Late Bathonian to Early Oxfordian dinoflagellate cyst stratigraphy of Jameson Land and Milne Land, East Greenland

Morten Smelror

The stratigraphic distribution of Upper Bathonian to early Middle Oxfordian dinoflagellate cysts from localities in Jameson Land and in Milne Land, East Greenland, is evaluated. Using the range of selected species, their earliest appearances and/or extinction, six dinoflagellate cyst zones and five subzones are proposed for the upper Middle and lower Upper Jurassic succession of central East Greenland. The proposed zonation scheme is correlated with the ammonite zonation of the investigated interval. Two new species, *Chytroeisphaeridia grossa* sp. nov. and *Escharisphaeridia laevigata* sp. nov. are formally described.

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Jurassic dinoflagellate cysts were first described from East Greenland by Sarjeant (1972), who recorded 51 species in two samples from the Vardekløft and Olympen Formations of Jameson Land. The results of a more extensive palynological study were published by Fensome (1979) who described 74 species of dinoflagellate cysts and acritarchs from Bajocian to Volgian strata. An important palynostratigraphic contribution was given by Piasecki (1980) who outlined the stratigraphic distribution of 95 dinoflagellate cyst species through the Upper Callovian to Volgian sequence of Milne Land. Piasecki proposed a dinoflagellate cyst zonation scheme which he correlated with the Jurassic ammonite zonation of East Greenland. Additional data on the dinoflagellate cyst stratigraphy of the lower part of the Hareelv Formation of Jameson Land have been given by Poulsen (1985). Information on dinoflagellate cyst floras from the Middle and Upper Jurassic of Jameson Land is also found in Lund & Pedersen (1985). Data on Jurassic pollen and spores from East Greenland are published by Muir (*in* Sarjeant, 1972) and Lund & Pedersen (1985).

The objective of this study has been to provide additional information on upper Middle and lower Upper Jurassic dinoflagellate cyst floras from Jameson Land and Milne Land, and to synthesise the previously published data on upper Middle and lower Upper Jurassic dinoflagellate cyst stratigraphy of East Greenland.

Geological framework

The Mesozoic rocks in central East Greenland are exposed in a basin 800 km long and a maximum of 140 km wide, which contains an up to 5 km thickness of sediments (Surlyk, 1978). The principal area of occurrence is in Jameson Land – Milne Land (fig. 1), the succession in Jameson Land being the most complete and best known (Surlyk *et al.,* 1973). The Jurassic basin was formed as a north–south trending graben system, which opened up from south to north, and thus was transgressed in consecutively later Jurassic times in a northward direction (Surlyk, 1978). The initial Jurassic transgression of the Jameson Land area took place in the Pliensbachian, while the irregular basement surface of Milne Land (bordering the Jameson Land basin to the west) was inundated for the first time in the Late Bathonian (Callomon & Birkelund, 1980). By this time fully marine conditions were established on the Jameson Land area (Surlyk, 1978). A general map of Middle Jurassic (Bathonian–Callovian) palaeogeography and facies of East Greenland is shown on fig. 2.

Descriptions of the stratigraphy of the Jurassic and Lower Cretaceous sediments of Jameson Land are given by Surlyk *et al.* (1973) and Surlyk & Zakharov (1982). Descriptions of the upper Middle and Upper Jurassic stratigraphy of Milne Land are given by Callomon & Birkelund (1980). Comparisons of the Bathonian to Oxfordian deposits of northern Jameson Land and the east coast of Milne Land in relation to the ammonite zonation are shown in fig.

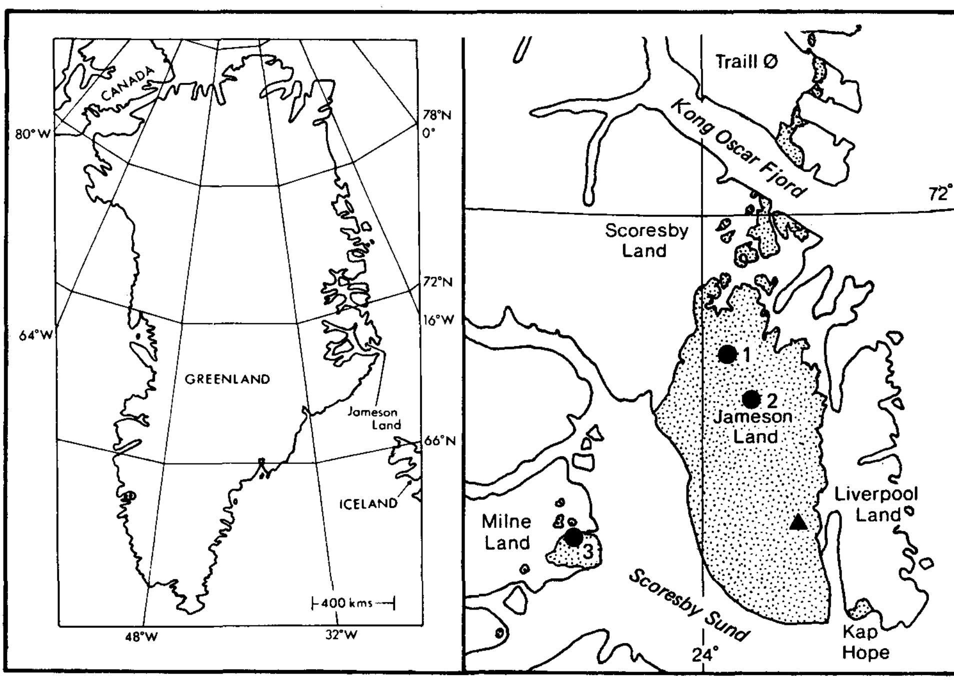

Fig. 1. Map of Milne Land and Jameson Land, East Greenland, showing the location of the studied sections. (Black dots: sections studied by the present author, black triangle: section studied by Poulsen, 1985.) 1: Fossilbjerget, 2: Olympen, 3: Kosmocerasdal.

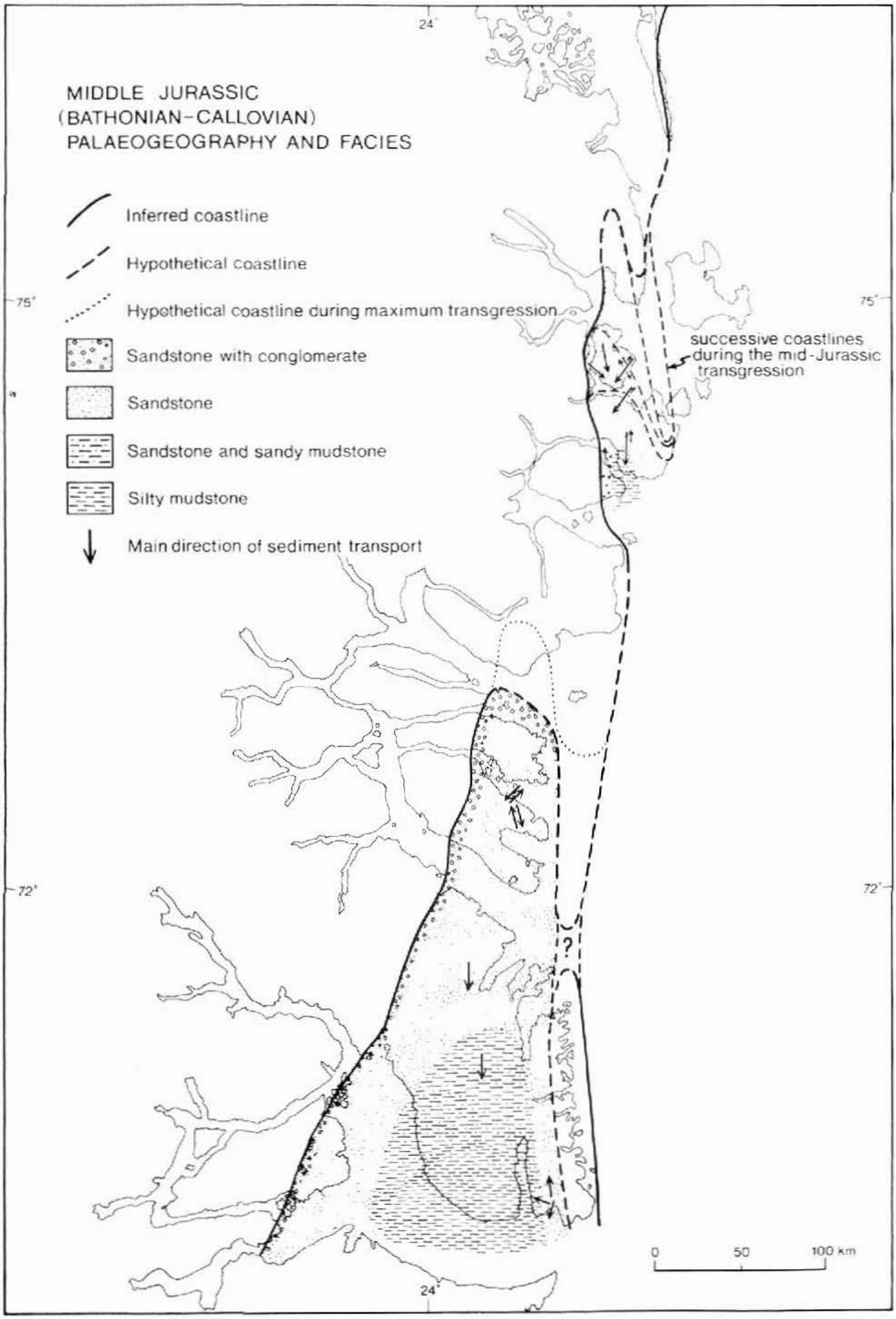

Fig. 2. Middle Jurassic palaeogeography and facies of East Greenland (From Surlyk, 1977).

3. As shown in fig. 3, the present study deals with material from the Fossilbjerget Member (Vardekløft Formation) and the lower Olympen Formation in Jameson Land, and from the Kosmocerasdal Member (Kap Leslie Formation) in Milne Land. Previously published data from the lower part of the Hareelv Formation in Jameson Land are included in the biostratigraphic synthesis.

The Fossilbjerget Member (Vardekløft Formation) in Jameson Land comprises silty, micaceous, non-argillaceous shales with subordinate fine-grained sandstone horizons, the lower part being more sandy than the upper part. Numerous horizons with phosphatic nodules, concretionary, indurated silt or fine-sand bodies, and calcareous concretions occur throughout the formation (Surlyk *et al.*, 1973). Many horizons are extremely fossiliferous, ammonites and belemnites dominating, and a number of trace fossil assemblages occur through the whole sequence. In the upper part fossil wood is widespread, including large petrified tree-trunks.

The upper boundary of the Vardekløft Formation (in northern Jameson Land) is marked by a sharp change in sedimentation to light sandstones of the Olympen Formation. The Olympen Formation shows a characteristic tripartite development. The lower unit consists of medium-grained, light-coloured, well sorted sands or massive sandstones, intercalated with subordinate laminated, dark, silty shales or fine laminated sands. The middle unit consists of dark silty shales passing upwards into gradually more sandy shales. The upper unit is developed as massive, cliff-forming, medium to coarse-grained, well-sorted sandstones with subordinate intercalations of silty shales (Surlyk *et al.*, 1973).

The Hareelv Formation is composed of black and grey shales with large irregular lenses

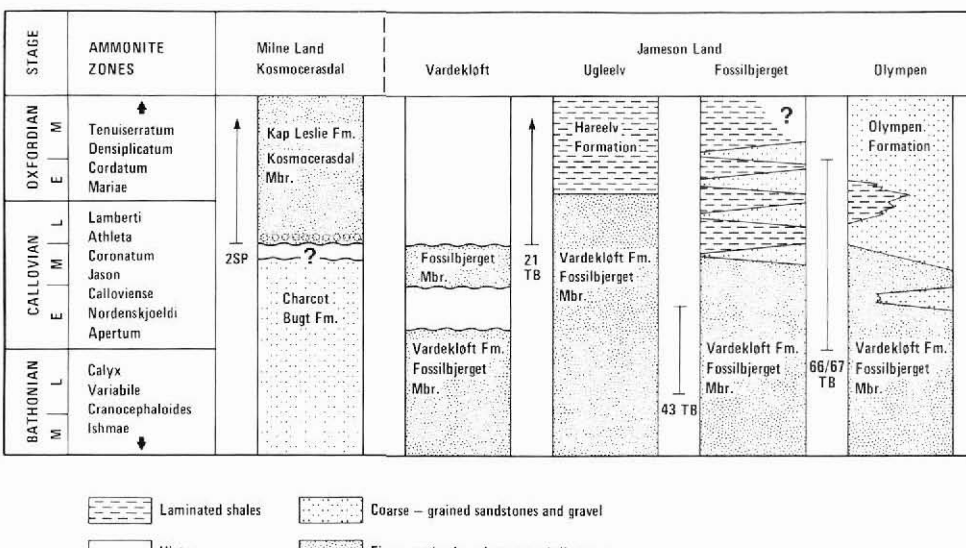

Fig. 3. Comparisons of the Middle Bathonian to Lower Oxfordian successions in Milne Land and Jameson Land. The intervals 2SP on Milne Land, and 43 TB and 66–67 TB on Jameson Land are examined during this present study. (Compiled with data from Surlyk *et al.*, 1973; Piasecki, 1980; Callomon & Birkelund, 1980; Poulsen 1985.)

and layers of yellow sandstones (Surlyk *et al.*, 1973). The shales are normally fine-grained, but also some more sandy horizons occur. The boundaries between the shales and sandstones are always sharp. The sandstones are well-sorted, medium-grained and rich in mica and sometimes glauconite. Silicified wood and charcoal are very common in the sandstones and often form the cores of the concretions found in the shales. Rare ammonites are recorded in thin hard glauconitic sandstones.

The Kosmocerasdal Member of the Kap Leslie Formation in Milne Land consists of soft, grey, bioturbated sandy siltstone, rich in plant debris. The otherwise monotonous sequence is broken by a series of concretionary levels ranging from well-spaced lenticles of merely indurated shale to large rounded yellow or rusty-weathering doggers of fine-grained sandstone locally fused into continuous beds (Callomon & Birkelund, 1980). The Kosmocerasdal Member is approximately laterally time-equivalent to the Olympen Formation in northern Jameson Land (see fig. 3).

Material and methods

The samples investigated in the present study are from Fossilbjerget and Olympen in northern Jameson Land (figs 1, 2), and from Kosmocerasdal in Milne Land (see location map fig. 1 in Callomon & Birkelund, 1980 and the present figs 1, 2). The material from northern Jameson Land was collected by T. Birkelund (profiles 66–67 TB and 43 TB), and the samples from Milne Land by S. Piasecki (profile 2SP).

From the section at Fossilbjerget (profile 43 TB), six samples covering the interval from the *Variabile* Zone to the *Nordenskjoeldi* Zone of the Vardekløft Formation have been examined (i.e. from the Fossilbjerget Member). From the section at Olympen (profile 66–67 TB), eighteen samples of the Vardekløft Formation and three samples of the Olympen Formation have been analysed. These samples range in age from the *Apertum* Zone (earliest Callovian) to the *Mariae* Zone (earliest Oxfordian).

From the Kosmocerasdal section in Milne Land (profile 2SP), thirteen samples from the Kap Leslie Formation (Kosmocerasdal Member) have been included in this study. The samples range from Callovian to the Early Oxfordian *Cordatum* Zone.

All sample numbers (GGU prefix) refer to the sample collection of the Geological Survey of Greenland, Copenhagen, Denmark; details on stratigraphic level and lithology of the investigated samples can be obtained from GGU. The samples were prepared by standard palynological techniques at the Continental Shelf and Petroleum Technology Research Institute (in Trondheim, Norway). Slides and SEM-stubs with the illustrated specimens are lodged in the collections of the Geological Museum, Copenhagen (refered to by MGUH numbers).

Remarks on dinoflagellate cyst frequency distribution

All samples investigated yielded relatively abundant, mostly moderately to well preserved, palynomorph assemblages. Terrestrially derived organic material dominates the overall palynofacies in all examined intervals, with gymnospermous pollen (in some samples *Cerebropollenites* spp. and *Callialasporites*) and bisaccate pollen dominating among the palynomorphs. Dinoflagellate cysts are numerically subordinate to pollen in all examined samples. The number of marine species recorded in each sample varies between 3 and 21, with the highest number of species recorded from the *Calloviense* and *Nordenskjoeldi* ammonite Zones.

Several of the recorded dinoflagellate cyst species show characteristic peaks in their abundance at various intervals. In the Upper Bathonian of Jameson Land, a peak in the abundance of *Lacrymodinium warrenii* has been observed in the *Calyx* Zone at the Fossilbjerget section. Apart from this species, no other marine taxa appear to be prominent in the Upper Bathonian – Lower Callovian (*Variabile* Zone – *Nordenskjoeldi* Zone) interval of the Fossilbjerget Member at Fossilbjerget. In the Lower Callovian strata at Olympen a peak in the abundance of *Endoscrinium galeritum* has been observed in one sample from the *Apertum* Zone. *Chlamydophorella ectotabulata* appears to be most frequent in samples examined from the *Nordenskjoeldi* Zone. Of further note are the peaks in the frequency distribution of *Chytroeisphaeridia grossa* sp. nov. within the Early Callovian *Nordenskjoeldi* and *Calloviense* Zones. This species also shows a relatively high abundance in the earliest sample of the earliest Oxfordian *Mariae* Zone at Olympen. The lowermost Oxfordian interval of the Olympen Formation is here further characterized by distinct peaks in the abundance of *Rhynchodiniopsis cladophora* and *Liesbergia scarburghensis*.

In the Late Callovian *Athleta* and *Lamberti* Zones at Kosmocerasdal in Milne Land, observable peaks in the abundance of *Gonyaulacysta jurassica, Escharisphaeridia laevigata* sp. nov., *Chlamydophorella ectotabulata, Rhynchodiniopsis cladophora, Ctenidodinium continuum* and *Mendicodinium groenlandicum* are seen at various horizons. Peaks in the abundance of *Mendicodinium groenlandicum* within the latest Callovian have earlier been observed within the Hareelv Formation on Jameson Land (Poulsen, 1985) and elsewhere in North-West Europe (Riley & Fenton, 1982). Furthermore this species is reported to have its highest abundance at the Callovian – Oxfordian boundary in Kong Karls Land (Smelror, in press) and in the Swiss Jura (Berger, 1986).

The Early Oxfordian *Cordatum* Zone is at Kosmocerasdal characterized by the incoming of relatively abundant *Rigaudella aemula,* and further by a relative increase in the abundance of *Liesbergia scarburghensis* compared with the Upper Callovian – lowermost Oxfordian interval below. Based on material from the Upper Jurassic of Great Britain and the central part of the North Sea, Raynaud (1978) noted a similar peak in the abundance of *L. scarburghensis* (registered as *Gonyaulacysta areolata*) within the *Cordatum* ammonite Zone. Riley & Fenton (1982), Woollam & Riding (1983) and Berger (1986), however, pointed out a characteristic increase in the abundance of this species near the base of the earliest Oxfordian *Mariae* Zone. Smelror (in press) also observed a distinct peak in the abundance of the species within the lowermost Oxfordian in Kong Karls Land, Svalbard.

Dinoflagellate cyst stratigraphy: discussion

There are several publications on European Jurassic dinoflagellate cyst biostratigraphy established in sequences with ammonite control, i.e. the ranges of cyst taxa are defined in terms of ammonite zones. The most important contributions with respect to the stratigraphic interval included in this present study are those published by Riley & Fenton (1982) and Woollam & Riding (1983). The contribution of Woollam & Riding (1983) also includes a review and correlations with previously published dinoflagellate cyst zonations within the late Triassic to early Cretaceous. Comparisons of the dinoflagellate cyst zonation schemes proposed for the late Middle and early Late Jurassic by Riley & Fenton (1982) and Woollam

STAGES	AMMONITE ZONES (NW EUROPE)	DINOCYST ZONATION (Woollam & Riding 1983)		DINOCYST ZONATION (Riley & Fenton 1982)		DINOCYST ZONATION (Piasecki 1980)	
OXFORDIAN		Gonyaulacysta jurassica –Scriniodinium crystallinum				Hystrichosphaerina orbifera	
	Tenuiserratum					Adnatosphaeridium aemulum	C. cerastes
	Densiplicatum	Acanthaulax senta	b	Acanthaulax senta			A. aemulum
	Cordatum		a	Wanaea digitata	Acanthaulax areolata		S. crystallinum T. groenlandicum
	Mariae	Wanaea fimbriata			Wanaea fimbriata	Wanaea fimbriata	
CALLOVIAN	Lamberti	Wanaea thysanota	b		Mendicodinium groenlandicum	Gonyaulacysta scarburghensis	
	Athleta		a				
	Coronatum	Ctenidodinium ornatum – Ctenidodinium continuum		Polystephanephorus paracalathus	Kalyptea stegasta	Gonyaulacysta jurassica	
	Jason				Nannoceratopsis pellucida		
	Calloviense			Dichadogonyaulax gochtii			
	Macrocephalus						
BATHONIAN	Discus	Ctenidodinium combazii – Ctenidodinium selwoodii	b				
	Aspidoides		a				
	Hodsoni						

Fig. 4. Comparisons of the dinoflagellate cyst zonation schemes proposed for the upper Middle and lower Upper Jurassic by Riley & Fenton (1982), Woollam & Riding (1983) and Piasecki (1980).

& Riding (1983) are shown in fig. 4, which also includes a correlation with the dinoflagellate cyst zonation of the East Greenland Jurassic proposed by Piasecki (1980).

A detailed dinoflagellate cyst stratigraphy of the Middle Callovian to Volgian on Jameson Land and Milne Land has earlier been proposed by Piasecki (1980). Middle and Upper Callovian strata were dividied into the *Gonyaulacysta jurassica* Zone covering the *Jason* and *Coronatum* ammonite Zones, and the *Gonyaulacysta scarburghensis* Zone (*G. scarburghensis* = *Acanthaulax scarburghensis*) covering the Late Callovian *Athleta* and *Lamberti* Zones. Lower and Middle Oxfordian strata were divided into the *Wanaea fimbriata* Zone, corresponding to the earliest Oxfordian *Mariae* ammonite Zone, and the *Adnatosphaeridium aemulum* Zone (*A. aemulum* = *Rigaudella aemula*) covering the *Cordatum, Densiplicatum* and partly the *Tenuiserratum* Zones. The *Adnatosphaeridium aemulum* dinocyst Zone was further divided into four subzones.

A list of the dinoflagellate cyst and acritarch species recorded from the Upper Bathonian to the Lower Oxfordian of Jameson Land and Milne Land from the investigated samples is given at the end of this paper. The stratigraphic distribution of these species in the studied sections (2SP in Milne Land and 43 TB and 66–67 TB in Jameson Land) is outlined in figs 5–7. Several of the recorded dinoflagellate cysts and acritarchs occur through the entire studied interval, while several of the other species recorded with a restricted stratigraphic distribution are known to have a wider distribution elsewhere. A few important species, however, have limited occurrence and are regarded as being of biostratigraphical importance.

Upper Bathonian – Lower Callovian

Within the Upper Bathonian and Lower Callovian sequence of East Greenland the dinoflagellate cysts *Meiourogonyaulax callomonii, Lacrymodinium warrenii, Kylindrocysta spinosa* and *Sirmiodinium grossii* appear to be usable biostratigraphic markers. According to Sarjeant (1979) *Meiourogonyaulax callomonii* has its earliest appearance within the *Aspidoides* ammonite Zone elsewhere in North-West Europe. In East Greenland this species occurs in the time-equivalent *Variabile* Zone, and ranges into lower Upper Callovian strata. In the material from East Greenland *Lacrymodinium warrenii* occurs within the Upper Bathonian and Lower Callovian, ranging from the *Variabile* Zone to the *Calloviense* Zone.

Kylindrocysta spinosa is most prominent within the Late Bajocian to the Middle Bathonian of the British Jurassic, but according to Woollam & Riding (1983) this species may range into the latest Bathonian *Discus* Zone. In East Greenland this species is observed within the Late Bathonian and the earliest Callovian *Apertum* Zone, and the extinction of this species within this ammonite zone appears to be of biostratigraphic significance.

Sirmiodinium grossii is known to have its earliest occurrence within the *Discus* Zone elsewhere in North-West Europe (Sarjeant, 1979; Woollam & Riding 1983), and the species also first appears within the time-equivalent latest Bathonian *Calyx* Zone in East Greenland. Woollam & Riding (1983) used the first appearance of this species to define the base of their *Ctenidodinium combazii – Ctenidodinium sellwoodii* (Ccb/Cs) Subzone b. Woollam & Riding (1983) further used the extinction of the key species *Ctenidodinium combazii* to define the upper boundary of their Ccb/Cs Subzone b. This species has so far not been recorded from East Greenland. Fensome (1979) described the new species *Ambonosphaera calloviana* from the *Calloviense* ammonite Zone of the Fossilbjerget Member in northern Jameson Land. In the present material this species has been recorded from the *Calloviense* Zone and undefined Middle to Upper Callovian deposits at the Olympen section and from strata of the *Athleta* Zone of the Kosmocerasdal section. The earliest incoming of this species might serve as a reliable biostratigraphic marker for the *Calloviense* Zone. Berger (1986) observed the last occurrence of *Ambonosphaera calloviana* to be within the Late Callovian *Athleta* Zone in the Berner Jura, Switzerland. This species has also been recorded within the *Athleta* Zone at the Kosmocerasdal section in Milne Land.

Piasecki (1980) used the earliest occurrence of *Gonyaulacysta jurassica* to define the base of his *Gonyaulacysta jurassica* Zone. The upper boundary was defined by the first appearance of *Liesbergia scarburghensis.* According to Piasecki the age of the zone was Early and Middle Callovian. In the range chart presented by Raynaud (1978) the earliest incoming of *Gonyaulacysta jurassica* was placed at the base of the earliest Callovian *Macrocephalus* Zone. In the present material this species has been recorded from the *Apertum* to the *Mariae* Zones at Olympen. However, this species has been recorded from Upper Bathonian deposits elsewhere in North-West Europe (Herngreen & De Boer, 1978; Fenton *et al.*, 1980; Davey & Riley, 1978; Herngreen *et al.*, 1983).

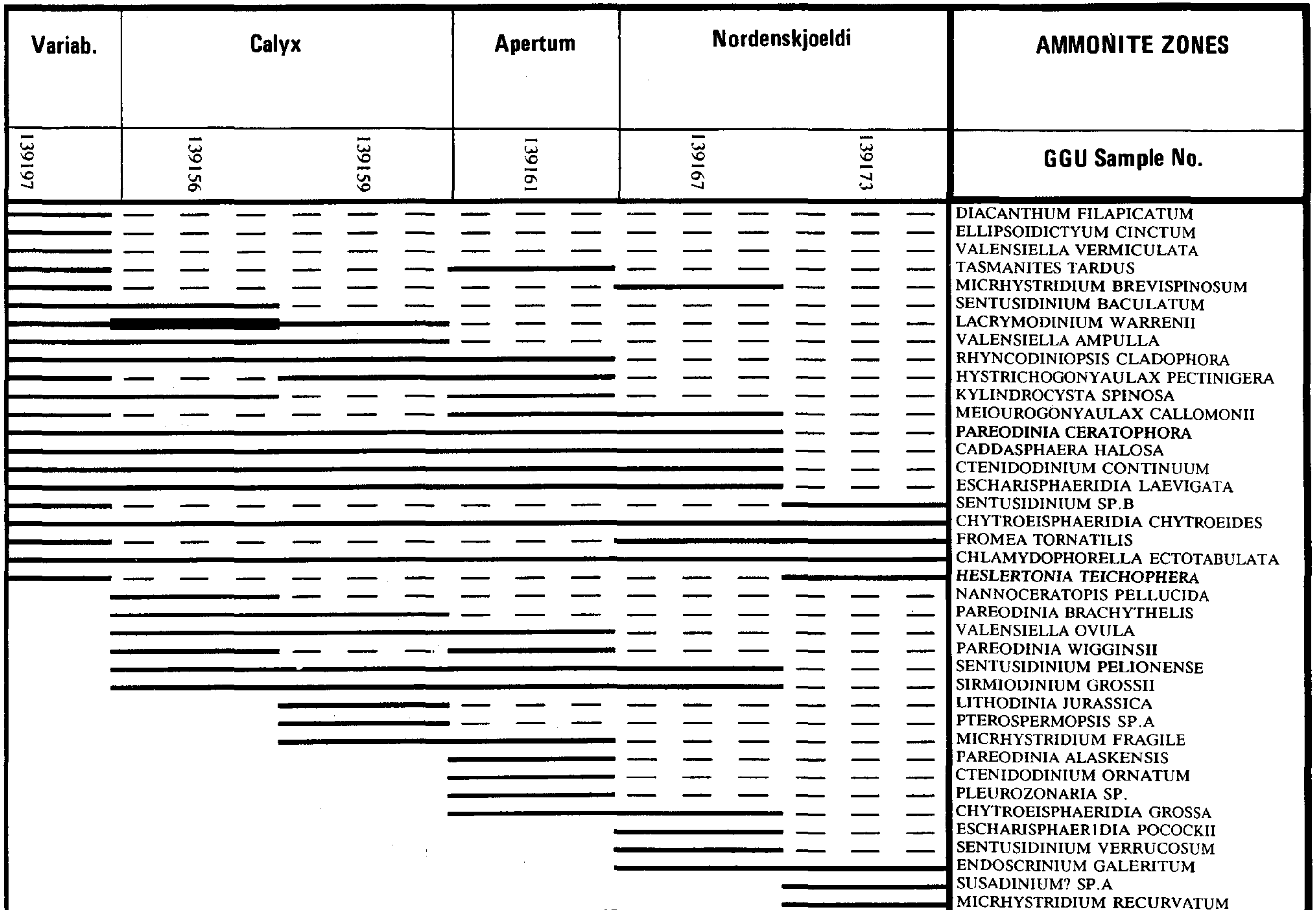

Fig. 5. Range chart of dinoflagellate cysts and acritarchs from the Fossilbjerget Member (Profil 43 TB) at Fossilbjerget, Jameson Land.

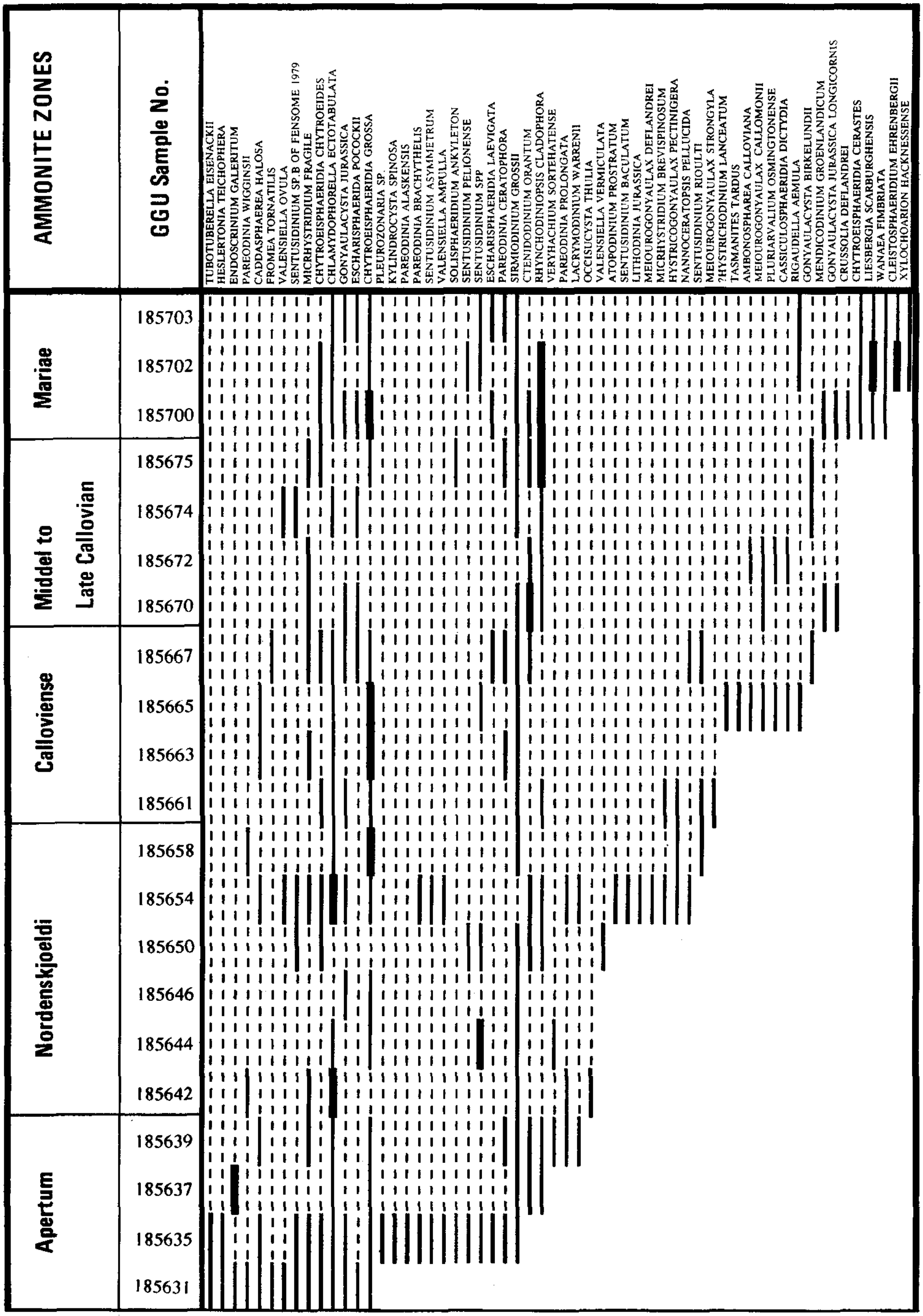

Fig. 6. Range chart of dinoflagellate cysts and acritarchs from the Fossilbjerget Member (Vardekløft Formation) and the Olympen Formation at Olympen, Jameson Land (Profil 66–67 TB).

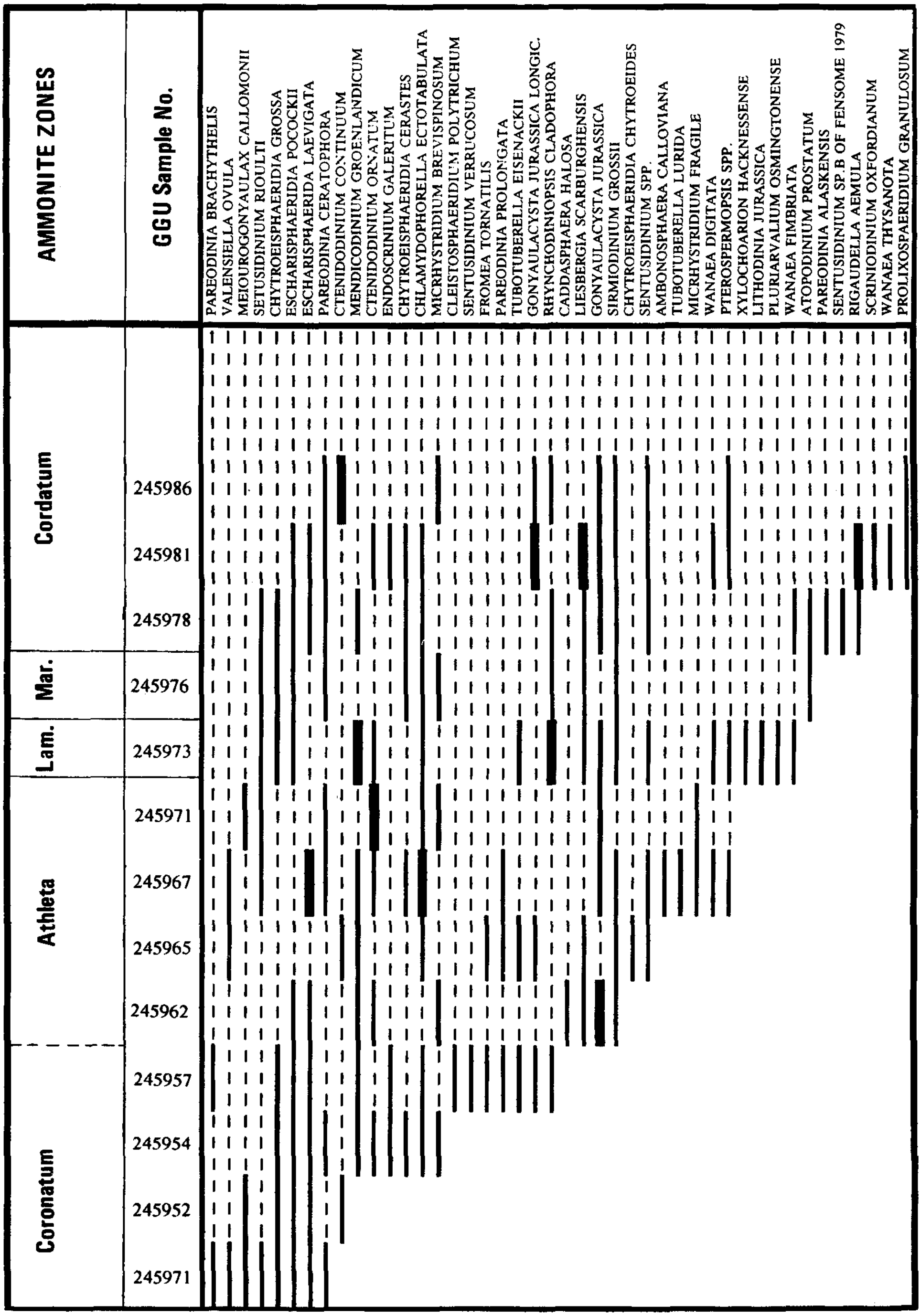

Fig. 7. Range chart of dinoflagellate cyst and acritarchs from the Kosmocerasdal Member (Kap Leslie Formation) at Kosmocerasdal, Milne Land (Profile 2SP).

Middle Callovian

The zonation schemes presented by Riley & Fenton (1982) and Woollam & Riding (1983) included both the late Early and the Middle Callovian within one single dinoflagellate cyst zone, i.e. the *Polystephanephorus paracalathus* Zone (Riley & Fenton, 1982) and the *Ctenidodinium ornatum – Ctenidodinium continuum* Zone (Woollam & Riding, 1983) respectively. Based on the present palynostratigraphic data it is not possible to give any further subdivision of this interval. Woollam & Riding (1983) used the earliest appearance of *Wanaea thysonata* to define the base of their *Wanaea thysonata* Zone. The base of this zone is equivalent to the base of the *Athleta* Zone, i.e. the base of the Late Callovian. Within the present material from East Greenland only a single specimen of *Wanaea thysonata* has been recorded from the *Cordatum* Zone of the Kosmocerasdal section, Milne Land.

Riley & Fenton (1982) defined their *Kalyptea stegasta* Subzone within the interval from the earliest appearance of *Wanaea digitata* to the earliest incoming of *Atopodinium prostatum.* The *Kalyptea stegasta* Subzone is time-equivalent to the *Coronatum* ammonite Zone, i.e. late Middle Callovian. From East Greenland *Wanaea digitata* has previously been described from the Lower Oxfordian of the Hareelv Formation (Fensome, 1979; Poulsen, 1985) in Jameson Land. In the present study this species has been recorded from the Late Callovian *Athleta* Zone and the Early Oxfordian *Cordatum* Zone at Kosmocerasdal in Milne Land. A few specimens of *Atopodinium prostatum* have been recorded from the *Nordenskjoeldi* Zone at Olympen and the *Cordatum* Zone at Kosmocerasdal.

Upper Callovian – Lower Oxfordian

Piasecki (1980) used the earliest appearance of *Liesbergia scarburghensis* to define the base of his *Gonyaulacysta scarburghensis* Zone. The top of this dinoflagellate cyst zone was defined by the first occurrence of *Wanaea fimbriata.* According to Piasecki (1980) the *Gonyaulacysta scarburghensis* Zone is equivalent to the *Athleta* and *Lamberti* Zones in Milne Land. According to Raynaud (1978) *L. scarburghensis* (recorded as *Gonyaulacysta areolata*) also occurs from the base of the *Athleta* Zone elsewhere in North-West Europe, although this species becomes more prominent within the *Lamberti* Zone and the Early Oxfordian. In East Greenland *Liesbergia scarburghensis* has previously been recorded from the uppermost Callovian and the Lower Oxfordian of the Hareelv Formation in Jameson Land (Fensome, 1979; Poulsen, 1985). In the present material this species has been recorded from the *Athleta, Lamberti, Mariae* and *Cordatum* Zones at the Kosmocerasdal section and from the *Mariae* Zone at Olympen. According to Riley & Fenton (1982) the earliest occurrence of *Liesbergia scarburghensis* is at the base of the *Lamberti* Zone. The earliest appearance of *Liesbergia scarburghensis* at the base of the *Lamberti* Zone was also used by Woollam & Riding (1983) to define the lower boundary of their *Wanaea thysanota* Subzone b. The upper boundary of this subzone was defined by the earliest appearance of *Wanaea fimbriata.* The earliest appearance of *Wanaea fimbriata* was also used by Riley & Fenton (1982) and Piasecki (1980) to define the lower boundaries of their *Wanaea fimbriata* Zones. Although the top of the *Wanaea fimbriata* Zones presented by Piasecki (1980), Riley & Fenton (1982) and Woollam & Riding (1983) were defined differently, all zones were described as equivalent to the earliest Oxfordian *Mariae* Zone, i.e. the lower boundaries of the zones correspond to the Callovian – Oxfordian boundary.

In East Greenland *Wanaea fimbriata* has been recorded from the *Mariae* Zone of the Olympen Formation in Jameson Land. In Milne Land this species is recorded within the *Mariae* and *Cordatum* Zones at the Kosmocerasdal section.

Piasecki (1980) defined the *Adnatosphaeridium aemulum* Zone as the interval from the first occurrence of *Rigaudella aemula* to the first occurrence of *Hystrichosphaerina orbifera*. The age of this zone is equivalent to the *Cordatum, Densiplicatum* and partly the *Tenuiserratum* ammonite Zones. In the present study the lower boundary has been recognized within the *Cordatum* Zone at the Kosmocerasdal section in Milne Land. However, at Olympen in Jameson Land, *Rigaudella aemula* has been recorded from the *Calloviense* Zone to the *Mariae* Zone. Poulsen (1985) further recorded this species within the uppermost Vardekløft Formation and the lower part of the Hareelv Formation at Ugleelv in Jameson Land. *Rigaudella aemula* is also known from Lower and Upper Callovian deposits elsewhere in North-West Europe (Raynaud, 1978; Riley & Fenton, 1982; Woollam & Riding, 1983).

Riley & Fenton (1982) used the earliest appearance of *Leptodinium eumorphum* and the extinction of *Wanaea digitata* to define the lower and upper boundary, respectively, of their *Acanthaulax areolata* Subzone. The age of this dinoflagellate cyst zone is Early Oxfordian, equivalent to the *Cordatum* Zone. *Leptodinium eumorphum* has so far not been recorded from Milne Land, but Poulsen (1985) found that this species first appears near the base of the Hareelv Formation at Ugleelv. Piasecki (1980) recorded the extinction of *Wanaea digitata* at the top of the *Cordatum* Zone within the Kap Leslie Formation in Milne Land. Although *Leptodinium eumorphum* seems not to be common within the Lower Oxfordian of East Greenland, the species can be used to define the *Cordatum* Zone as suggested by Riley & Fenton (1982).

Dinoflagellate cyst zonation

Most of the upper Middle and lower Upper Jurassic dinoflagellate cyst species included in the range chart presented by Riley & Fenton (1982) and Woollam & Riding (1983) have also been recorded from the contemporaneous strata in East Greenland. However, several of their key species are apparently missing in East Greenland. Thus the earlier proposed zonation schemes are only partly applicable to the East Greenland successions. The zonation scheme presented by Piasecki (1980) for the succession in Milne Land is considered too broadly defined to serve as an appropriate dinoflagellate cyst zonation of the Upper Bathonian – Middle Oxfordian. Even though most of the dinoflagellate cysts recorded are regarded as relatively long-ranging species a few forms appear to be useful as biostratigraphic markers. The stratigraphic distribution of selected dinoflagellate cysts which appear to have a well-defined range within the Upper Bathonian to the lower Middle Oxfordian of East Greenland is presented in fig. 8.

Based on the appearance, extinction and association of specific dinoflagellate cyst species a new zonation scheme covering the Upper Bathonian – Lower Oxfordian strata of the East Greenland basin is proposed here (fig. 9). The proposed zones are all related to the Late Bathonian – Middle Oxfordian ammonite zonation proposed by Callomon & Birkelund (1980). The dinoflagellate cyst zonation consists of both range zones and interval zones.

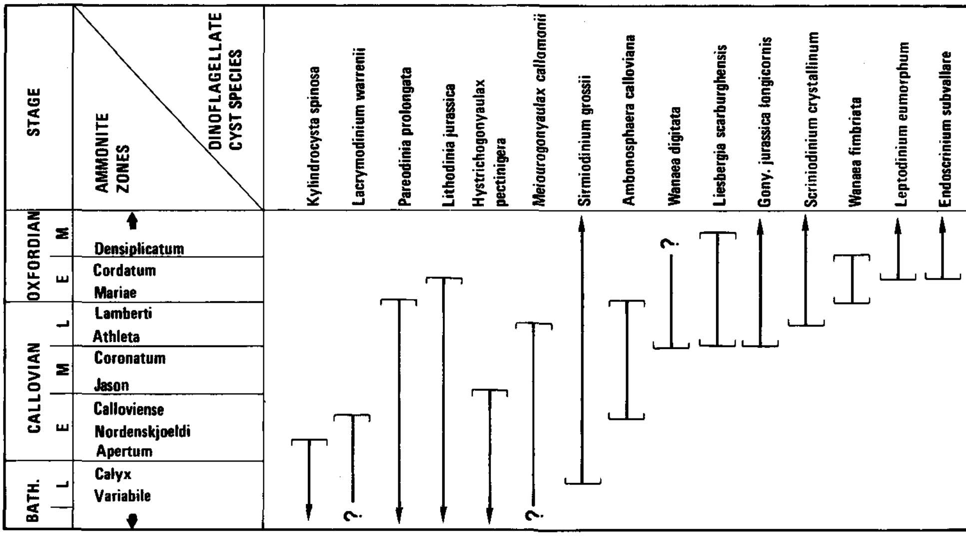

Fig. 8. Range chart of selected dinoflagellate cysts species within Upper Bathonian to lower Middle Oxfordian strata of East Greenland. Based on the present study, including some data from Fensome (1979), Piasecki (1980) and Poulsen (1985).

STAGE		AMMONITE ZONES	DINOFLAGELLATE CYST ZONES	
Oxfordian	Mi.	↑		
		Densiplicatum	Liesbergia scarburghensis	
	E.	Cordatum	Wanaea fimbriata	b
		Mariae		a
Callovian	L.	Lamberti	Mendicodinium groenlandicum	
		Athleta	Wanaea digitata	
	Mi.	Coronatum	Ambonosphaera calloviana	
		Jason		
	E.	Calloviense		
		Nordenskjoeldi	Lacrymodinium warrenii	c
		Apertum		b
Upper Bathonian		Calyx		
		Variabile		a
		↓		

Fig. 9. Dinoflagellate cyst zonation of the Upper Bathonian – Lower Oxfordian sequence of East Greenland, correlated with the ammonite stratigraphy.

Lacrymodinium warrenii Zone

Definition. Interval from the earliest appearance to the local disappearance of *Lacrymodinium warrenii* and the earliest incoming of *Ambonosphaera calloviana.*

Age. Base not determined. Recognized within the *Variabile, Calyx, Apertum* and *Nordenskjoeldi* ammonite Zones.

Subzone a. Interval from the earliest appearance of *Lacrymodinium warrenii* to the earliest incoming of *Sirmiodinium grossii.*

Age. Variabile Zone.

Subzone b. Interval from the earliest incoming of *Sirmiodinium grossii* to the extinction of *Kylindrocysta spinosa.*

Age. Calyx and *Apertum* Zones.

Subzone c. Interval from the extinction of *Kylindrocysta spinosa* to the local disappearance of *Lacrymodinium warrenii* and the earliest appearance of *Ambonosphaera calloviana.*

Age. Nordenskjoeldi Zone.

Ambonosphaera calloviana Zone

Definition. Interval from the earliest incoming of *Ambonosphaera calloviana* (and local disappearance of *Lacrymodinium warrenii*) to the earliest appearance of *Liesbergia scarburghensis, Gonyaulacysta jurassica* var. *longicornis* and *Wanaea digitata.*

Age. Calloviense, Jason and *Coronatum* Zones.

Wanaea digitata Zone

Definition. Interval from the earliest appearance of *Liesbergia scarburghensis, Gonyaulacysta jurassica* var. *longicornis* and *Wanaea digitata,* to the extinction of *Meiourogonyaulax callomonii* (and local earliest incoming of *Scriniodinium crystallinum*).

Age. Athleta Zone.

Mendicodinium groenlandicum Zone

Defintion. Interval from the extinction of *Meiourogonyaulax callomonii* (and local incoming of *S. crystallinum*) to the earliest appearance of *Wanaea fimbriata* (and extinction of *Pareodinia prolongata* and *Ambonosphaera calloviana*). Locally abundant *Mendicodinium groenlandicum.*

Age. Lamberti Zone.

Wanaea fimbriata Zone

Definition. Interval from the earliest appearance of *Wanaea fimbriata* (and disappearance of *Pareodinia prolongata* and *Ambonosphaera calloviana*) to the extinction of *Wanaea fimbriata,* i.e. range zone of *W. fimbriata.*

Age. Mariae and *Cordatum* Zones.

Subzone a. Interval from the earliest appearance of *Wanaea fimbriata* to the earliest incoming of *Leptodinium eumorphum* (and locally *Endoscrinium subvallare*).

Age. Mariae Zone.

Subzone b. Interval from the earliest appearance of *Leptodinium eumorphum* (and locally *Endoscrinium subvallare*) to the extinction of *Wanaea fimbriata.*

Age. Cordatum Zone.

Liesbergia scarburghensis Zone

Definition. Interval from the disappearance of *Wanaea fimbriata* to the extinction of *Liesbergia scarburghensis.*

Age. Densiplicatum Zone.

Systematic palynology

Class Dinophyceae Fritsch, 1935
Order Periodiniales Haechel, 1894
Division Pyrrophyta Pascher, 1914
Class Dinophyceae Fritsch, 1935
Order Peridiniales Haeckel, 1984

Genus *Chytroeisphaeridia* (Sarjeant) Sarjeant & Downie, 1965, emend., Davey, 1979

Type species. Chytreisphaeridia chytroeides (Sarjeant) Downie & Sarjeant, 1965, emend., Davey, 1970.

Chytroeisphaeridia grossa sp. nov.

Figs 10C, E

Holotype. Fig. 10C, MGUH 18.261, GGU sample 185658, England finder ref. R17/1.

Paratype. Fig. 10E, MGUH 18.623, GGU sample 185631, England finder ref. N38/0.

Description. Dinoflagellate cysts approximately spherical in shape, or when flattened appearing more subspherical elongated, possessing one or more arcuate folds. The cysts are single-walled, the autophragm being relatively thick (1–2.5 μm). The autophragm is smooth externally and is unstructured internally. The archeopyle is simple, precingular and formed by the loss of just the fourth precingular paraplate (following the Taylor-Evitt notation

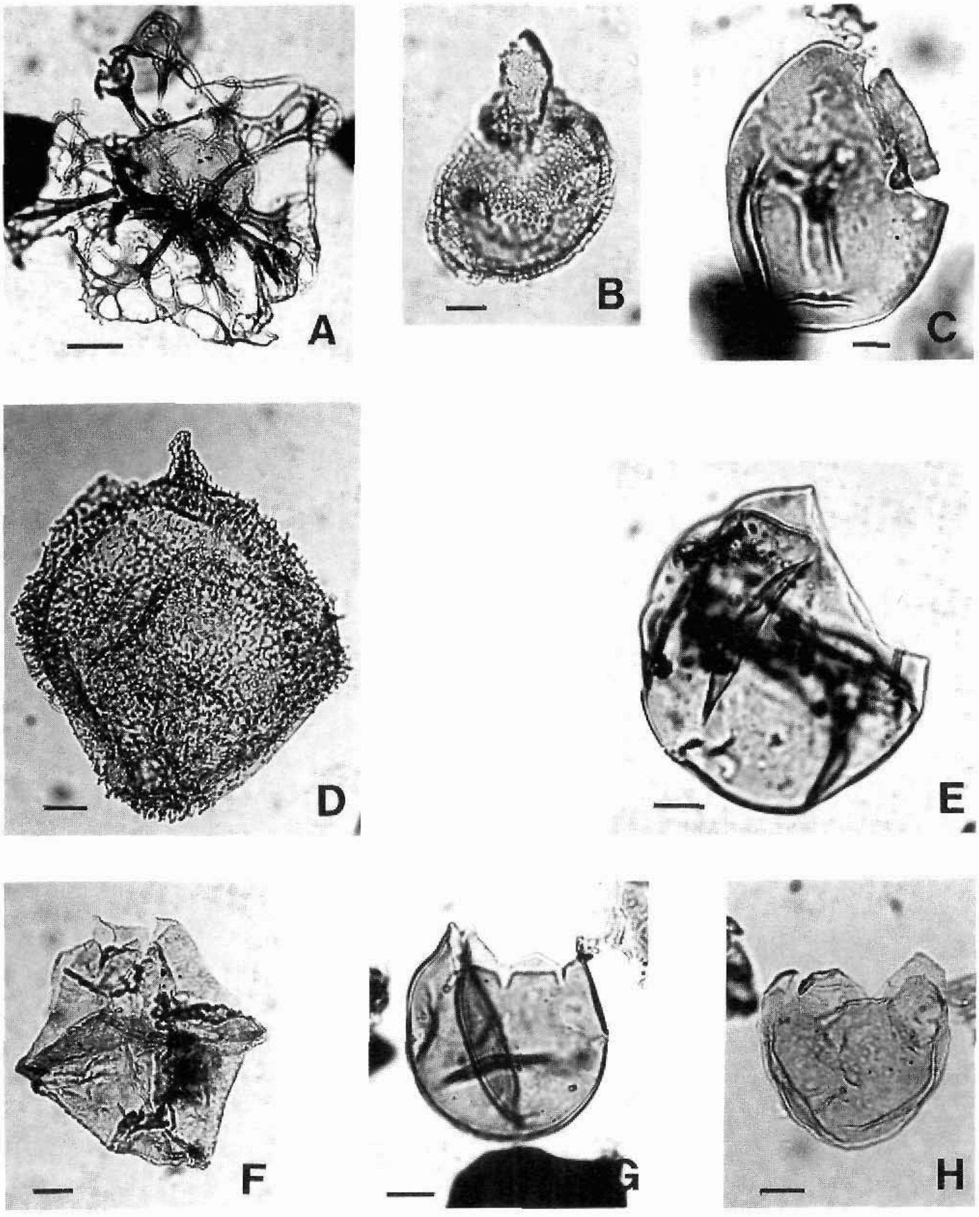

Fig. 10. Upper Middle and lower Upper Jurassic dinoflagellate cysts from East Greenland. Figured specimens can be relocated in permanent slide mounts with the aid of an England Finder using the coordinates given after the comma following the sample numbers. Scale bars represent 10 μm in all figures.

A: *Rigaudella aemula* (Deflandre) Below, 1982. MGUH 18.619, GGU sample 185703, H19/2.

B: *Chlamydophorella ectotabulata* Smelror, in press. MGUH 18.620, GGU sample 185654, J22/2.

C, E: *Chytroeisphaeridia grossa* sp. nov. C, holotype, MGUH 18.621, GGU sample 185658, R17/1. E, paratype, MGUH 18.623, GGU sample 185631, N38/0.

D: *Liesbergia scarburghensis* (Sarjeant) Berger, 1986. MGUH 18.622, GGU sample 185700, E29/3.

F: *Atopodinium prostatum* Drugg, 1978. MGUH 18.624, GGU sample 245977, V27/2.

G, H: *Escharisphaeridia laevigata* sp. nov. G, holotype, MGUH 18.625, GGU sample 185700, U32/1. H, paratype, MGUH 18.626, GGU sample 185700, K35/2.

system; i.e. the third Kofoidian precingular paraplate). The operculum is free and has a tapering hexagonal shape.

Dimensions. Cyst diameters range between 65 and 105 μm (20 specimens measured).

Type stratum and locality. Vardekløft Formation, Fossilbjerget Member, *Calloviense* Zone, at Olympen, northern Jameson Land.

Occurrence. Callovian and Lower Oxfordian of Jameson Land and Milne Land, East Greenland. According to Davey (1979) the stratigraphic range of this species is from Bathonian to Oxfordian. In the North Sea Basin it is particularly characteristic of the Callovian (Davey, 1979).

Remarks. The overall character of *Chytroeisphaeridia grossa* sp. nov. is similar to *Chytroeisphaeridia chytroeides* (Sarjeant) Sarjeant & Downie, 1965, but is considerably larger (in general 35–50 μm larger in cyst diameters) and appears more thick-walled.

Genus *Escharisphaeridia* Erkmen & Sarjeant, 1980

Type species. Escharisphaeridia pocockii (Sarjeant) Erkmen & Sarjeant, 1980.

Escharisphaeridia laevigata sp. nov.
Figs 10G, H

Holotype. Fig. 10G, MGUH 18.625 GGU sample 185700, England finder ref. U32/1.

Paratype. Fig. 10H, MGUH 18.626, GGU sample 185700, England finder ref. K35/2.

Description. Dinoflagellate cysts generally subspherical in outline, occasionally appearing more ovoidal in shape. The cyst wall is composed of only one layer. The autophragm is smooth, i.e. laevigate with no kind of ornamentation visible even when examined with scanning electron microscopy at high magnifications. Evidence of paracingulum or parasulcus has not been observed, and the only indication of paratabulation is expressed by the apical archeopyle and accessory archeopyle sutures, suggesting the presence of 4 apical and 6 precingular paraplates. A sulcal notch formed where *1u* extends toward the paracingulum to meet *ai* is a typical feature. Specimens with the operculum in place have not been observed, but the shape of the archeopyle indicates that the archeopyle is of type (4A).

Dimensions. Length 36–53 μm, width 30–41 μm (19 specimens measured).

Type stratum and locality. Olympen Formation, Lower Oxfordian at Olympen northern Jameson Land.

Occurrence. Upper Bathonian – Lower Oxfordian strata of southern France, England, East Greenland, Svalbard and Franz Josef Land (Arctic U.S.S.R.).

Remarks. Escharisphaeridia laevigata sp. nov. appears similar to the specimens illustrated as *Escharisphaeridia* sp. from the Bathonian Stage type area in South-West England by Riding *et al.* (1985, pl. V, fig. 8) and to the specimens illustrated as Dinocyst sp. A from the Callovian – Oxfordian of the East Midlands, England, by Woollam (1980, pl. 1, figs 1, 4). *Escharisphaeridia laevigata* sp. nov. is conspecific with *Escharisphaeridia* sp. A of Smelror (in press) described from Kong Karls Land, Svalbard.

Genus *Liesbergia* Berger, 1986

Type species. Liesbergia liesbergensis Berger,1986.

Liesbergia scarburghensis (Sarjeant) Berger, 1986

Fig. 10D

1961 *'Gonyaulax areolata'* Sarjeant, pp. 95–97, pl. 13, fig. 13, text-fig. 5.
1964 *Gonyaulacysta scarburghense* Sarjeant, pp. 472–473.
1978 *Gonyaulacysta areolata* Raynaud, p. 396, pl. 2, fig. 7.
1978 *Gonyaulacysta areolata* Davey & Riley, pl. 1, fig. 1.
1978 *Gonyaulacysta areolata* Thusu, pl. 9, figs 4, 6.
1978 *Acanthaulax senta* Drugg, p. 62, pl. 3, fig. 13, pl. 4, figs 1–3.
1980 *Acanthaulax senta* Woollam, pl. 3, fig. 3.
1980 *Acanthaulax senta* Bjærke, p. 150, pl. 3, figs 1–4.
1982 *Acanthaulax areolata* Riley & Fenton, p. 199.
1983 *Acanthaulax senta* Woollam & Riding, p. 3, pl. 4, figs 5, 6.
1984 *Acanthaulax senta* Riding, pl. 3, figs 6, 9.
1985 *Acanthaulax areolata* Lund & Pedersen, p. 384, pl. 8, fig. 3.
1985 *Acanthaulax scarburghensis* Lentin & Williams, p. 2.
1986 *Liesbergia scarburghensis* Berger, p. 343, fig. 5: 12.

Remarks. This species was originally introduced as *Gonyaulax areolata* by Sarjeant (1961). It was subsequently given the name *Gonyaulacysta scarburghense* by Sarjeant (1964, pp. 472–473). According to Lentin & Williams (1985) *G. areolata* was a junior homonym, which is illegitimate (*International Code of Botanical Nomenclature* Art. 6.4; Art. 64.1) and had to be replaced by a validly published nom. nov., i.e. *G. scarburghense.* This nom. nov. is the oldest legitimate name (Art. 6.3). Riley & Fenton (1982, p. 199) made an illegitimate transfer of this species to *Acanthaulax* Sarjeant, 1968 by using the junior homonym (*G. areolata*), thus failing to conform to the rule that the oldest legitimate species name is transferred to a new generic name (Lentin & Williams, 1985). Following the *I. C. B. N.* Art. 55 this species was transfered to the genus *Acanthaulax* as *A. scarburghensis* by Lentin & Williams (1985).

Riley & Fenton (1982, p. 119) and Woollam & Riding (1983, p. 3) stated that *Acanthaulax senta* Drugg, 1978 may be conspecific with *Gonyaulacysta scarburghense* Sarjeant, 1964. Berger (1986, p. 343) confirmed that *A. senta* and *G. scarburghense* are synonymous and subsequently transferred this species to the genus *Liesbergia* Berger, 1986. According to Berger (1986, p. 341) the genus *Liesbergia* can be distinguished from *Acanthaulax* in "having a very characteristic apical horn which is only formed by a development of the external ornamentation and not by the entire periphragm as in *Acanthaulax*".

Genus *Atopodinium* Drugg, 1978

Type species. Atopodinium prostatum Drugg, 1978

Atopodinium prostatum Drugg, 1978
Fig. 10F

1978 *Atopodinium prostatum* Drugg, p. 63, pl. 1, figs 1–7, text figs 1A-D.
1978 Dinoflagellate type 4, Thusu, pl. 7, figs 12, 13.
1985 *Atopodinium prostatum* Herngreen, pl. 2, fig. 1.
1985 *Atopodinium prostatum* Lund & Pedersen, p. 382, pl. 7, fig. 2.
1985 *Atopodinium prostatum* Riding *et al.*, pl. IV, fig. 8.

Remarks. Several of the specimens observed have less well developed protruding sack-like lobes at the antapex than the specimens illustrated by Drugg (1978, pl. 1, figs 1–7), and a few specimens seem more or less to lack such features. This is also observed among specimens recorded from Kong Karls Land, Svalbard (Thusu, 1978; Smelror, in press), and the Canadian Arctic (E. H. Davies, personal communication 1986). Both forms with extremely developed protruding sack-like lobes, and those completely lacking such features, are here regarded as end members of the species-complex *A. prostatum.*

Genus *Rigaudella* Below, 1983

Type species. Rigaudella aemula (Deflandre) Below, 1982.

Rigaudella aemula (Deflandre) Below, 1982
Fig. 10A

1938 *Hystrichosphaeridium aemulum* Deflandre, p. 688, fig. 6.
1947 *Cannosphaeropsis aemula* Deflandre, p. 19, fig. 5.
1960 *Cannosphaeropsis paucispina* Klement, p. 72, pl. 10, figs 9, 10
1969 *Adnatosphaeridium aemulum* Williams & Downie, p. 17.
1982 *Rigaudella aemula* Below, pp. 139–140, 143–144, 146, figs 1–6, 16, 17, 18–21, 22–23, 24 (pars.). (With detailed synonymy list.)

Remarks. As noted by Below (1982) there is a gradational transition between *R. aemula* and specimens which are described as *Rigaudella filamentosa* (Cookson & Eisenack) Below, 1982. Both forms are known from Middle and Upper Jurassic strata elsewhere in North-West Europe (Sarjeant, 1979). Since the species appear to have nearly equivalent stratigraphic ranges, no attempt has been made to separate these two forms during the present study. Consequently, several specimens which may fit the description of *R. filamentosa* may here have been recorded as *R. aemula.*

List of recorded acritarchs, dinoflagellate cysts and tasmanitids

Representative specimens are illustrated in figs 10–12

Ambonosphaera calloviana Fensome, 1979
Atopodinium prostatum Drugg, 1978
Caddasphaera halosa (Filatoff) Fenton, Neves & Piel, 1980
Cassiculosphaeridia dictydia (Sarjeant) Riley & Fenton, 1982
Chlamydophorella ectotabulata Smelror, in press
Chytroeisphaeridia cerastes Davey, 1979
Chytroeisphaeridia chytroeides (Sarjeant) Downie & Sarjeant, 1965
Chytroeisphaeridia grossa sp. nov.
Cleistosphaeridium ehrenbergii (Deflandre) Davey *et al.*, 1969
Cleistophaeridium polytrichum (Valensi) Davey *et al.*, 1969
Crussolia deflandrei Wolfard & Van Erve, 1981
Ctenidodinium continuum Gocht, 1970
Ctenidodinium ornatum (Eisenack) Deflandre, 1939
Diacanthum filapicatum (Gocht) Stover & Evitt, 1978
Ellipsoidictyum cinctum Klement, 1960
Endoscrinium galeritum (Deflandre) Vozzhennikova, 1967
Escharisphaeridia laevigata sp. nov.
Escharisphaeridia pocockii (Sarjeant) Erkmen & Sarjeant, 1980
Fromea tornatilis (Drugg) Lentin & Williams, 1981
Gonyaulacysta birkelundii Fensome, 1979
Gonyaulacysta jurassica (Deflandre) Norris & Sarjeant, 1965
Gonyaulacysta jurassica longicornis (Deflandre) Sarjeant, 1982
Heslertonia teichophera (Sarjeant) Sarjeant, 1976
?Hystrichodinium lanceatum Davies, 1983
Hystrichogonyaulax pectinigera (Gocht) Stover & Evitt, 1978
Kylindrocysta spinosa Fenton *et al.*, 1980
Lacrymodinium warrenii Albert, Evitt & Stein, 1986
Liesbergia scarburghensis (Sarjeant) Berger, 1986
Lithodinia jurassica Eisenack, 1935
Meiourogonyaulax deflandrei Sarjeant, 1968
Meiourogonyaulax callomonii Sarjeant, 1972
Meiourogonyaulax strongyla Sarjeant, 1972
Mendicodinium groenlandicum (Pocock & Sarjeant) Davey, 1979
Micrhystridium brevispinosum Valensi, 1953
Micrhystridium fragile Deflandre, 1947
Micrhystridium recurvatum Valensi, 1953
Nannoceratopsis pellucida Deflandre, 1938
Occisucysta thulia Davies, 1983
Pareodinia alaskensis Wiggins, 1975
Pareodinia brachythelis Fensome, 1979
Pareodinia ceratophora Deflandre, 1947
Pareodinia prolongata Sarjeant, 1959
Pareodinia wigginsii Smelror, in press
Pleurozonaria sp.
Pluriarvalium osmingtonense Sarjeant, 1962
Prolixosphaeridium granulosum (Deflandre) Davey *et al.*, 1966
Pterospermopsis sp. A of Fensome, 1979
Rhynchodiniopsis cladophora (Deflandre) Below, 1981
Rigaudella aemula (Deflandre) Below, 1982
Scriniodinium oxfordianum Sarjeant, 1962
Sentusidinium asymmetrum (Fenton *et al.*) Lentin & Williams, 1981
Sentusidinium baculatum (Dodekova) Sarjeant & Stover, 1978
Sentusidinium pelionense Fensome, 1979
Sentusidinium rioultii (Sarjeant) Sarjeant & Stover, 1978
Sentusidinium verrucosum Wiggins, 1973
Sentusidinium sp. B of Fensome, 1979
Sirmiodinium grossii Alberti, 1961
Solisphaeridium ankyleton Fensome, 1979
Susadinium? sp. A of Smelror, 1987
Tasmanites tardus Eisenack, 1958
Tubotuberella eisenackii (Deflandre) Stover & Evitt, 1978
Tubotuberella lurida (Deflandre) Davies, 1983
Valensiella ampulla Gocht, 1970
Valensiella ovula (Deflandre) Eisenack, 1963
Valensiella vermiculata Gocht, 1970
Veryhachium sortehatense Fensome, 1979
Wanaea digitata Cookson & Eisenack, 1958
Wanaea fimbriata Sarjeant, 1961
Wanaea thysanota Woollam, 1982
Xylochoarion hacknessense Erkmen & Sarjeant, 1978

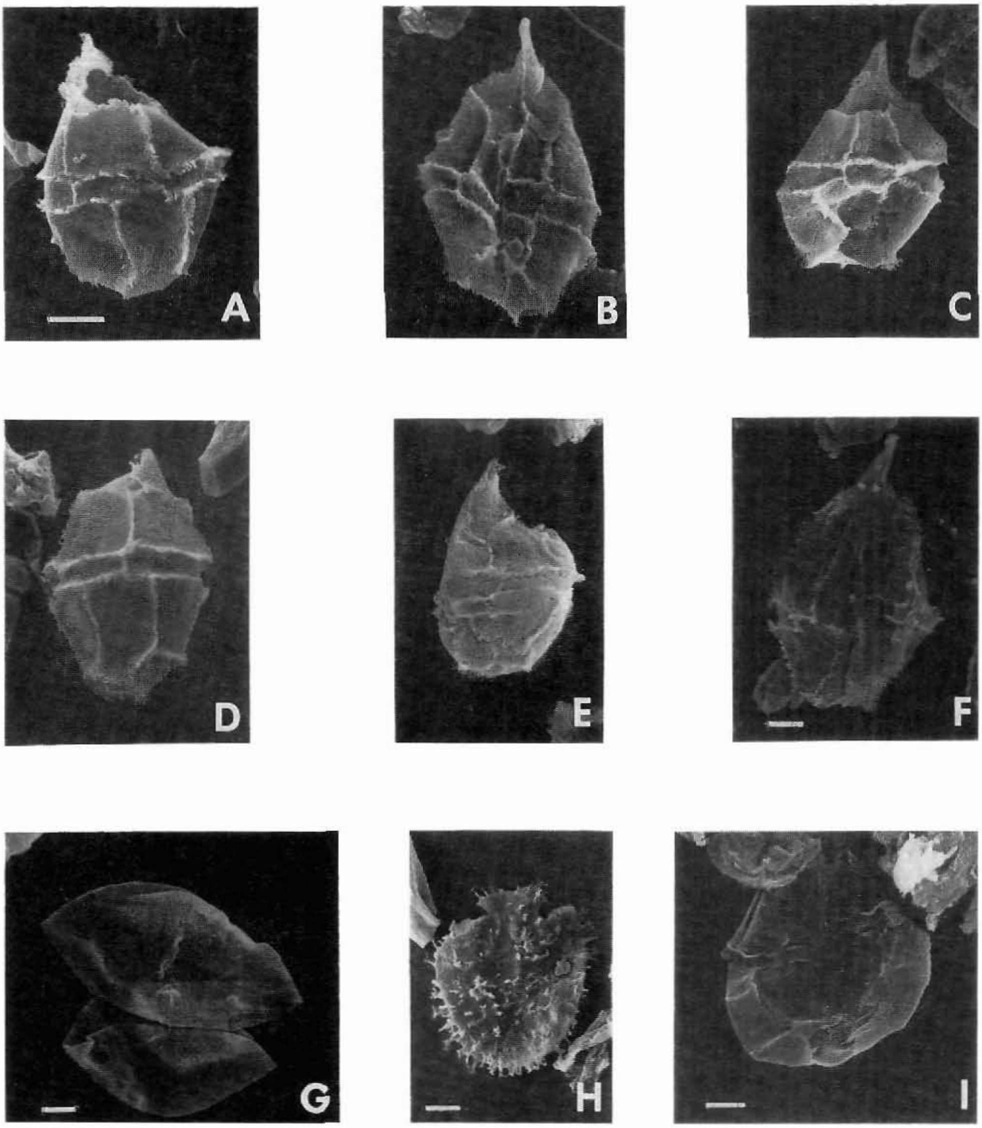

Fig. 11. Upper Middle and lower Upper Jurassic dinoflagellate cysts from East Greenland. Scale bars represent 10 μm in all figures. Figs A-E all same magnification.

A-E: *Lacrymodinium warrenii* Albert, Evitt & Stein, 1986. SEM: MGUH 18.627–31, GGU sample 139156.

F: *Gonyaulacysta jurassica* (Deflandre) Norris & Sarjeant, 1965. SEM: MGUH 18.632, GGU sample 245977.

G: *Mendicodinium groenlandicum* (Pocock & Sarjeant) Davey, 1979. SEM: MGUH 18.633, GGU sample 245977.

H: *Sentusidinium rioultii* (Sarjeant) Sarjeant & Stover, 1978. SEM: MGUH 18.634, GGU sample 245967.

I: *Sirmiodinium grossii* Alberti, 1961. SEM: MGUH 18.635, GGU sample 245967.

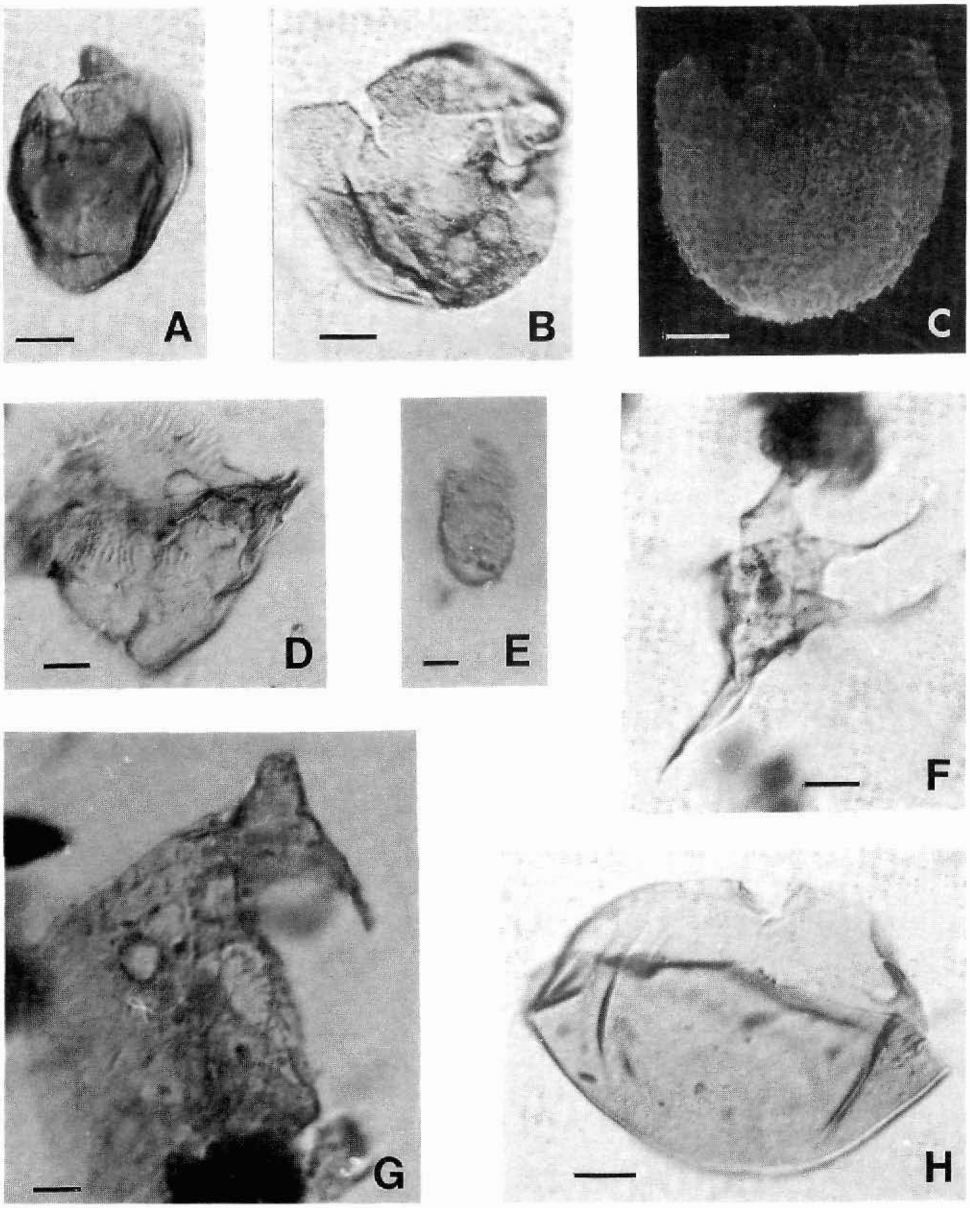

Fig. 12. Upper Middle and lower Upper Jurassic dinoflagellate cysts and acritarchs from East Greenland. Scale bars represent 10 μm in all figures.

A: *Pareodinia brachythelis* Fensome, 1979. MGUH 18.636, GGU sample 185635, F34/2.

B: *Escharisphaeridia pocockii* (Sarjeant) Erkmen & Sarjeant, 1980. MGUH 18.637, GGU sample 185635, G41/0.

C: *?Sentusidinium* sp. SEM: MGUH 18.638, GGU sample 139156.

D: *Wanaea thysanota* Woollam, 1982. MGUH 18.639, GGU sample 245981, 040/2.

E: *Kylindrocysta spinosa* Fenton, Neves & Piel 1980. MGUH 18.640, GGU sample 139197, C32/0.

F: *Veryhachium sortehatense* Fensome, 1979. MGUH 18.641, GGU sample 185639, M35/0.

G: *Occisucysta thulia* Davies, 1983. MGUH 18.642, GGU sample 185642, E35/3.

H: *Mendicodinium groenlandicum* (Pocock & Sarjeant) Davey, 1979. MGUH 18.643, GGU sample 185700, K35/2.

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