1.2430-31, MI 1755.

Fig. 11. *Scriniodinium* sp. (granular), Autissiodorensis ammonite zone, GGU 234 106, K34/4, LVR 1.2302, MI 1645.

Kimmeridgian - Milne Land

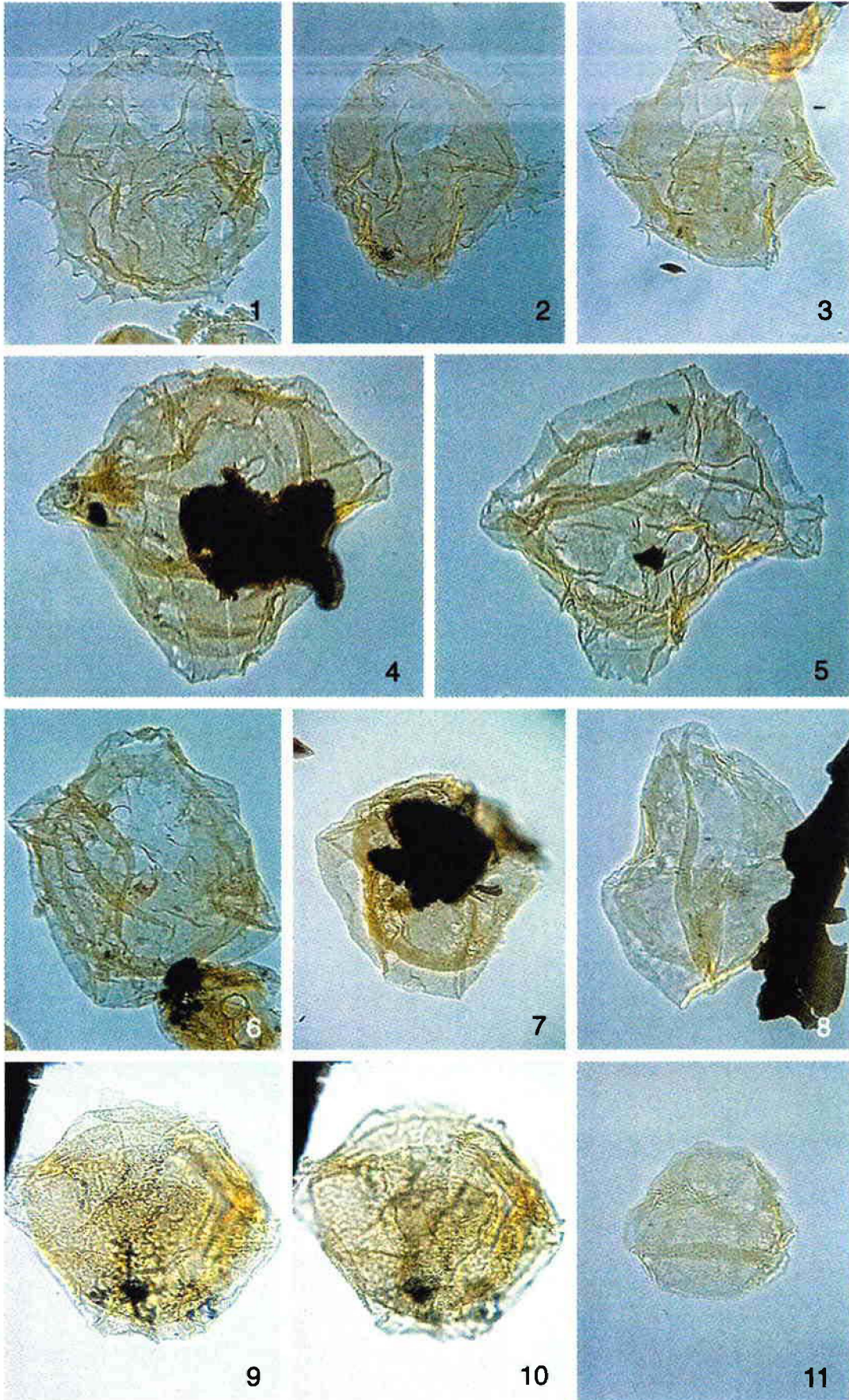


Plate 13

Figs 1-2. *Leptodinium arcuatum* (Klement) Sarjeant, 1984, Eudoxus /Autissiodorensis ammonite zones, GGU 234 102, K32/8, LVR 1.2582, MI 1890 & LVR 1.2588, MI 1894.

Fig. 3. *Leptodinium millioudii* (Sarjeant) Sarjeant, 1969, Autissiodorensis ammonite zone GGU 234 105, K37/3, LVR 1.2353, MI 1687.

Figs 4-6. *Leptodinium subtile* Klement, 1960. **Fig. 4:** ventral view; Eudoxus ammonite zone, GGU 234 101, K31/4, LVR 1.2287, MI 1631. **Fig. 5:** lateral view; Autissiodorensis ammonite zone GGU 234 105, K37/3, LVR 1.2345, MI 1680. **Fig. 6:** with vertically elongated fenestrae in the sutural membranes; Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2498, MI 1817.

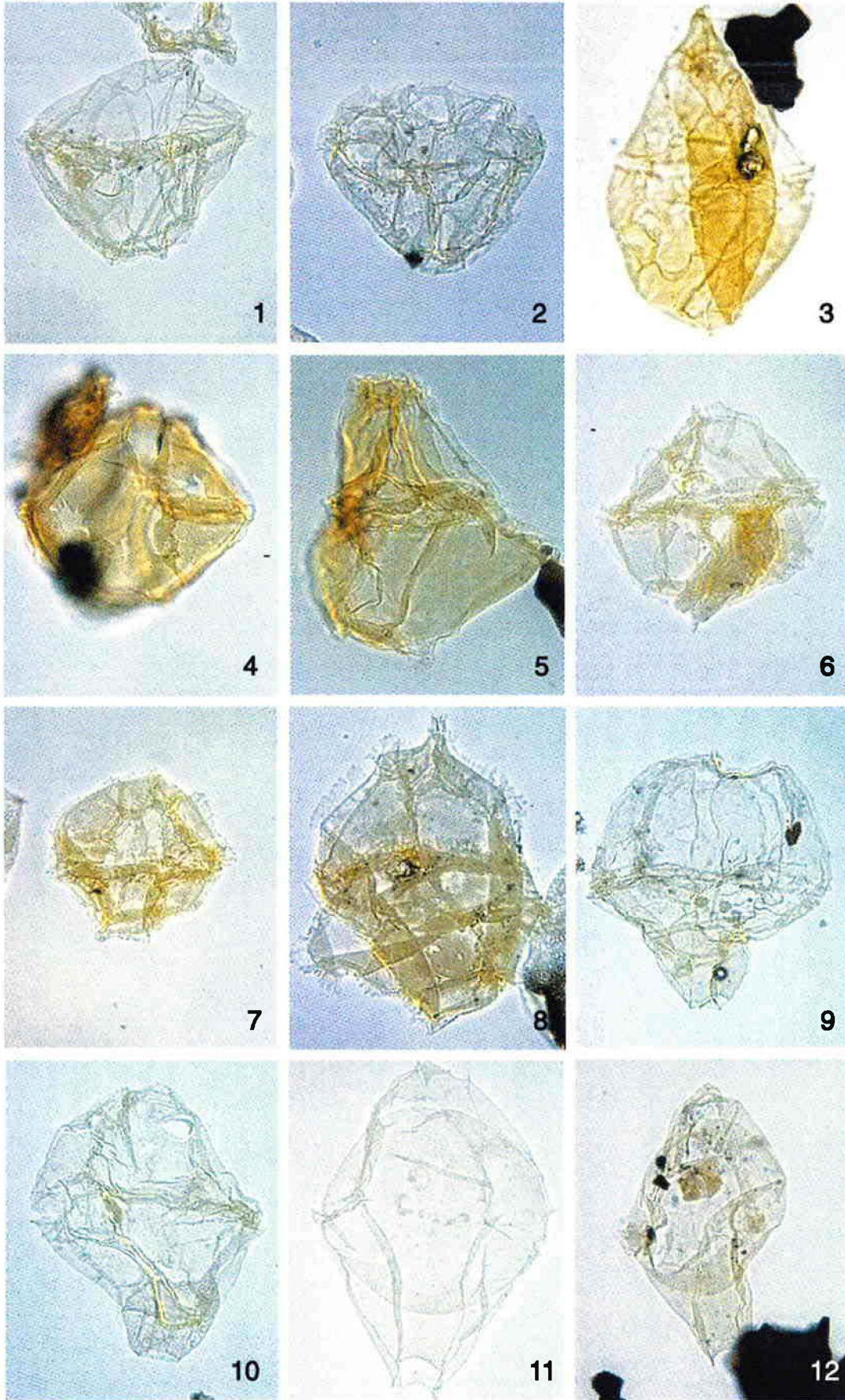
Figs 7-8. *Leptodinium cf. subtile* Klement, 1960 in both cases with strongly perforated sutural membranes. **Fig. 7:** Autissiodorensis ammonite zone GGU 234 105, K37/2, LVR 1.2372, MI 1704. **Fig. 8.** Scitulus ammonite zone GGU 234 123, K185/3, LVR 1.2447, MI 1770.

Figs 9-10. *Tubotuberella egemenii* (Gitmez) Stover & Evitt, 1978, Mutabilis / Eudoxus ammonite zones, GGU 245 876, K98/7, LVR 1.2098, MI 1488 & LVR 1.2101, MI 1491.

Fig. 11. *Tubotuberella sphaerocephalis* Vozzhennikova, 1967, Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2509, MI 1825.

Fig. 12. *Tubotuberella apatela* (Cookson & Eisenack) Sarjeant, 1982, Scitulus ammonite zone GGU 234 127, K40/7, LVR 1.2552, MI 1863.

Kimmeridgian - Milne Land



20 μm

Plate 14

Figs 1-2. *Epiplosphaera bireticulata* Klement, 1960, Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2512, MI 1827 & LVR 1.2515, MI 1829.

Figs 3-4. *Epiplosphaera "cingulatum"*. **Fig. 3:** Wheatlyensis ammonite zone, GGU 234 121, K173/4, LVR 1.2520, MI 1833. **Fig. 4:** Autissiodorensis ammonite zone GGU 234105, K37/3, LVR 1.2480, MI 2362.

Fig. 5. *Valensiella* sp., Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2480, MI 1803.

Figs 6-7. *Chlamydophorella* sp., periphragm only partly preserved, Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2491, MI 1811 & LVR 1.2501, MI 1820.

Fig. 8. *Sentusidinium* cf. *rioultii* (Sarjeant) Courtinat, 1989, Elegans ammonite zone, GGU 234 119, L128/3, LVR 1.2388, MI 1719.

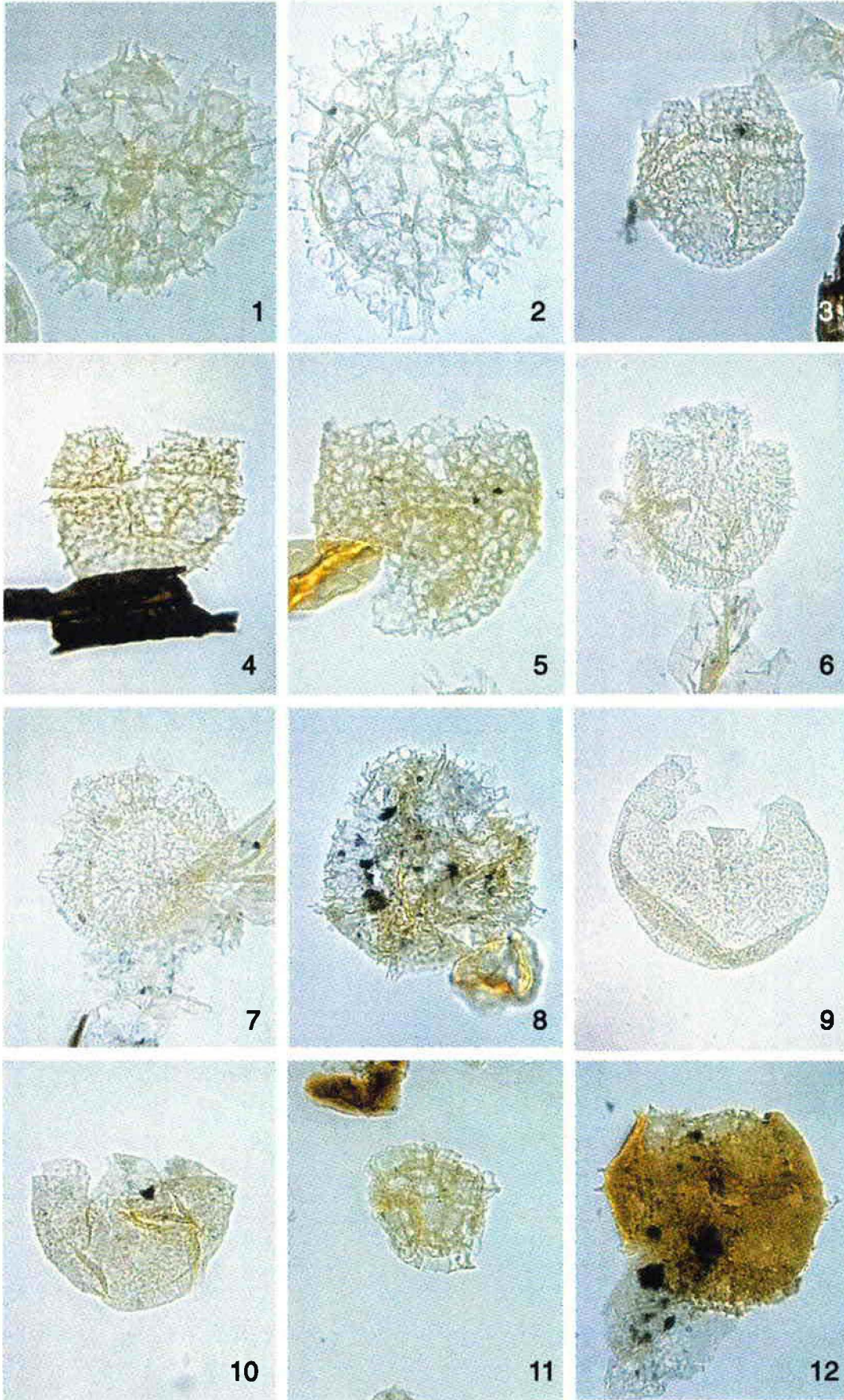
Figs 9-10. *Sentusidinium pelionense* Fensome, 1979 with and without attached operculum.

Fig. 9: Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2470, MI 1792. **Fig. 10:** Scitulus ammonite zone GGU 234 127, K40/7, LVR 1.2543, MI 1855.

Fig. 11. Cf. *Heslertonia* sp., Elegans ammonite zone, GGU 234 119, L128/3, LVR 1.2467, MI 1735.

Fig. 12. *Lithodinia* sp., Elegans ammonite zone, GGU 234 119, L128/2, LVR 1.2417, MI 1742.

Kimmeridgian - Milne Land



20 μm

Plate 15

Figs 1-2. *Prolixosphaeridium granulosum* (Deflandre) Davey *et al.*, 1966. **Fig 1:** Scitulus ammonite zone, GGU 234 123, K1 85/4, LVR 1.2441, MI 1764. **Fig. 2:** Fairly similar to *Prolixosphaeridium floccum*, Wheatleyensis Zone, GGU 234 121, K1 73/4, LVR 1.2522, MI 1835.

Figs 3-5. *Cleistosphaeridium tribuliferum* (Sarjeant) Davey *et al.*, 1969. **Fig. 3:** Eudoxus ammonite zone, GGU 245 896, L148/9, LVR 1.2237, MI 1591. **Fig. 4:** Scitulus ammonite zone GGU 234 127, K40/7, LVR 1.2553, MI 1864. **Fig. 5:** Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2483, MI 1806.

Fig. 6. *Cleistosphaeridium* sp., Scitulus ammonite zone, GGU 234 127, K40/7, LVR 1.2538, MI 1851.

Fig. 7-8. *Kleithriasphaeridium telaspinosum* (Fisher & Riley) Lentin & Williams, 1981, Wheatlyensis ammonite zone, GGU 234 121, K 173/11, LRV 2500, MI 1819 & LVR 1.2518, MI 1832.

Figs 9-11. *Avellodinium* cf. *falcificum* Duxbury, 1977. **Fig. 9:** Scitulus ammonite zone GGU 234 123, K185/4, LVR 1.2439, MI 1763. **Fig. 10:** Eudoxus ammonite zone, GGU 245 891, K101/8, LVR 1.2147, MI 1528. **Fig. 11:** Mutabilis ammonite zone, GGU 245 875, K168/7, LVR 1.2092, MI 1483.

Fig. 12. *Hystrichodinium* sp. (?cf. *Furzidinium sentum*), Elegans ammonite zone, GGU 234 119, L128/3, LVR 1.2374, MI 1706.

Kimmeridgian - Milne Land

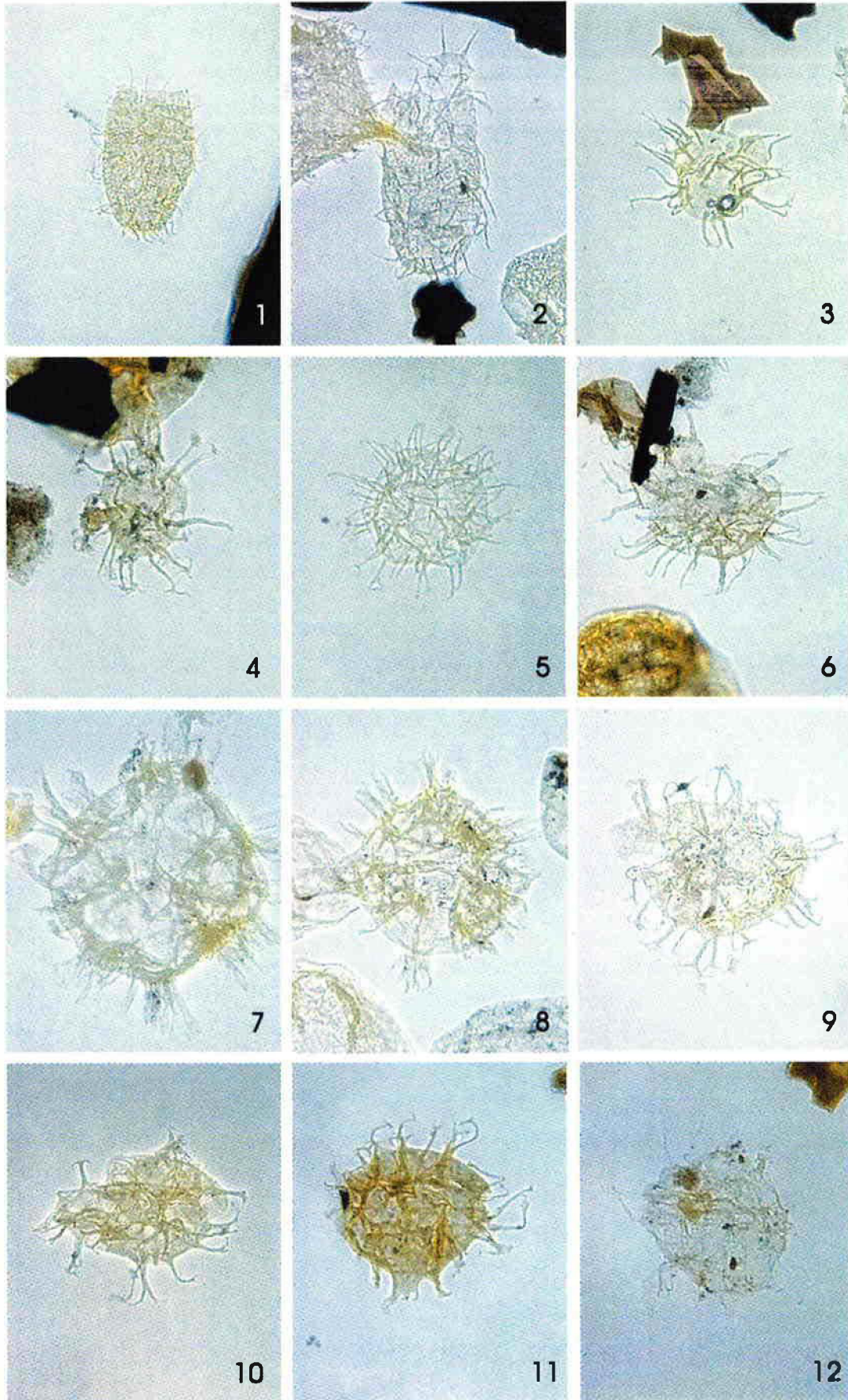


Plate 16

Figs 1-5. *Perisseiasphaeridium pannosum* Davey & Williams, 1966. **Fig. 1:** Detached operculum, Mutabilis / Eudoxus ammonite zone, GGU 245 876, K98/7, LVR 1.2096, MI 1487. **Fig. 2:** Eudoxus ammonite zone, GGU 245 889, K101/6, LVR 1.2110, MI 1499. **Fig. 3:** Autissiodorensis ammonite zone GGU 234 106, K34/4, LVR 1.2317, MI 1657. **Fig. 4:** Eudoxus ammonite zone, GGU 245 894, K102/6, LVR 1.2174, MI 1544. **Fig. 5:** With processes similar to *O. patulum* but clearly with cingular processes, Autissiodorensis ammonite zone GGU 234 106, K34/4, LVR 1.2335, MI 1671. Magnification of figs 2-3 is approximately x0.6 in relation to the standard size in this report.

Fig. 6. *Perisseiasphaeridium cf. insolitum* Davey, 1982, Scitulus ammonite zone GGU 234 123, K43/4, LVR 1.2418, MI 1743.

Figs 7-8. *Oligosphaeridium patulum* Riding & Thomas, 1988. **Fig. 7:** Processes very similar to the *P. pannosum* type but without any cingular processes, Elegans Zone, GGU 234 119, L128/3, LVR 1.2380, MI 1711; **Fig. 8.** Eudoxus / Autissiodorensis ammonite zone, GGU 234105, K37/3, LVR 1.2373, MI 1705. Magnification of figs 7-8 is approximately x1.2 in relation to the standard size in this report.

Figs 9-11. *Oligosphaeridium* aff. *patulum* Riding & Thomas, 1988; all with short, distally wide processes; fenestration of processes varies significantly. **Fig. 9:** Eudoxus ammonite zone, GGU 245 894, K102/6, LVR 1.2166, MI 1539. **Fig. 10:** Eudoxus / Autissiodorensis ammonite zones, GGU 234 105, K37/3, LVR 1.2346, MI 1681. **Fig. 11:** (Scitulus ammonite zone) GGU 234 127, K40/7, LVR 1.2546, MI 1857.

Kimmeridgian - Milne Land

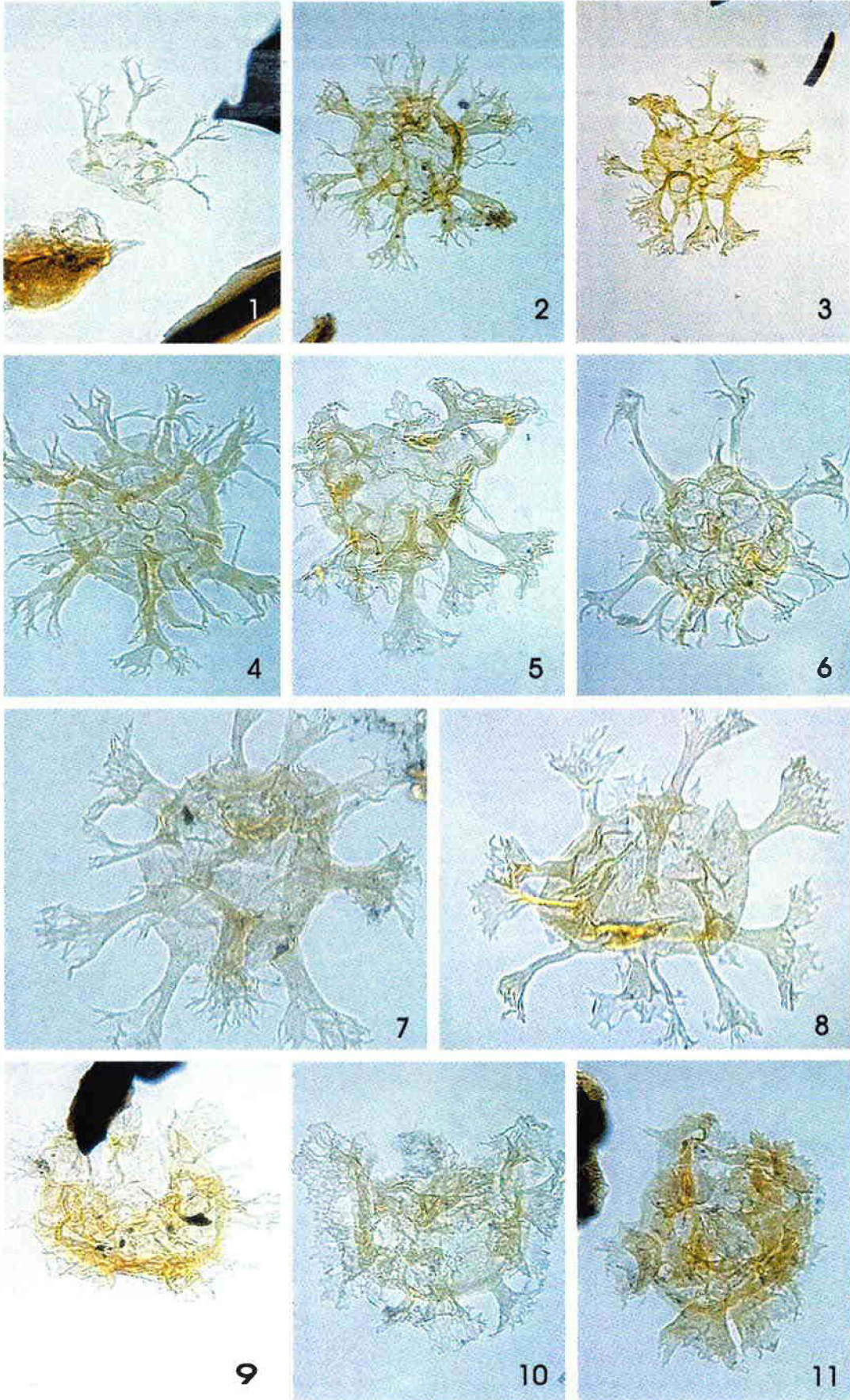


Plate 17

Fig. 1. *Adnatosphaeridium "hartzi"*, GGU 245 896, L148/9, LVR 1.2217, MI 1579.

Fig. 2. *Adnatosphaeridium* sp. 1, Mutabilis ammonite zone, GGU 245 874, L143/8, LVR 1.2090, MI 1482.

Figs 3-4. *Adnatosphaeridium* sp. 2, **Fig. 3:** Mutabilis ammonite zone, GGU 245 873, K97/7, LVR 1.2084, MI 1477. **Fig. 4:** GGU 245 878, L144/7, LVR 1.2067, MI 1464.

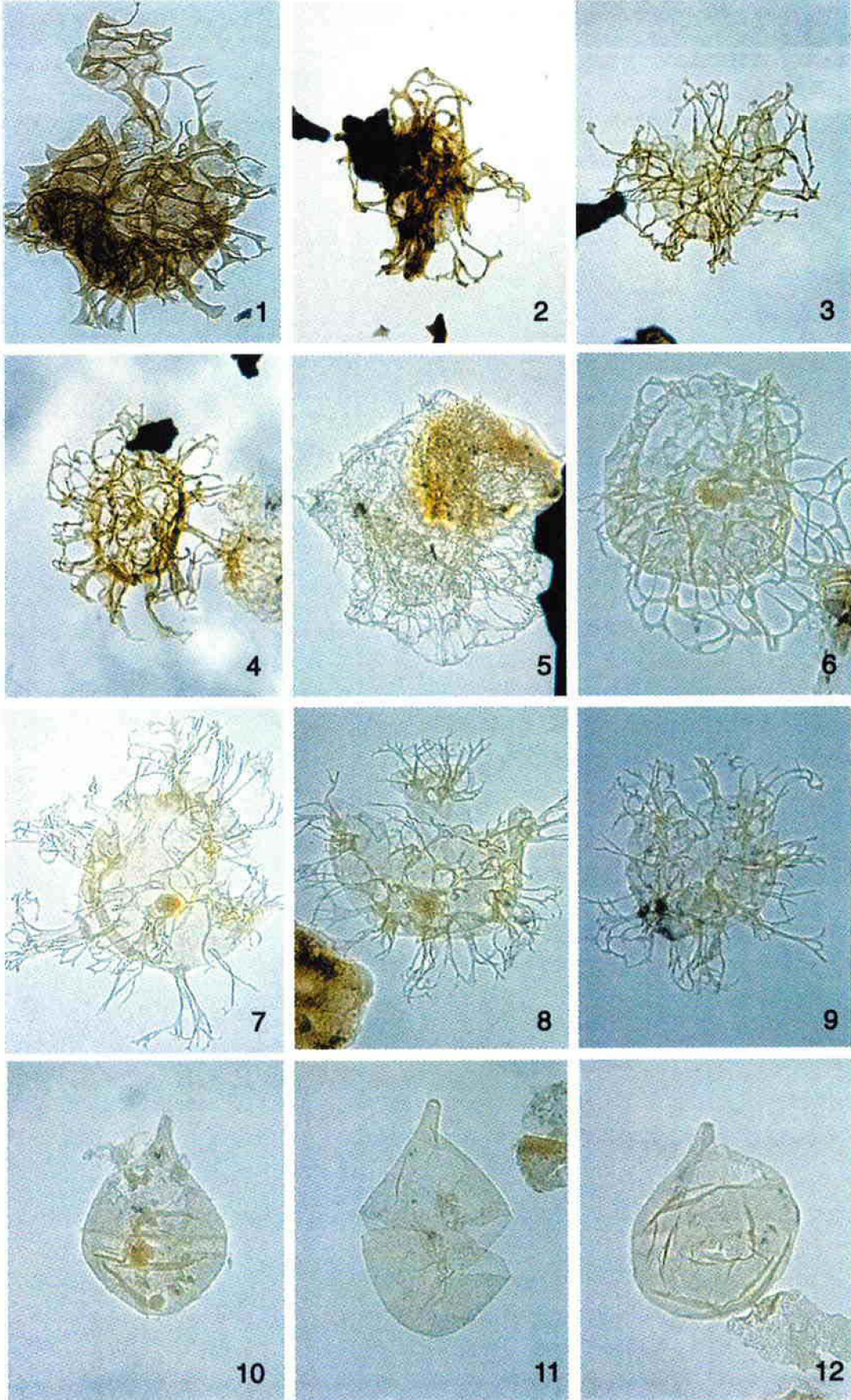
Fig. 5. *Rotosphaeropsis* aff. *thula* (Davey) Riding & Davey, 1989, Wheatlyensis ammonite zone, GGU 234121, K173/11, LVR 1.2477, MI 1800.

Fig. 6. *Rotosphaeropsis thula* (Davey) Riding & Davey, 1989, Wheatlyensis ammonite zone, GGU 234 121, K173/4, LVR 1.2531, MI 1844.

Figs 7-9. *Systematophora fasciculigera* Klement, 1960. **Fig. 7:** morphological transition from *Perisseiasphaeridium* cf. *pannosum* to *Systematophora fasciculigera*, Eudoxus ammonite zone, GGU 245 894, K102/6, LVR 1.2189, MI 1555. **Fig. 8:** Eudoxus ammonite zone, GGU 245 896, L148/9, LVR 1.2247, MI 1598. **Fig. 9:** Wheatlyensis ammonite zone, GGU 234 121, K173/4, LVR 1.2530, MI 1843.

Figs 10-12. *Pareodinia* sp. C with clear cingulum and with 2a archaeopyle. **Fig. 10:** Scitulus ammonite zone, GGU 234 127, K40/7, LVR 1.2533, MI 1846. **Fig. 11:** Scitulus ammonite zone, GGU 234 123, K185/4, LVR 1.2433, MI 1757. **Fig. 12:** Eudoxus ammonite zone, GGU 245 891, L147/8, LVR 1.2142, MI 1523.

Kimmeridgian- Milne Länd



20 μ m

Plate 18

Figs 1-5, 7. *Gochteodinia mutabilis* (Riley) Below, 1990. Shape of main-body and length of antenna varies; all from Wheatlyensis ammonite zone, GGU 234 121, K173/4, /11 & /12. **Figs 1 & 4:** LVR 1.2468-67, MI 1790. **Fig. 2:** LVR 1.2490, MI 1810. **Fig. 3:** LVR 1.2457, MI 1781. **Fig. 5:** LVR 1.2511, MI 1826. **Fig. 7:** LVR 1.2524, MI 1837. Magnification of fig. 4 is approximately x 0.6 in relation to the other figures on the plate.

Fig. 8. *Gochteodini mutabilis* var.?, short main-body and apical horn but otherwise very similar to *G. mutabilis*, Elegans/Wheatlyensis ammonite zones, GGU 234 127, K40/7, LVR 1.2547, MI 1858.

Figs 6, 9-12. *Paragonyaulacysta capillosa* (Brideaux & Fisher) Stover & Evitt, 1978. Fig. 6: Eudoxus / Autissiodorensis ammonite zones, GGU 234 105, K33/8, LVR 1.2300, MI 1643. **Figs 9-10:** Eudoxus ammonite zone, GGU 234 101, K31/4, LVR 1.2296, MI 1639 & LVR 1.2268, MI 1615. **Fig. 11:** Eudoxus ammonite zone, GGU 245 894, K102/6, LVR 1.2201, MI 1564. **Fig. 12:** Eudoxus / Autissiodorensis ammonite zones, GGU 234 105, K33/8, LVR 1.2298, MI 1641.

Kimmeridgian - Milne Land

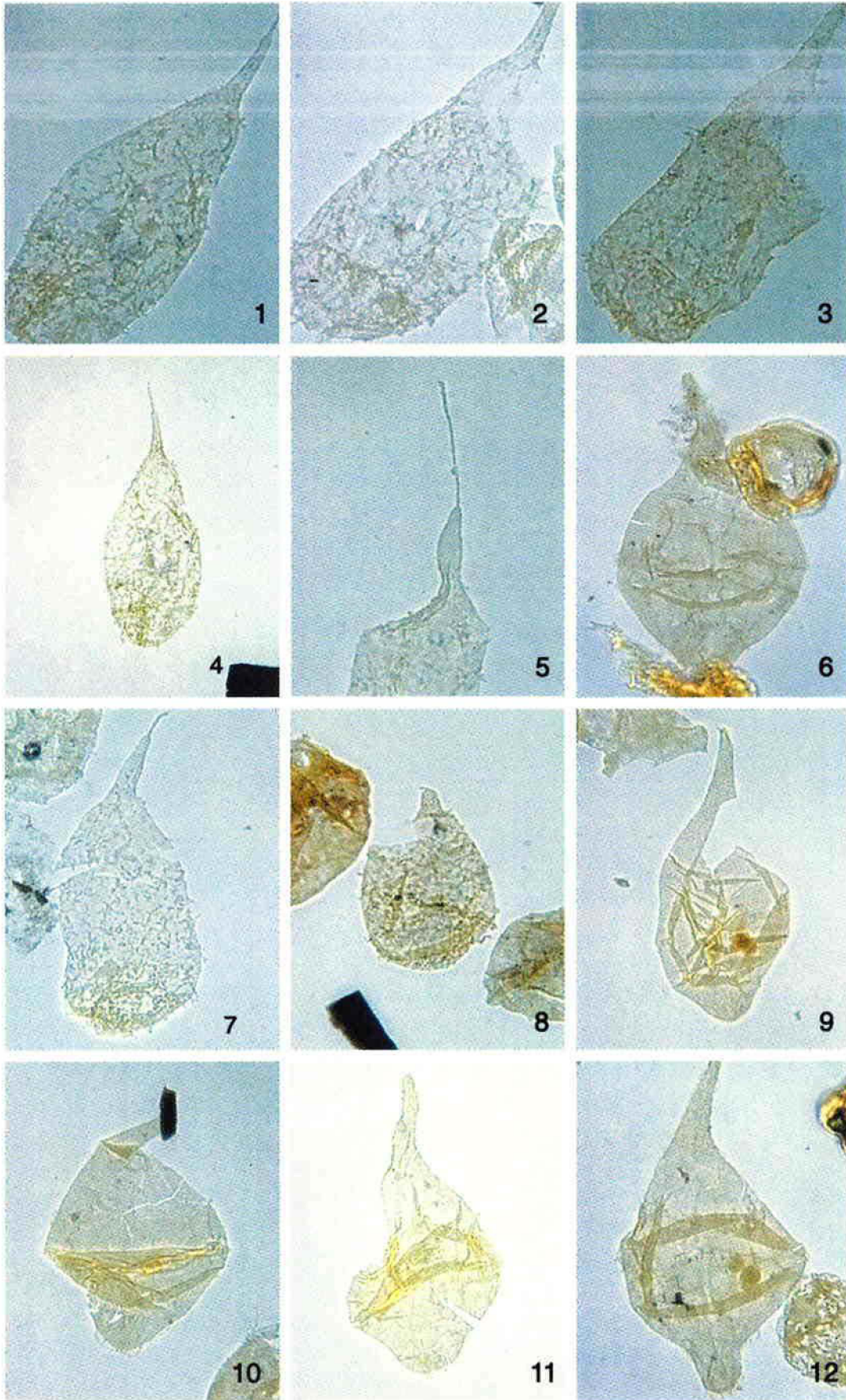


Plate 19

Figs 1-2. *Ctenidodinium tenellum* Deflandre, 1938. **Fig. 1:** Eudoxus / Autissiodorensis ammonite zones, GGU 234 105, K37/3, LVR 1.2363, MI 1695. **Fig. 2:** *Wheatlyensis* ammonite zone, GGU 234 121, K173/11, LVR 1.2479, MI 1802.

Fig. 3. *Stephanelytron redcliffense* (Sarjeant) Stover *et al.*, 1977, Elegans/Wheatlyensis ammonite zones GGU 234 127, K40/8, LVR 1.2561, MI 1870.

Figs 4-5. *Leiosphaeridia* sp., smooth and partly degraded, respectively. **Fig. 4:** Mutabilis / Eudoxus ammonite zones, GGU 245 878, L 144/9, LVR 1.2071, MI 1466. **Fig. 5:** *Wheatlyensis* ammonite zone, GGU 234 121, K173/11, LVR 1.2481, MI 1804.

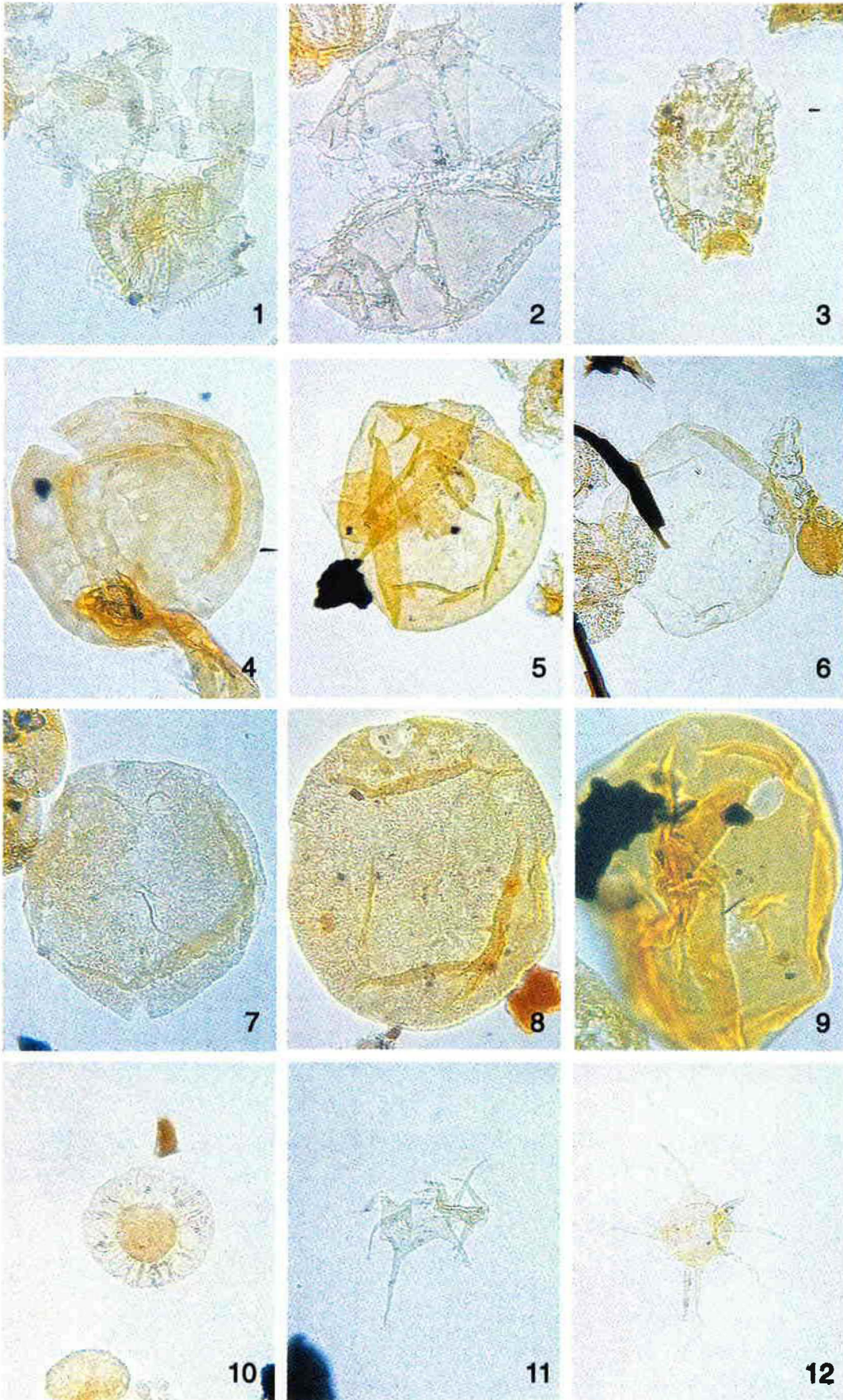
Fig. 6. *Leiosphaeridia* sp. 2, very thin-walled, *Wheatlyensis* ammonite zone, GGU 234 121, K173/11, LVR 1.2493, MI 1813.

Figs 7-9. ?*Nummus similis* (Cookson & Eisenack) Burger, 1980, with foveo-reticulate surface and circular aperture with thickened rim, approximately in "polar" position. **Fig. 7:** Eudoxus ammonite zone, GGU 245 896, L148/9, LVR 1.2220, MI 1581. **Fig. 8:** Autissiodorensis ammonite zone GGU 234 111, K170/6, LVR 1.2563, MI 1873. **Fig. 9:** GGU 245 894, K102/6, LVR 1.2176, MI 1546.

Fig. 10. *Pterospermella* spp., *Wheatlyensis* ammonite zone, GGU 234 121, K173/12, LVR 1.2460, MI 1784.

Figs 11-12. *Veryhachium* spp. **Fig. 11:** Eudoxus ammonite zone, GGU 234 101, K31/4, LVR 1.2281, MI 1627. **Fig. 12:** Autissiodorensis ammonite zone GGU 234 106, K34/4, LVR 1.2324, MI 1660.

Kimmeridgian - Milne Land



20 μ m

Plate 20

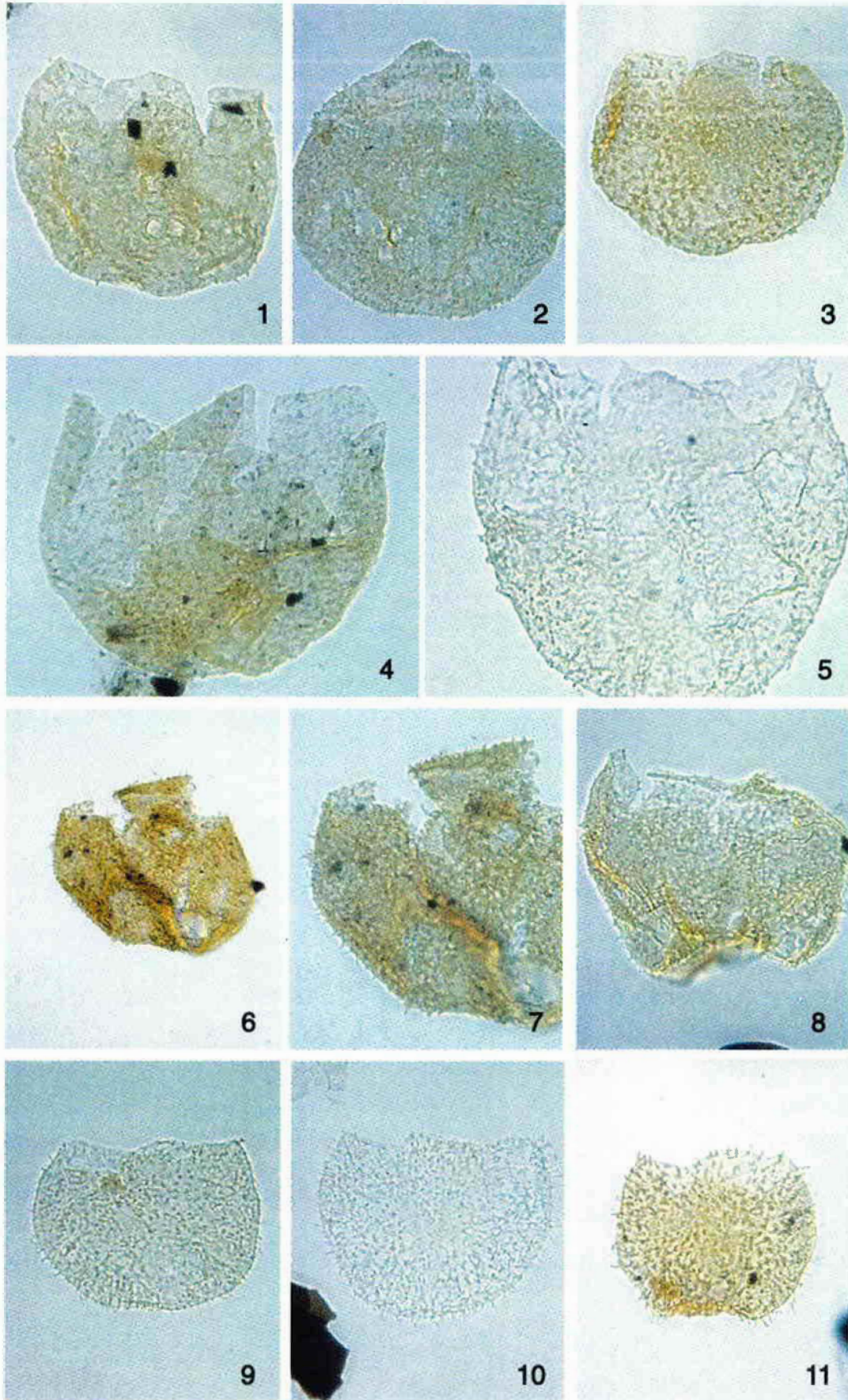
Figs 1-2,4: *Circulodinium downei* comb. nov. (*Acanthaulax downei* Sarjeant 1960) Elegans/Wheatlyensis ammonite zones, GGU 234 127, K40/3. **Fig. 1:** LVR 1.3748, MI 2467. **Fig. 2:** LVR 1.3791, MI 2795. **Fig. 4:** LVR 1.3723, MI 2742. **Fig. 3:** *Circulodinium downei* comb. nov. (*Acanthaulax downei* Sarjeant 1960), Pseudoapertum ammonite zone, GGU 245 676, L115/3, LVR 1.4158, MI 3101.

Fig. 5: *Circulodinium* sp., Elegans/Wheatlyensis ammonite zones, GGU 234 121, K173/11, LVR 1.2462, MI 1786 (possibly *C. downei*).

Figs 6-8: *Circulodinium* sp. 2. **Figs 6-7:** Wheatlyensis ammonite zone, GGU 245 787, L142/2, LVR 1.3861-62, MI 2861. **Fig. 8:** Wheatlyensis/Pectinatus ammonite zone, GGU 245 790, K47/2, LVR 1.3907, MI 2890. Surface sculpture similar to sculpture of *Trichodinium* aff. *ciliatum* but clearly with an apical archaeopyle.

Figs 9-11: *Circulodinium* sp. 3 (?*Tenua hystrix* Eisenack 1958). **Fig. 9:** Pseudoapertum ammonite zone, GGU 245 676, L115/7, LVR 1.4148, MI 3092. **Fig. 10:** Liostracus/Gracilis ammonite zones, GGU 245 686, L117/9, LVR 1.4141, MI 3085. **Fig. 11:** Pectinatus/Rugosus ammonite zones, GGU 245 758, L140/2, LVR 1.3989, MI 2960.

Voigian - Milne Land



20 μm

Plate 21

Figs 1-3. *Sentusidinium* sp. C. **Figs 1-2:** Scitilus ammonite zone, GGU 234 127, K40/3, LVR 1.3728 & 3714, MI 2747 & 2744. **Fig. 3:** Iatriensis ammonite zone, GGU 245 758, L140/2, LVR 1.3987, MI 2958.

Figs 4-6. *Sentusidinium sparsibarbatum* Erkmen & Sarjeant, 1980. **Figs 4-5:** Cymodoce / Mutabilis ammonite zones, GGU 245 869, L84/3, LVR 1.2749 & 2751, MI 2033 & 2035. **Fig. 6.** Rosenkrantzi ammonite zone, GGU 245 826, L72/4, LVR 1.2937, MI 2210. Spines with swollen, hollow bases.

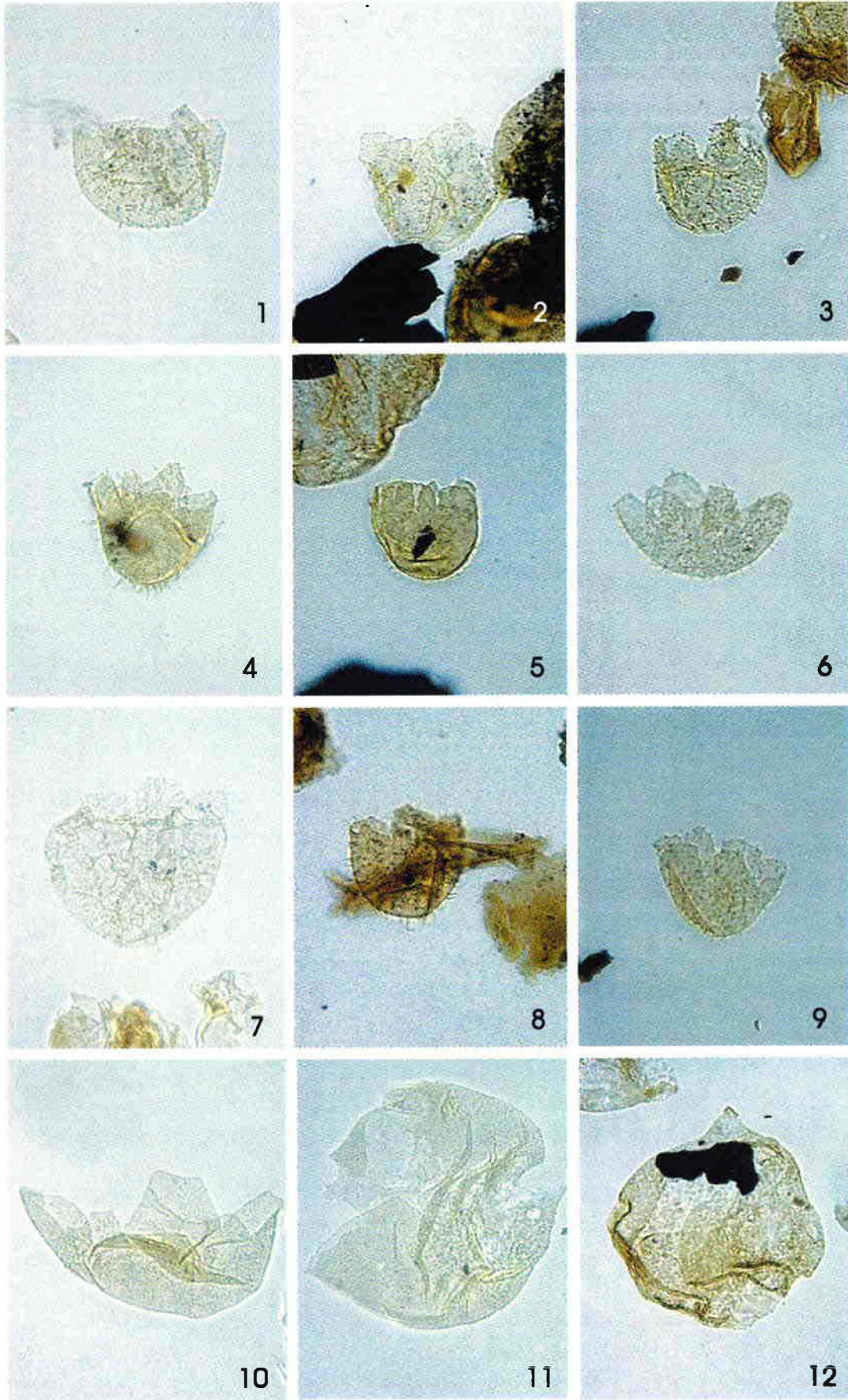
Fig. 7. *Sentusidinium* sp. D Fensome, 1979, Mutabilis / Eudoxus ammonite zones, GGU 245 878, L144/7, LVR 1.2817 MI 2103.

Figs 8-9. *Sentusidinium* cf. *sparsibarbatum*. **Fig. 8:** Cymodoce / Mutabilis ammonite zones, GGU 245 869, L84/7, LVR 1.2994, MI 2252. **Fig. 9:** Mutabilis ammonite zone, GGU 245 873, K97/3, LVR 1.3018, MI 2273.

Fig. 10. *Sentusidinium pelionense* Fensome, 1979, Pseudapertum ammonite zone, GGU 245 676, L115/3, LVR 1.4183, MI 3120.

Figs 11-12. *Pyxidiniopsis granulata* (Ioannides *et al.*, 1977) Lentin & Williams, 1985. **Fig. 11:** Hudlestoni ammonite zone, GGU 245 790, L115/3, LVR 1.3925, MI 2911. **Fig. 12:** Wheatlyensis / Hudlestoni ammonite zones, GGU 245 787, L142/8, LVR 1.3887, MI 2880.

Volgian - Milne Land



20 μm

Plate 22

Figs 1-3: *Kleithriasphaeridium porosispinum* Davey, 1982, Pseudoapertum ammonite zone, GGU 245 673, K227/7, LVR 1.4185-86 & 4192, MI 3122 & 3127.

Figs 4-6. *Criboperidinium granulatum* group. **Figs 4-5:** Pseudapertum ammonite zone, GGU 245 676, L115/3, LVR 1.4176 & 4161, MI 3115 & 3104. **Fig. 6:** Liostracum ammonite zone, GGU 245 686, L117/3, LVR 1.4131, MI 3077.

Figs 7-9. *Criboperidinium* cf. *longicorne* (Downie) Lentin & Williams, 1985, Liostracum ammonite zone, GGU 245 686, L117/3, LVR 1.4020-1 & 4124, MI 3069 & 3072. (Figs 7 & 9 with reduced magnification; x 0.6).

Figs 10-12. *Rhyncodiniopsis pennata* Fisher & Riley, 1980. **Fig. 10:** Eudoxus ammonite zone, GGU 245 891, L147/3, LVR 1.3602, MI 2632. **Fig. 11:** Scitulus ammonite zone, GGU 234 127, K40/3, LVR 1.3734, MI 2632. **Fig. 12:** Wheatleyensis / Hudlestoni ammonite zones, GGU 245 790, K47/2, LVR 1.3923, MI 2909.

Volgian - Milne Land

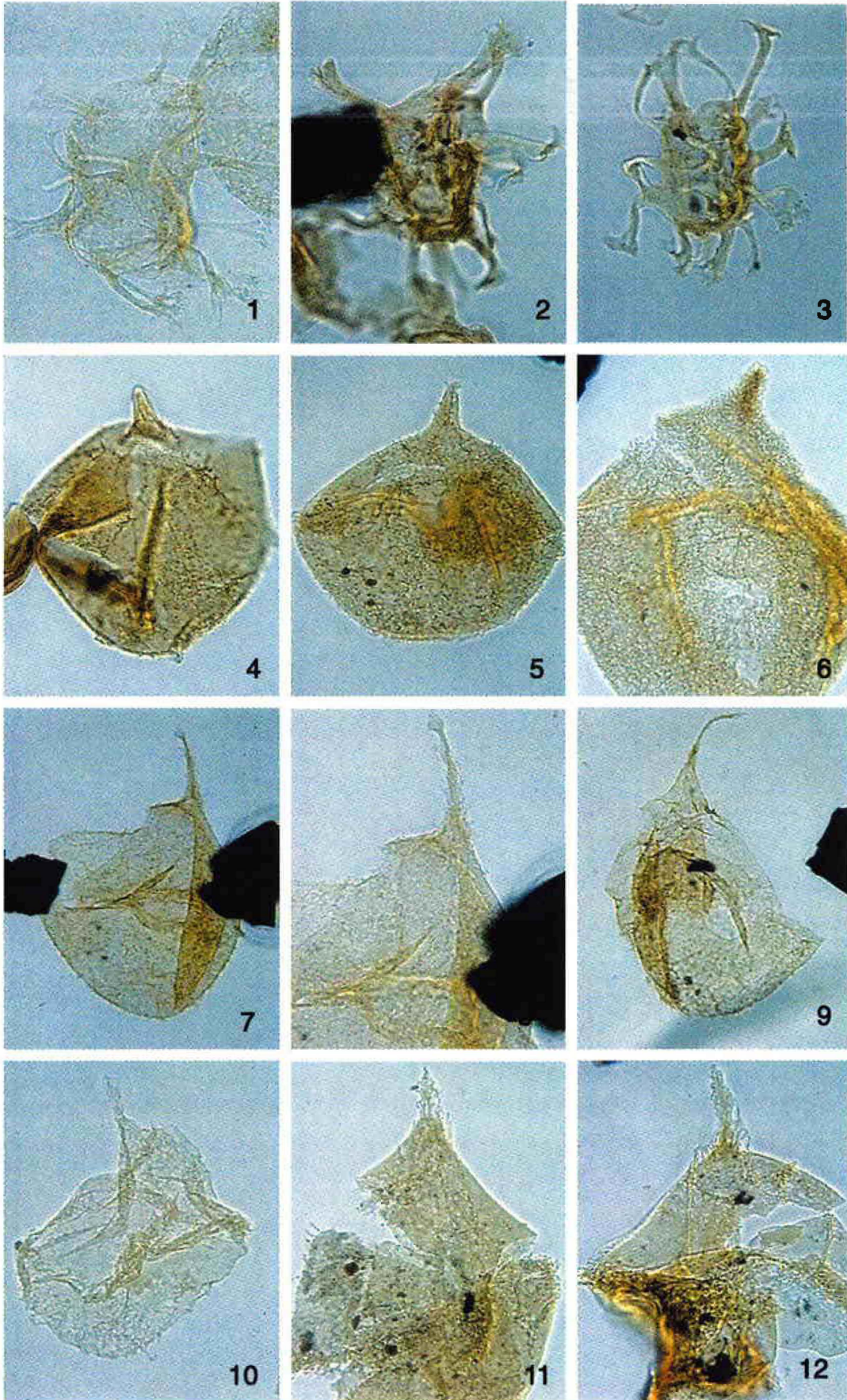


Plate 23

Figs 1-3. *Kleithriasphaeridium telaspinosum* (Fisher & Riley) Lentin & Williams, 1981, Wheatlyensis ammonite zone, GGU 234 121, K173/4, LVR 1.2518-19, MI 1832 & LVR 1.2500, MI 1819.

Figs 4-6. *Kleithriasphaeridium* cf. *corrugatum* Davey, 1974. **Fig. 4:** Liostracus - Ilovaisky ammonite zones, GGU 245 686, L117/3, LVR 1.4127, MI 3073. **Figs 5-6:** Pseudapertum ammonite zone, GGU 245 676, L115/7, LVR 1.4145-46, MI 3089-90.

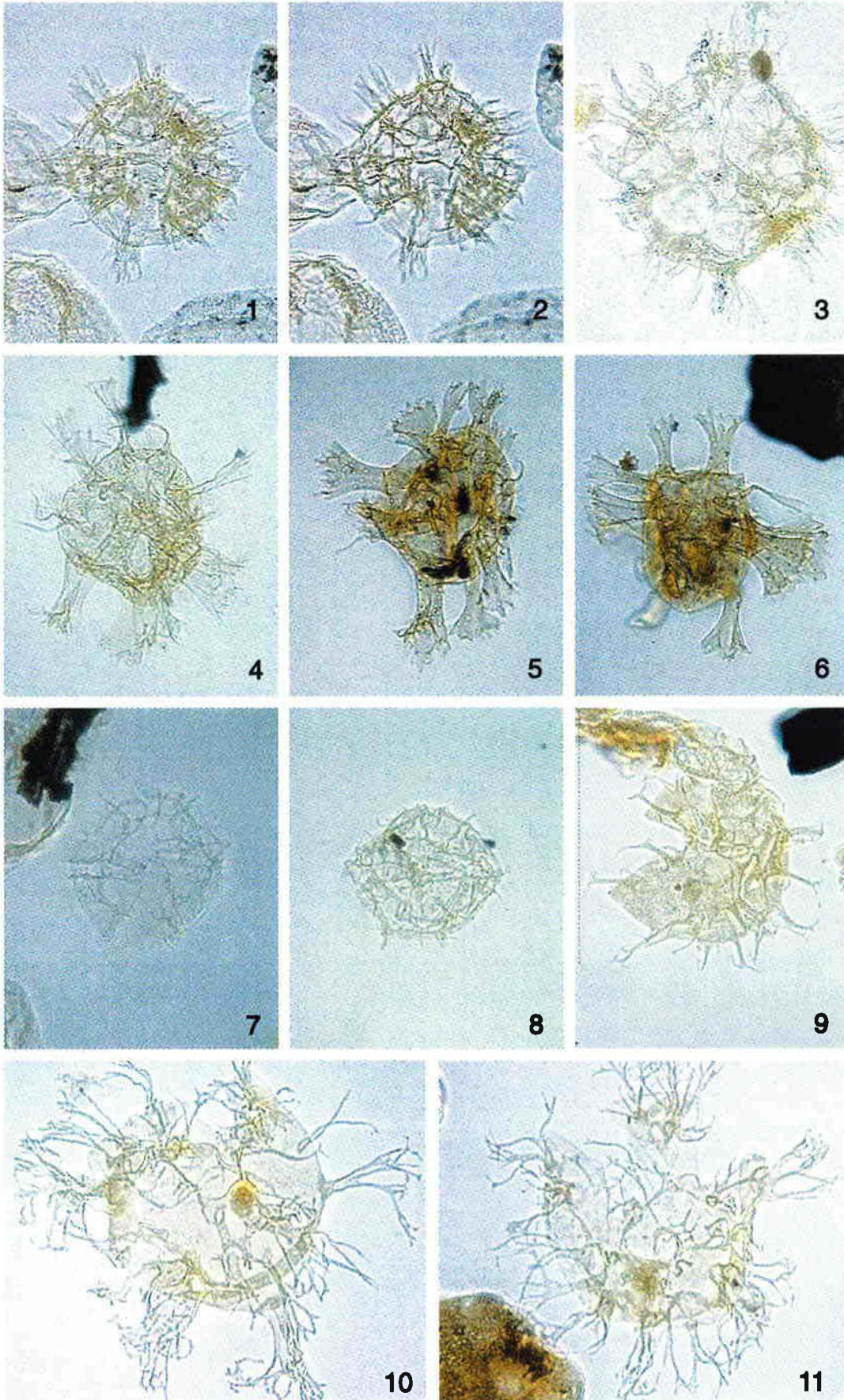
Figs 7-8. *Dichadogoryaulax cumula* (Norris, 1965) Loeblich & Loeblich, 1968. **Fig. 7:** Anguinus ammonite zone, GGU 234 196, L53/10, LVR 1.4198, MI 3132. **Fig. 8:** Pseudapertum ammonite zone, GGU 245 673, K227/6, LVR 1.4193, MI 3128.

Fig. 9. *Avellodinium* cf. *falcificum* Duxbury, 1977, Wheatlyensis / Hudlestoni Zones, GGU 245 787, L142/8, LVR 1.3892, MI 2883.

Fig. 10. *Systematophora fasciculigera* Klement, 1960, Communis / Rugosa ammonite zones, GGU 245 894, K102/6, LVR 1.2189, MI 1555.

Fig. 11. *Kleithriasphaeridium porosipinum* Davey, 1982, Anguinus Zone, GGU 234 198, L54/10, LVR 1.4326, MI 3235.

Volgian- Milne Land



20µm

Plate 24

Figs 1-2. *Senoniasphaera "janei"*. Fig. 1: Pseudoapertum ammonite zone, GGU 245 676, L115/3, LVR 1.4154, MI 3098. **Fig. 2:** LVR 1.3903, MI 2892, GGU 245 790, K47/2.

Fig. 3. *Muderongia sp. A* Davey, 1982, Anguinus ammonite zone, GGU 234 196, L53/10, LVR 1.4196, MI 3131.

Figs 4-5. *Tubotuberella "sphaerocephalis"* Vozzhennikova, 1967. **Fig. 4:** Wheatlyensis ammonite zone, GGU 234 121, K173/11, LVR 1.2509, MI 1825. **Fig. 5:** Wheatlyensis / Hudlestoni ammonite zones, GGU 245 787, L142/8LVR 1.3886, MI 2879.

Fig. 6. *Mendicodinium groenlandicum* (Pocock & Sarjeant 1972) Davey, 1979, Pseudapertum ammonite zone, GGU 245 676, L115/3, LVR 1.3996, MI 3103.

Figs 7-9. *Escharisphaeridia pocockii* (Sarjeant 1968) Erkmen & Sarjeant, 1980, (*Canningia* cf. *compta*, Statoil). **Fig. 7:** Eudoxus ammonite zone, GGU 245 891, L147/3, LVR 1.3605, MI 2634. **Fig. 8:** Cymodoce / Mutabilis ammonite zones, GGU 245 869, L84/7LVR 1.3004, MI 2261. **Fig. 9:** Eudoxus ammonite zone, GGU 245 891, L147/3, LVR 1.3603, MI 2633.

Figs 10-12. *Trichodinium "simplicum"*. Fig. 10: Scitulus ammonite zone, GGU 234 127, K40/7, LVR 1.2550, MI 1861. **Fig. 11:** Wheatlyensis / Hudlestoni ammonite zones, GGU 245 790, K47/2, LVR 1.3921, MI 2907. **Fig. 12:** Scitulus ammonite zone, GGU 234 123, K185/4, LVR 1.3432, MI 1756.

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