Palynology and depositional history of the Paleocene? Thyra Ø Formation, Wandel Sea Basin, eastern North Greenland

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The Thyra Ø Formation in eastern North Greenland has been dated as Late Paleocene to possibly earliest Eocene based on its content of palynomorphs. The palynomorph assemblage is dominated by long ranging taxa and reworked Upper Cretaceous species. The Late Paleocene age of the formation is based on the occurrence of *Cerodinium speciosum* and *Spinidinium pilatum*. However, the presence of *Cerodinium markovae, Spinidinium sagittula,* and *?Ilexpollenites* sp. suggests that the formation may range into the earliest Eocene.

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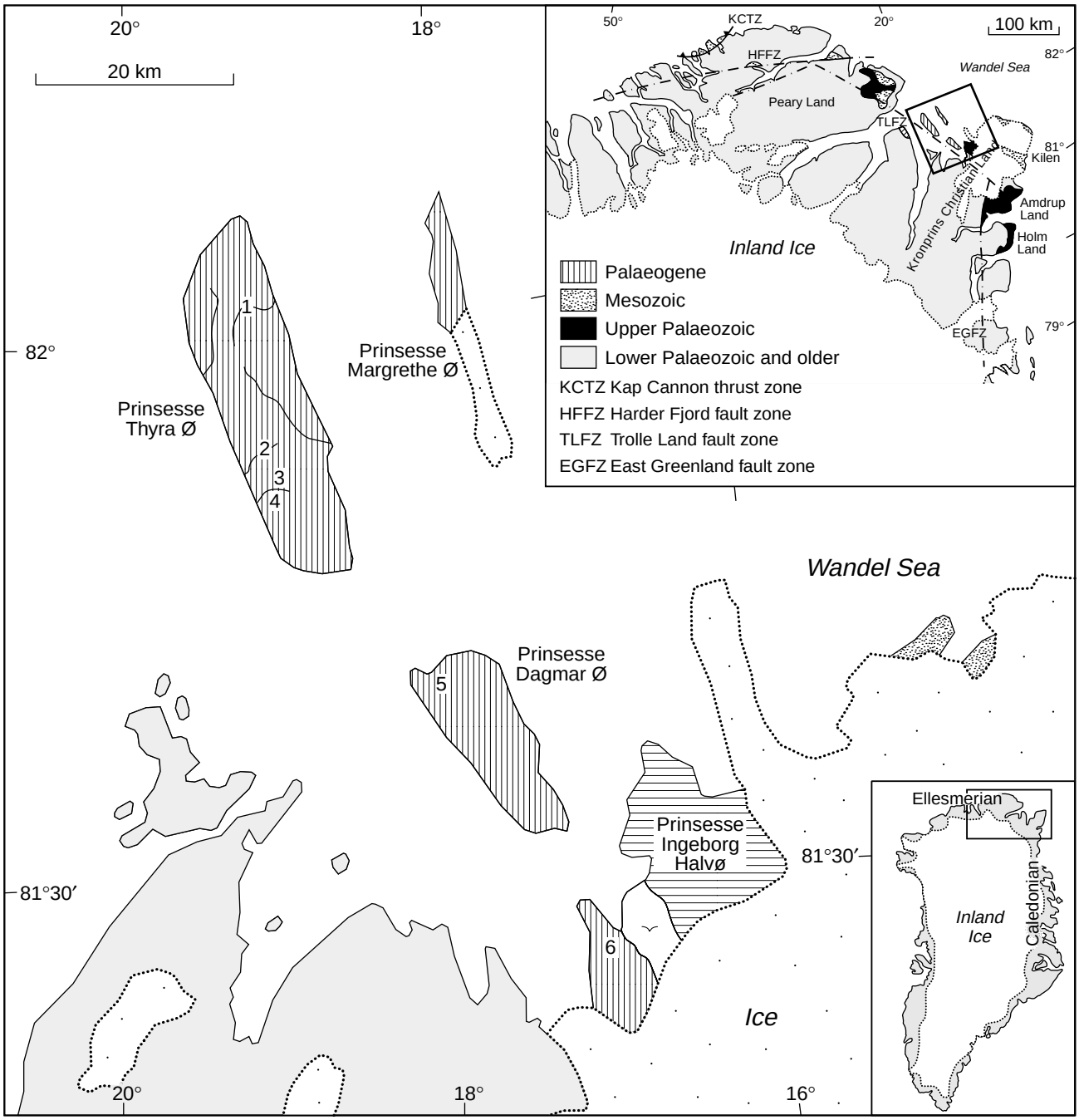
The Early Carboniferous to Palaeogene Wandel Sea Basin of North Greenland and the surrounding shelf areas are located in a geologically complex area at the junction between the Palaeozoic Caledonian fold belt in East Greenland and the Ellesmerian fold belt in North Greenland, and along the zone of Palaeogene continental break-up (Fig. 1; Håkansson & Stemmerik 1989). The basin history is accordingly very complex in the northern part of the basin where Late Palaeozoic to Early Triassic rifting was followed by a series of transtensional to extensional events in the mid-Jurassic to Late Cretaceous. The youngest preserved sediments within the basin are marginal marine and fluvial deposits of the Thyra Ø Formation (Håkansson *et al.* 1981, 1991). Following mapping of the area in 1978 a few samples were processed palynologically and a Paleocene age was suggested based on a few poorly preserved dinoflagellate cysts (Håkansson & Pedersen 1982). More precise age assignments of these deposits are important as they form the only sediments in the basin that have not been affected by compressive tectonism related to lateral movements between North Greenland and Svalbard thus placing an upper age limit on these movements (Håkansson & Stemmerik 1989; Håkansson *et al.* 1991). However, during mapping of the Wandel Sea Basin in 1978 to 1980 (Håkansson 1979; Håkansson *et al.* 1981) little attention was paid to the Thyra Ø Formation.

The present study forms an integrated part of modelling the basin that was initiated in 1994 (Stemmerik *et al.* 1995). It gives the first comprehensive description of the microflora of the formation based on material from Prinsesse Thyra Ø, Prinsesse Dagmar Ø and Prinsesse Ingeborg Halvø in the easternmost part of North Greenland (Fig. 1). There the Thyra Ø Formation consists of interbedded fine-grained sandstones, siltstones and coal with a composite thickness of 50 m. Based on sedimentological observations, the sediments were originally interpreted as dominantly fluviatile, possibly deposited on a broad fluvial plain (Håkansson *et al.* 1991). However, the present study documents dinoflagellate cysts to be common in many samples, suggesting that deposition took place in a marine influenced environment.

The Thyra Ø Formation sediments were affected by a Palaeogene thermal event centred over northern Kronprins Christian Land (Fig. 1; Håkansson & Pedersen 1982; Christiansen *et al.* 1991). The least thermally af-



Surficial deposits
Palaeogene
Mesozoic
Carboniferous and Permian
Neoproterozoic–Silurian
Ice cover

1: GGU 420963
2: GGU 424195–198
3: GGU 196268, 269, 271, 274
4: GGU 424199, 201–206
5: GGU 256621
6: GGU 220345–347, 349, 351, 354

Fig. 1. Simplified geological maps of north-eastern Greenland and the islands investigated in this study. The position of the samples referred to in Tables 1 and 2 are shown on the large map. Blank areas on the upper inset map are ice.

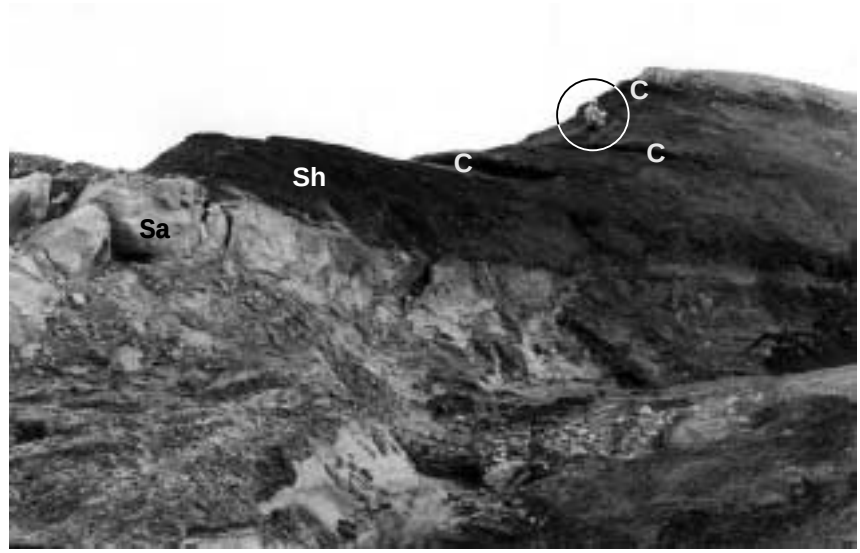


Fig. 2. Interbedded sandstone (**Sa**), siltstone (**Sh**) and coal (**C**) characterising the Thyra Ø Formation at southern Prinsesse Ingeborg Halvø. Person for scale encircled.

fected and most productive samples come from the south-easternmost parts of the study area, i.e. southern Prinsesse Ingeborg Halvø where light, transparent dinoflagellate cysts are common. In contrast, material from Prinsesse Thyra Ø is darker and more extensively corroded.

Regional setting

The Wandel Sea Basin is the northernmost of a series of fault-bounded Late Palaeozoic – Mesozoic basins exposed along the eastern margin of Greenland. The basin developed during the Carboniferous as a result of extension and rifting between Greenland and Norway, and Greenland and Svalbard (Håkansson & Stemmerik 1989; Gudlaugsson *et al.* 1998). The depositional basins are separated from the stable Greenland craton by the East Greenland, Trolle Land and Harder Fjord fault zones, and the areas to the west and south of these fault zones have been land for most of the Late Palaeozoic and Mesozoic (Fig. 1; Håkansson & Stemmerik 1989).

Deposition began during the Early Carboniferous in the southernmost part of the basin and was followed by widespread Late Carboniferous to Late Permian marine sediments (Stemmerik & Håkansson 1989, 1991). Following Middle Triassic sedimentation, the basin was uplifted and eroded during the mid-Triassic to mid-Jurassic (Håkansson & Pedersen 1982). Sedimentation started again in the northern part of the basin during the Late Jurassic, and Late Mesozoic sedimentation was mainly confined to small pull apart basins within the NW–SE-striking Trolle Land fault zone (Fig. 1; Håkansson & Stemmerik 1989; Håkansson *et al.* 1991).

Outcrops of the Thyra Ø Formation are located in the southern part of the Trolle Land fault zone (Fig. 1). In contrast to the Mesozoic and older sediments, they are not affected by deformation related to strike slip movements in this fault system and they are therefore regarded as post-dating these movements. Based on correlation of fault trends in eastern Peary Land and Kronprins Christian Land it is likely that Prinsesse Thyra Ø and Prinsesse Ingeborg Halvø were located on two different fault blocks within the Trolle Land fault zone.

The base of the Thyra Ø Formation is not known, and the formation is directly overlain by Quaternary marine sediments.

Depositional facies

The Thyra Ø Formation is generally poorly exposed, and most information comes from isolated outcrops along rivers on southern Prinsesse Thyra Ø and Prinsesse Ingeborg Halvø (Fig. 1). The formation is dominated by laminated, organic-poor siltstones and fine-grained sandstones with coal seams (Håkansson *et al.* 1991). The poor quality outcrops do not allow any detailed facies analysis; the presence of coal seams was used by Håkansson *et al.* (1991) to propose a fluvial origin of the sediments. However, the presence of marine dinoflagellates in all investigated siltstones indicates that sedimentation of these units took place in a marine environment. The lack of bioturbation or the absence of marine macrofossils may indicate a bio-

Table 1. Distribution and abundance (rough counts) of dinoflagellates in the Thyra Ø Formation

Taxa	GGU sample number																						
	420963	424195	424196	424197	424198	424199	424201	424202	424203	424204	424205	424206	196268	196269	196271	196274	256621	220345	220346	220347	220349	220351	220354
Achomosphaera spp.			1																1	1			
Alterbidinium sp.										1	5			1	?	?		?		5	5	?	
Areoligera spp.			5						1			1	1	1	5	5	5	1	5	1	1		
Cerodinium diebelii												1	1		5	1		1			1		
Cerodinium markovae																?		10			5		
Cerodinium speciosum		1	1	5	10	1		1	1	5	5	5	1		1			5	1	5	5		
Cerodinium striatum	?	1	1	1	5					1	5	5		1	5			?	2	?	1		
Cerodinium sp.						1		5									1	1	1		5	?	5
Chatangiella granulifera	5		5	5	1	10		5	5	5	5	5	5	10		1	5	1	1	5	5	5	1
Chatangiella spp.	1		1		5				1					1			5	1		1	1		
Circulodinium distinctum	?	1	1		1	1		1				1			1		5	1	5			1	
Cleistosphaeridium spp.		1	1									1	1	1			5	1	1		1	5	1
Desmocysta plekta																			10	1			5
Fromea fragilis														1								1	1
Glaphyrocysta ordinata			5	1							5	10			10	5	1	1	5	?			
Hystrichosphaeridium tubiferum		5	1		1			1	5		5			1	5	1		1	5		1	?	1
Isabelidinium aff. *I. acuminatum*																	1					?	
Isabelidinium aff. *I. viborgense*			1		5						?	1			?		1				5		
Isabelidinium spp.			1			5							5	5			1	1	1				
Laciniadinium arcticum	1			1		5				1			5	1	1	1	5	5	?	5	?	10	
Laciniadinium? sp.														?									5
Odontochitina operculata																	1	1			?	5	
Oligosphaeridium spp.			1		1							1					5		5		1		
Palaeocystodinium lidiae			1	1	5				?		1		1	1		5	5		5	5			1
Palaeocystodinium australinum			1					5							1	1	1	5	1	1	5	5	
Palaeoperidinium pyrophorum			5	1					?			?	5		5	?	>15	5	1	1	1	5	
Paralecaniella indentata			1		5					?	?		1		1		1	5	>15		5	1	
Phelodinium kozlowskii																	1						
Pterodinium spp.																	1					1	
Quadrina pallida											?							10					
Senegalinium aff. *S. dilwynense*			?							1											1		
Senegalinium microgranulatum		1	1		1				?		1		5	1	5	1		?	1	?	1		
Senegalinium obscurum	?	10	5	5	5				1	1	1	5	5	1	5	5	1	1	5	?	5	5	5
Senegalinium sp.		5								1							1		10			?	
Spinidinium cf. *S. clavus*								?	?			?						5			1		
Spinidinium densispinatum			?	?								?				1			1	1	5	?	
Spinidinium essoi					?							?			5							1	
Spinidinium pilatum			10	10	5			1			5	1	5	5	1						1	1	
Spinidinium sagittula																		?			10		
Spinidinium spp.			1		5			5		1					1	5	5					1	
Spiniferites spp.				1				5	1	5			5		1	1	1	1			1	1	1
Spongodinium delitiense			1	5					1	1	5	1	10		5	5	>15	5	1	1	1		1
Trithyrodinium evittii		5	>15	10	5	10		5		5	10	5	5	1	10	1	1	10					
Trithyrodinium fragile			5	1				?				1	1		5	1	1					5	
Trithyrodinium ornatum					1	1		1	1			1					1				5	1	
Trithyrodinium sp.		15						5		1		5		1	5	1	1		5		5	?	?
Trithyrodinium? sp.																			15		10	5	

Table 2. Distribution and abundance (rough counts) of terrestrial palynomorphs in the Thyra Ø Formation

Taxa	GGU sample number																					
	420963	424195	424196	424197	424198	424199	424201	424202	424203	424204	424205	424206	196268	196269	196271	196274	256621	220345	220346	220347	220349	220351	220354
Gleicheniidites spp.	5		5	1		1	10				1	1	5		5	1		15	10	10	5	10	
Lycopodiumsporites spp.		1		1		1			1			5		1					5	1	10	1	
Osmundacidites spp.	5	5		5	5	10	>15	1	1		5	15	1	10			1				5	5	1
Triplanosporites spp.	10		5	5		1	5	5	1			5	5							10	5	1	
Hazaria sheopiariae	1											1						5			5	10	
Ilexpollenites spp.																						?	
Laevigatosporites spp.		1				5		1	1			5	5	1							1	5	
Bisaccate pollen	>15	5		10				>15				>15	>15	15	15		>15	5	5		5	>15	
Taxodiaceae, papillate spp.	1												5								5		
Taxodiaceae, split spp.											?		1	10				5			10	10	5
Inaperturopollenites magnus													1	1	1					?	1		1
Ovoidites spp.								1	1					1								1	
Alnipollenites spp.						?			1			1						1	1		10	5	
Caryapollenites spp.		?		1					?			1	5								5	5	
Myricipites speciosus	5						1				1	5		10	5	1		5			10	5	5
Other porate pollen												?		1							?	?	
Extratriporopollenites spp.																		5		1	5	5	
Colporate spp.						1		1				15						5					
Colpate spp.	5			5				1													1		
Aquilapollenites spp.					1	1		1		5	10	5	1	10	5		5		5	1	5	10	5
Aquilapollenites spp, dark										1					5	>15						1	
Grevilloideaepites spp.			?		?						5		5					1		1	5	1	
Mancicorpus spp.				1									10					1			1	10	5
Orbiculapollis spp.					?								?				?					1	?
Pseudointegricorpus spp.	1								1		1	?	1		1	1				1			
Trudopollis spp.														1			1						
Wodehouseia spinata			?												10	1					5		
Pesavis sp.																					?	1	
Palambages sp.															5			1	1				
Ulvella nannae			1															15			10	5	
Fungal palynomorphs indet.																		10	1		1	1	
Black phytoclasts			10				>15	5						5				15					10
Brown phytoclasts			15			>15							>15	>15	15			>15					>15
Cuticle				15			?	15															

logically stressed environment during deposition of the siltstones. Most sandstones are very fine grained with non-erosive planar bases. They are homogeneous, low-angle trough cross-bedded or contain small-scale cross lamination.

All three measured sections show an overall fining upwards tendency and are dominated by siltstones and coal in the upper part (Fig. 2). The close association of siltstones and coal indicates deposition in a shallow, protected environment, and most likely deposition took place in shallow-marine lagoons and marshes. The small amount of available data indicates that the thickness of the coal beds increases south-eastwards suggesting that land was located to the south of the outcrop area. This is in accordance with the palaeogeography seen in the Late Palaeozoic and Mesozoic (Håkansson *et al.* 1991; Stemmerik & Håkansson 1991).

Palynomorph assemblages

A total of 24 surface samples from Prinsesse Thyra Ø, Prinsesse Dagmar Ø, Prinsesse Margrethe Ø and Prinsesse Ingeborg Halvø have been examined palyno-

logically (Fig. 1; Tables 1, 2). Of these, 23 samples were found to be palynologically productive. Only a sample from Prinsesse Margrethe Ø was found to be barren of palynomorphs; it only contains hairy, chitinous (insect?) tubes. The processing procedures described by Hansen & Gudmundsson (1979) have been adapted to enrich the palynomorph content in the organic residues. Different fractions of the residues were isolated according to their specific weight and floating properties. Strew mounts representing the different fractions were mounted in a permanent medium Eukitt®. The quantitative data listed in the distribution chart represent rough counts of several slides, where available (Tables 1, 2).

The palynomorph assemblages in the Thyra Ø Formation are mixed, with a consistently large, moderately diverse terrestrial fraction, and a marine fraction of very variable size and diversity. All samples are dominated by degraded brown phytoclasts, with large bisaccate pollen dominant among the palynomorphs. Preservation of the palynomorphs is generally poor, they are worn, torn and pitted. There is no obvious difference in state of preservation between palynomorphs of terrestrial and marine origin in individual samples, but regional preservational differences exist within the study area. The material from Prinsesse Ingeborg Halvø in the south-eastern part of the study area is lighter in colour and less thermally altered than the material from northern Prinsesse Thyra Ø.

The dominant *terrestrial* component is degraded brown wood, followed in abundance by smaller angular to rounded inertinite particles. Large cuticular fragments are very common in some samples, particularly from Prinsesse Thyra Ø. The most prominent among the palynomorphs, and next in overall abundance are large bisaccate pollen. They dominate the palynomorph assemblage completely in northern Prinsesse Thyra Ø, and are also very common in other samples. Thick-walled trilete spores, particularly *Osmundacidites wellmanii*, are common in some samples, and smooth *Gleicheniidites*-type spores are locally common. Monolete spores like *Hazaria sheopiariae* and *Laevigatosporites* sp. are less abundant. Porate angiosperm pollen are usually present, increasing in abundance towards the south. They are generally smaller and less conspicuous than the spores, and their preservation in conjunction with their original relatively featureless character precludes a precise identification in most cases. The most common of these porate types is identified as *Myricipites speciosus*, a species also found in the Palaeogene of Svalbard. In some samples (e.g. GGU 424206) many pollen grains seem to have pores, but the grains are very corroded and these characters may well be artefacts produced by corrosion or crystal growth in the palynomorph wall. Representatives of the *Aquilapollenites* group (*sensu lato*) are larger and more conspicuous; they are locally common in Prinsesse Ingeborg Halvø. *Pseudointegricorpus protrusum* and *Wodehouseia spinata* are rare. Fungal palynomorphs are only recognised in a few samples from southern Prinsesse Ingeborg Halvø (e.g. GGU 220345, Table 2). The recognised forms are primarily known from Early Palaeogene and younger deposits (Elsik 1976; Day 1991; Gregory & Hart 1995; Tyson 1995) but probably range into the Late Cretaceous. *Ulvella nannae*, a marine, encrusting green alga, described by Hansen (1980b) from the Maastrichtian and Lower Palaeogene deposits of West Greenland, is common in a few samples.

The *marine* component is completely dominated by peridinioid dinoflagellate cysts of the genera *Senegalinium*, *Spinidinium*, *Trithyrodinium*, *Cerodinium* and *Palaeoperidinium*, which are considered to be common in nearshore environments. The few representatives of gonyaulacoid cysts mainly belong to *Glaphyrocysta* and *Spongodinium*, although a few *Spiniferites* spp. are present in many samples, and *Hystrichosphaeridium tubiferum* and possibly *Areoligera* spp. are occasionally found.

A large percentage of the dinoflagellate cysts and terrestrial palynomorphs are considered to be *reworked* from older deposits in the area as they belong to Cretaceous taxa, whereas age diagnostic palynomorphs point towards a Late Paleocene or earliest Eocene age of the formation. Most abundant among the reworked dinoflagellate cysts are *Chatangiella* spp. and *Isabelidinium* spp. whereas *Aquilapollenites* spp. (including *Mancicorpus* spp.) are most common among the terrestrially derived grains.

The composition of the organic material changes slightly from Prinsesse Thyra Ø to Prinsesse Ingeborg Halvø and possibly two different assemblages are present. The Prinsesse Ingeborg Halvø assemblage is the most diverse and is characterised by the presence of thin-walled dinoflagellate cysts, particularly *Cerodinium markovae* and *Spinidinium sagittula*, light, hyaline *Palaeocystodinium australinum*, light and more common *Glaphyrocysta ordinata*. Furthermore, the assemblage has a much higher proportion of taxodiaceous pollen, *Hazaria sheopiariae*, fungal palynomorphs and more common *Myricipites speciosus* than the material from Prinsesse Thyra Ø. The regional dif-

ferences may be due to preservational factors, i.e. the extra elements in the Prinsesse Ingeborg Halvø assemblage may be missing in material from Prinsesse Thyra Ø due to degradation. Alternatively, there may be slight differences in the depositional environment or age.

Comparison with the material of Manum & Throndsen (1986) from Svalbard indicates that the Thyra Ø Formation has some features in common with the Basilika Formation which, based on dinoflagellate cyst evidence, is considered to be transitional Early to Late Paleocene in age. Earlier work by Manum (1960, 1962) on spores and pollen from Svalbard, though extensive, has not given any precise age indications. The macroflora of Spitsbergen indicates that gymnosperms and ferns producing taxodiaceous pollen and *Osmundacidites* spp. were very common in the Early Palaeogene; these pollen and spores are moderately common in the Thyra Ø Formation.

Age of the Thyra Ø Formation

The age of the Thyra Ø Formation is thought to be Late Paleocene to possibly earliest Eocene, even though many of the more conspicuous palynomorphs are of Late Cretaceous (Santonian–Maastrichtian) age. Others are known from both Maastrichtian and Early Palaeogene deposits. Several of the *Spinidinium* species, *Spongodinium delitiense*, *Trithyrodinium evittii* and *Senegalinium obscurum* have a known range crossing the Cretaceous–Tertiary boundary. These taxa indicate a general Late Cretaceous – Early Palaeogene age for the Thyra Ø Formation, but are less useful deciding the precise age for the formation. Representatives of *Chatangiella* are considered to be confined to deposits of Early Maastrichtian or older age, and are thus regarded as reworked. The same is true for the *Aquilapollenites* group (*sensu lato*) as well as *Pseudointegricorpus protrusum* and *Wodehouseia spinata* that are typical of (Upper Campanian –)Maastrichtian deposits.

From the suite of palynomorphs listed in Table 2, few taxa are considered both to be in place and to be sufficiently short ranging to be age diagnostic. *Cerodinium speciosum*, thought to indicate a (Late) Paleocene age (Hansen 1980a; Heilmann-Clausen 1985; Powell 1992) and *Spinidinium pilatum* indicating a Paleocene age (Stanley 1965) are the most diagnostic. Representatives of the *Cerodinium speciosum* group of cysts have been reported in low numbers from the Maastrichtian of USA (*C.* aff. *C. speciosum;* Benson 1976) and Late Campanian of Canada (*C. speciosum glabrum*; Kurita & McIntyre 1994) – although they are more typical of Lower Palaeogene than of Upper Cretaceous deposits. In the southern North Sea *Cerodinium speciosum sensu* Powell and Heilmann-Clausen is confined to the early Late Paleocene (Heilmann-Clausen 1985; Powell 1992), and unpublished work by Hansen (1980a) expresses the same opinion on West Greenland and Danish material. Thus, the occurrence of *Cerodinium speciosum* in the Thyra Ø Formation is interpreted as indicating a Late Paleocene age, although there is a slight possibility that it may represent older material. *Cerodinium markovae* has been reported from western Siberia where it has a Paleocene–Eocene range (Lentin & Vozzhennikova 1990) and *Spinidinium sagittula* has been reported from sediments of Early Eocene age (Drugg 1970). Other dinoflagellate cysts found in the Thyra Ø Formation are less reliable age indicators due to poor preservation leading to problems with precise identification. A few specimens of *Isabelidinium* aff. *I viborgense* fall in this category.

Many of the terrestrial taxa, e.g. the porate pollen, are more typical of Early Palaeogene than of Cretaceous deposits. The presence of a few specimens of ?*Ilexpollenites* sp. may indicate an Early Eocene age which is also suggested by the presence of the dinoflagellate cysts *Cerodinium markovae* and *Spinidinium sagittula*.

Systematic palynology

Selected palynomorphs from the Thyra Ø Formation are discussed below because they are considered to have stratigraphic or palaeoenvironmental significance. The entire microflora is illustrated in Figs 3–13.

Dinoflagellate cysts

The genera and species names cited below are in accordance with Lentin & Williams (1993).

Genus *Cerodinium* Vozzhennikova 1963; emend. Lentin & Williams 1987

***Cerodinium diebelii* (Alberti 1959) Lentin & Williams 1987**
Fig. 3d

Comments. Cerodinium diebelii is slender, elongate

with long apical and antapical horns and a finely striate periphragm. All but one of the specimens found are dark brown and in most specimens the distal parts of the horns are missing.

Occurrence in the Thyra Ø Formation. Rare specimens occur in samples from southern Prinsesse Ingeborg Halvø.

Previous occurrences. The species is known from many localities including the North Sea area where it occurs in the Late Campanian to Late Paleocene (Powell 1992). Ioannides (1986) reported it from the Maastrichtian to Early Paleocene of Arctic Canada, and Nøhr-Hansen (1996) from the Early Maastrichtian to Late Paleocene of West Greenland.

Cerodinium markovae (Vozzhennikova 1967) Lentin & Williams 1987

Fig. 3a–c

Comments. Large *Cerodinium* species with very thin, smooth periphragm and a granular endophragm. The apical and antapical horns are typically short, wide, tapering to a pointed tip, although a few specimens have a long apical horn with a rounded tip. The antapical horns do not diverge and they are finely serrate on the inner (centrally oriented) side as seen on text figure 16 in Lentin & Vozzhennikova (1990). The paracingulum is often poorly defined. The specimens from the Thyra Ø Formation therefore compare well to the rather poor type material, although they are smaller, ranging from 90 to 120 µm in length, as compared to the size range of 120–132 µm given for the type material.

Occurrence in the Thyra Ø Formation. Common in GGU 220345 from southern Prinsesse Ingeborg Halvø, a few specimens are found in the other samples from that area.

Previous occurrences. Cerodinium markovae has been previously recorded from the Paleocene–Eocene of Western Siberia by Vozzhennikova (1967).

Cerodinium speciosum (Alberti 1959) Lentin & Williams 1987

Fig. 3g–i, k

Comments. The specimens from the Thyra Ø Formation are rather small (approximately 80 µm long) compared to specimens of *C. speciosum* reported from Europe and the North Sea, which are often 150 µm long (e.g. Heilmann-Clausen 1985). However, specimens from West Greenland illustrated by Nøhr-Hansen (1996) are not much larger than the Thyra Ø Formation specimens, and Kurita & McIntyre (1995) demonstrated a large variation in size in material from Manitoba, Canada. The Greenland material may thus be one (small) end-member of a north–south size-trend within *Cerodinium*. *Cerodinium speciosum* has a large, granular endocyst which almost fills the central part of the thin pericyst, thus making the cyst essentially cornucavate. Parasutural and non-tabular coni are present on the pericyst. The species often has a compressed appearance, and short apical and antapical horns. It is distinguished from *C. striatum* by the lack of linearly arranged non-tabular coni and crenulations and its wider, more delicate horns. The specimens shown as Fig. 3g, h seem to be very similar to an unpublished specimen from West Greenland recorded by Hansen (1980a).

Occurrence in the Thyra Ø Formation. Relatively common in samples from the southern part of Prinsesse Thyra Ø, especially in GGU 424196 and GGU 424205, and in samples from the southern part of Prinsesse Ingeborg Halvø.

Previous occurrences. In the southern North Sea area *C. speciosum speciosum* is a relatively short ranging form indicative of the early part of the Late Paleocene (Heilmann-Clausen 1985; Powell 1992). Williams *et al.* (1993) on the other hand indicated a considerably longer range (Late Maastrichtian to the Early Eocene) for this form in the northern hemisphere, and Kurita & McIntyre (1995) stated that the species ranges from Campanian to Paleocene. Neither McIntyre (1974) nor Ioannides (1986) reported it from the Cretaceous of the Canadian Arctic; Ioannides (1986) reported it from the Early Paleocene. Benson (1976) reported a few specimens of *C.* cf. *C. speciosum* from Upper Maastrichtian sediments of Maryland, USA, Kurita & McIntyre (1994) reported rare *C. speciosum glabrum* from the Upper Campanian of Alberta, Canada, but these seem to be the only reports of *Cerodinium speciosum*-type cysts from sediments older than the Paleocene, and the possibility that the specimens recorded from the Cretaceous are not true *C. speciosum* cannot be excluded.

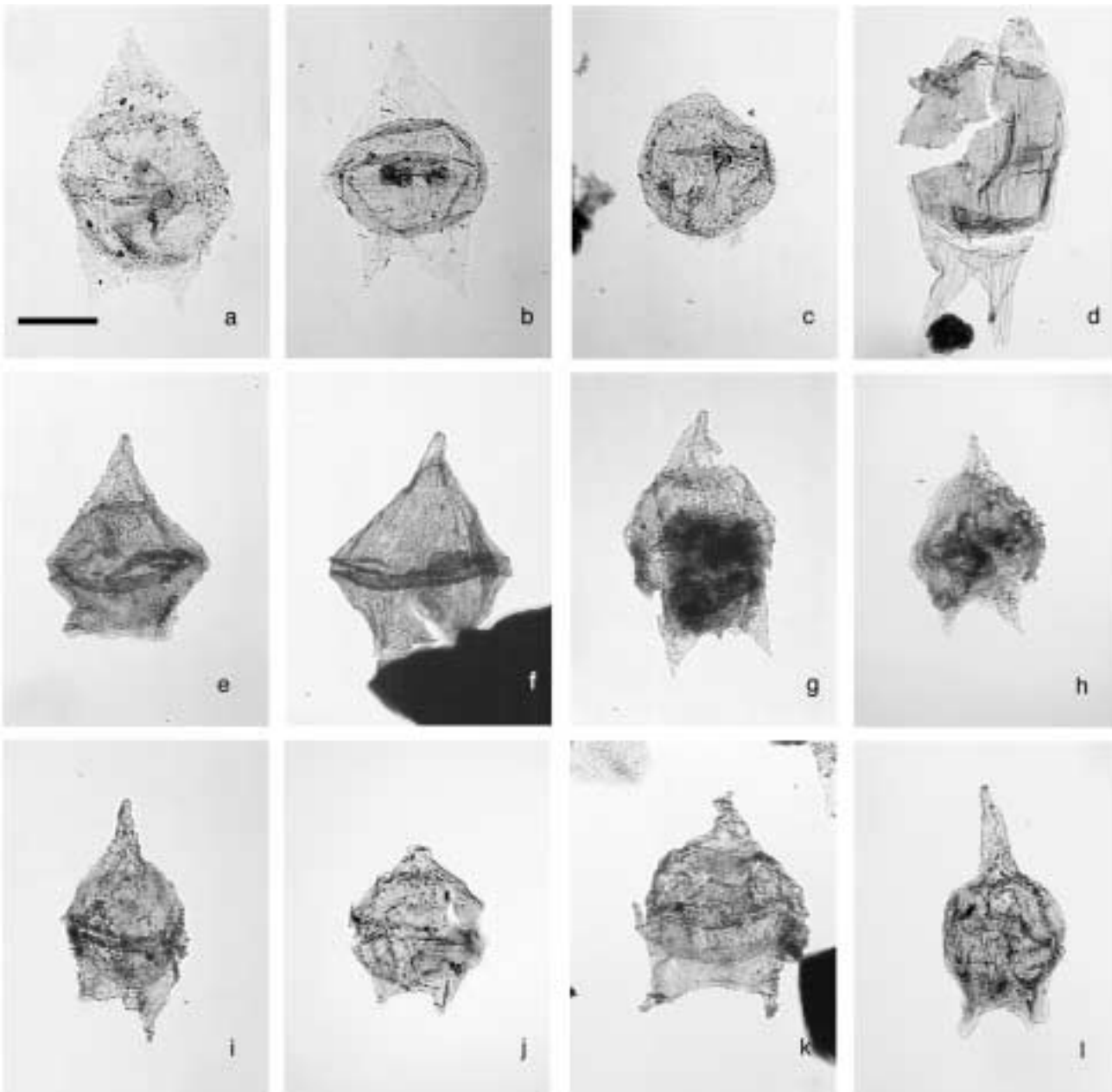


Fig. 3. *Cerodinium* spp. Scale bar is 30 µm; all figures are the same size. **a**: *Cerodinium markovae* MGUH 24887 from GGU 220345, MI 5300; **b**: *Cerodinium markovae* MGUH 24888 from GGU 220345, MI 5301; **c**: *Cerodinium markovae* (endocyst) MGUH 24889 from GGU 220345, MI 5833; **d**: *Cerodinium diebelii* (light specimen) MGUH 24890 from GGU 220345, MI 5298; **e**: *Cerodinium* aff. *C. striatum* (echinate ectophragm) MGUH 24891 from GGU 196271, MI 5619; **f**: *Phelodinium kozlowskii* MGUH 24892 from GGU 256621, MI 5057; **g**: *Cerodinium speciosum* MGUH 24893 from GGU 220345, MI 5227; **h**: *Cerodinium speciosum* MGUH 24894 from GGU 424196, MI 5835; **i**: *Cerodinium speciosum* MGUH 24895 from GGU 424195, MI 5347; **j**: *Cerodinium* sp. (short, wide) MGUH 24896 from GGU 424199, MI 5837; **k**: *Cerodinium speciosum* (wide, large cavation) MGUH 24897 from GGU 424206, MI 5840; **l**: *Cerodinium striatum* MGUH 24898 from GGU 196271, MI 5834.

Cerodinium striatum (Drugg 1967) Lentin & Williams 1987

Fig. 3e, l

Comments. Echinate, robust forms with a triangular epipericyst and pointed subparallel antapical horns which may be reduced. The robustness and a striation consisting of aligned coni and longitudinal wrinkles of the periphragm over most of the cyst separate this species from other forms of *Cerodinium* in the material. The species is often found as dark brown specimens.

Occurrence in the Thyra Ø Formation. This species is never common, but occurs regularly in samples from the southern part of Prinsesse Thyra Ø, and sporadically in most other sections.

Previous occurrences. In the North Sea area *Cerodinium striatum* occurs in the mid-Paleocene, i.e. in the late Early Paleocene and the early Late Paleocene (Powell 1992). From the Arctic it has previously been reported from Paleocene strata in West Greenland (Hansen 1980a; Piasecki *et al.* 1992).

Genus *Chatangiella* Vozzhennikova 1967; emend. Lentin & Williams 1976; emend. Marshall 1988

Chatangiella granulifera (Manum 1963) Lentin & Williams 1976

Fig. 4b, c

Comments. The specimens conform to the description of Manum (1963). Specimens are often less corroded than most of the other palynomorphs present in the samples. Possibly they are more resistant to corrosion.

Occurrence in the Thyra Ø Formation. A few specimens are found in most samples; they are considered to be reworked from Upper Cretaceous sediments, most probably Campanian or Santonian.

Previous occurrences. Manum (1963) and Manum & Cookson (1964) described *Chatangiella granulifera* from the Upper Cretaceous of Arctic Canada. McIntyre (1974) reported this species from the Santonian to ?Early Maastrichtian of Arctic Canada. From the same region, Ioannides (1986) reported *Chatangiella granulifera* from the Santonian to Campanian, and reworked in the Paleocene. Nøhr-Hansen (1996) reported it from Campanian and older deposits of West Greenland.

Genus *Glaphyrocysta* Stover & Evitt 1978

Glaphyrocysta ordinata (Williams & Downie 1966) Stover & Evitt 1978

Fig. 5a–c, f

Comments. The species is large, with a smooth to finely granular central body and has very robust elkhorn-like trabeculate processes (a few have more delicate processes and more elaborate trabeculae). All specimens are torn to some degree, so the complete configuration of the processes could not be determined.

Occurrence in the Thyra Ø Formation. The species is found in the southern part of Prinsesse Thyra Ø (GGU 424205), and is common in a few samples from the southern part of Prinsesse Ingeborg Halvø.

Previous occurrences. The species was originally described from the Early Eocene of England by Williams & Downie (1966). It occurs in deposits of Late Paleocene age in the North Sea area (Powell 1992). Ioannides (1986) reported the species from the Early Paleocene of Arctic Canada. Williams *et al.* (1993) indicated a Late Paleocene to Early Eocene range in the northern hemisphere for this species.

Genus *Laciniadinium* McIntyre 1975

Laciniadinium arcticum (Manum & Cookson 1964) Lentin & Williams 1980

Fig. 6j, k

Comments. Species with a short, relatively blunt apical horn and one well-developed off-centered, pointed antapical horn; a second, rudimentary antapical horn is often present.

Occurrence in the Thyra Ø Formation. A few specimens are found in most samples from Prinsesse Dagmar Ø and southern Prinsesse Ingeborg Halvø.

Previous occurrences. McIntyre (1974) reported the species consistently from the Santonian to the ?Early Maastrichtian. Nøhr-Hansen (1996) reported it from the ?Coniacian–Campanian of West Greenland, questionably also from the Early Maastrichtian and Paleocene. Dinoflagellate sp. E of Ioannides (1986) from the Maastrichtian of the Canadian Arctic resembles the specimens here recorded as *Laciniadinium arcticum*.

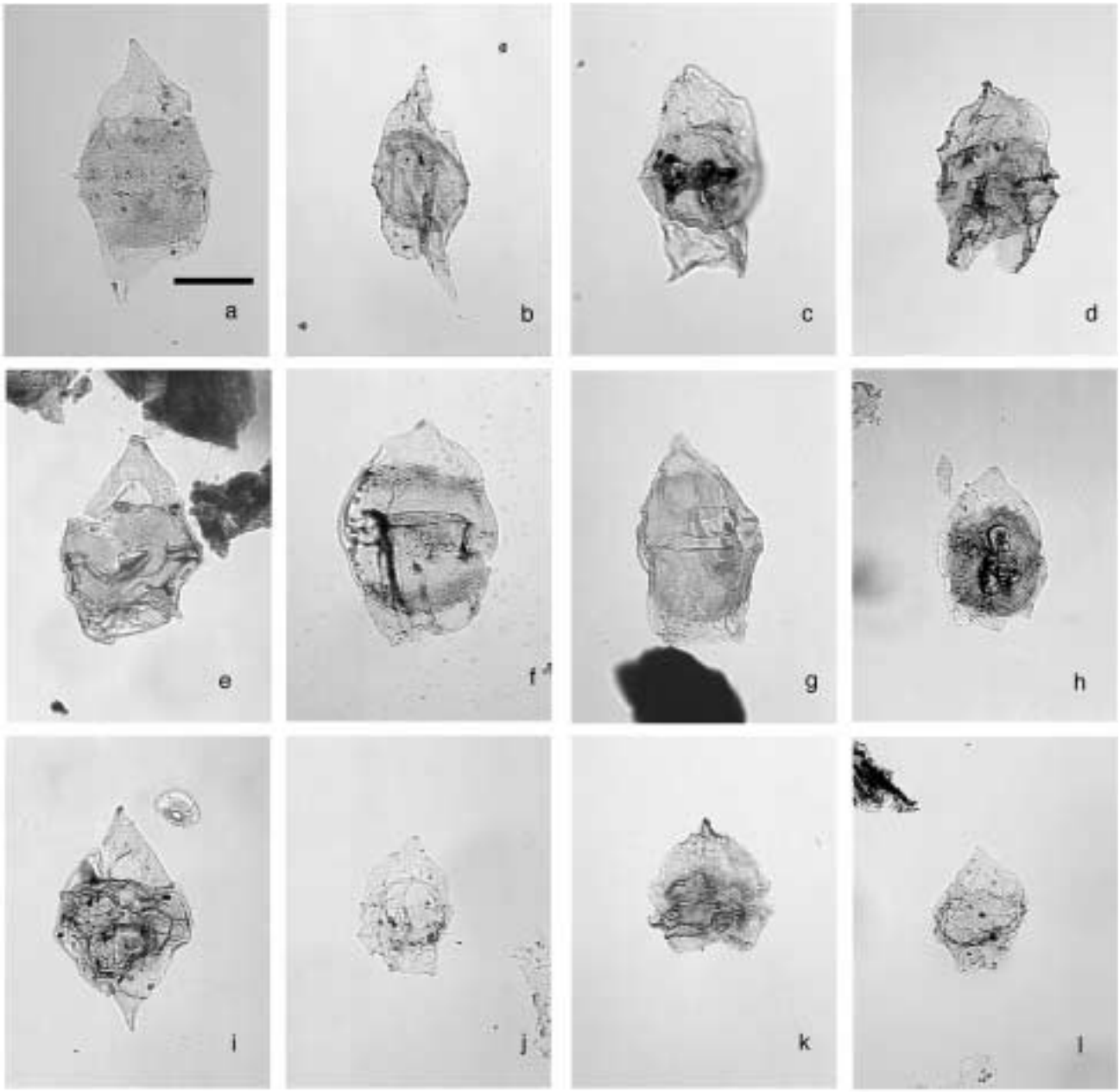


Fig. 4. *Chatangiella*, *Isabelidinium* spp. Scale bar is 30 µm; all figures are the same size. **a**: *Chatangiella* sp. MGUH 24899 from GGU 220345, MI 5299; **b**: *Chatangiella granulifera* (long and slender specimen) MGUH 24900 from GGU 196271, MI 5099; **c**: *Chatangiella granulifera* MGUH 24901 from GGU 256621, MI 5858; **d**: *Chatangiella* sp. MGUH 24902 from GGU 424195, MI 5646; **e**: *Isabelidinium/Chatangiella* sp. MGUH 24903 from GGU 256621, MI 5051; **f**: *Isabelidinium* sp. (aff. *Chatangiella dakotaensis*) MGUH 24904 from GGU 220351, MI 5563; **g**: ?*Alterbidinium* sp. MGUH 24905 from GGU 424204, MI 5317; **h**: ?*Alterbidinium* sp. MGUH 24906 from GGU 220349, MI 5474; **i**: *Isabelidinium* sp. MGUH 24907 from GGU 256621, MI 5056; **j**: Aff. *Isabelidinium viborgense* MGUH 24908 from GGU 220345, MI 5425; **k**: Aff. *Isabelidinium viborgense* MGUH 24909 from GGU 424196, MI 5649; **l**: Aff. *Senegalinium dilwynense* MGUH 24910 from GGU 220349, MI 5465.

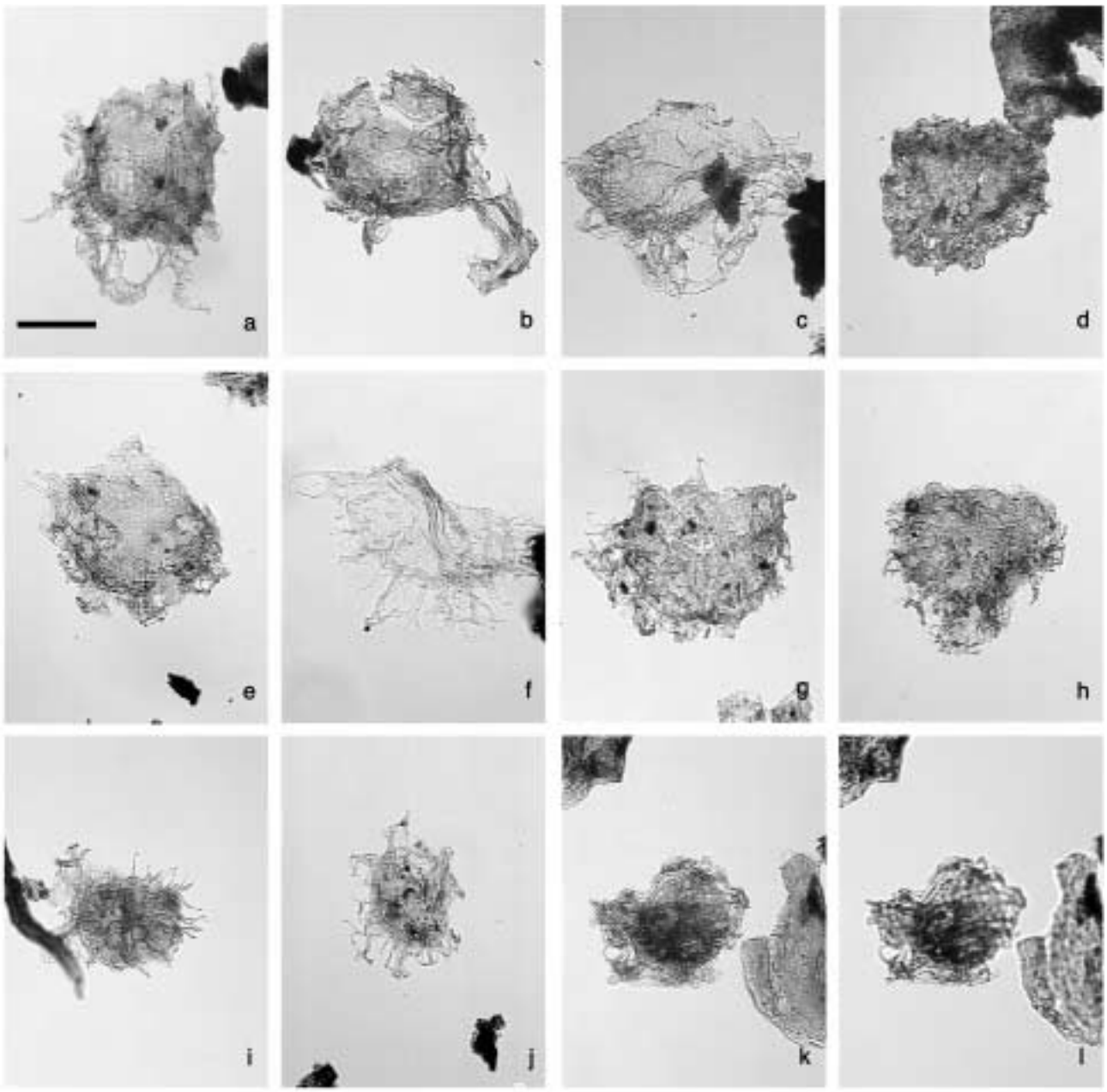


Fig. 5. *Glaphyrocysta*, *Areoligera*. Scale bar is 30 µm; all figures are the same size. **a**: *Glaphyrocysta ordinata* MGUH 24959 from GGU 196274, MI 5182; **b**: *Glaphyrocysta* ?*ordinata* MGUH 24960 from GGU 196271, MI 5615; **c**: *Glaphyrocysta ordinata* MGUH 24961 from GGU 220345, MI 5268; **d**: *Glaphyrocysta* ?*divaricata* MGUH 24962 from GGU 196271, MI 5087; **e**: *Glaphyrocysta* sp. MGUH 24963 from GGU 424206, MI 5651; **f**: *Glaphyrocysta* ?*ordinata* MGUH 24964 from GGU 220346, MI 5848; **g**: *Glaphyrocysta* sp. MGUH 24965 from GGU 220345, MI 5625; **h**: *Glaphyrocysta*/*Areoligera* sp. MGUH 24966 from GGU 424203, MI 5652; **i**: Aff. *Areoligera gippingensis* (small) MGUH 24967 from GGU 196271, MI 5623; **j**: *Spiniferites* sp. MGUH 24968 from GGU 196269, MI 5210; **k**, **l**: *Adnatosphaeridium*/*Nematosphaeropsis*? sp. MGUH 24969 from GGU 424196, MI 5653.

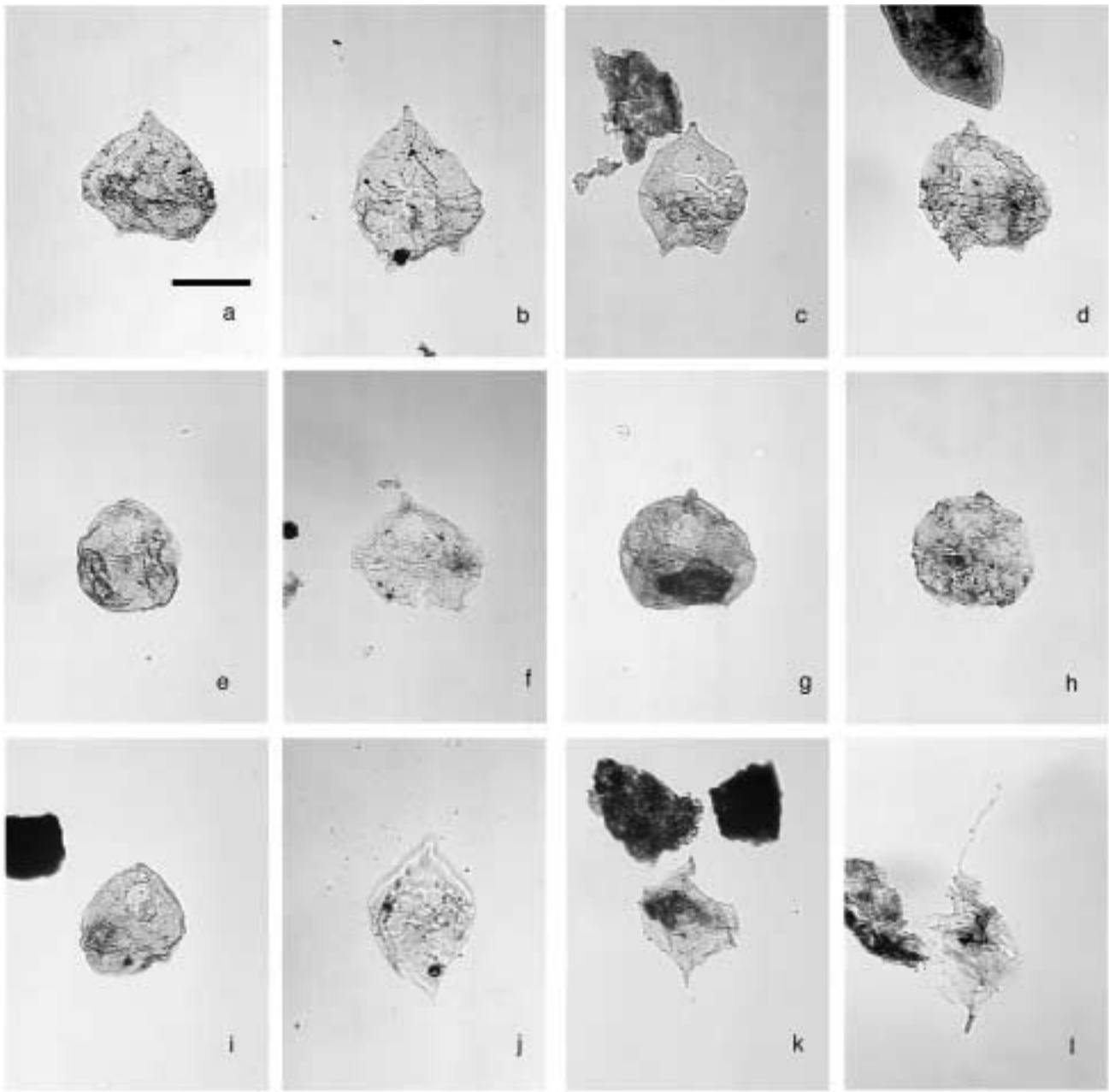


Fig. 6. *Senegalinium* spp. Scale bar is 30 µm; all figures are the same size. **a**: *Senegalinium* ?*microgranulatum* MGUH 24911 from GGU 196274, MI 5186; **b**: *Senegalinium microgranulatum* MGUH 24912 from GGU 196269, MI 5212; **c**: *Senegalinium* sp. MGUH 24913 from GGU 220345, MI 5288; **d**: *Senegalinium* ?*microgranulatum* MGUH 24914 from GGU 424196, MI 5642; **e**: *Senegalinium* sp. (close to *Trithyrodinium evittii* endocyst) MGUH 24915 from GGU 424196, MI 5338; **f**: *Senegalinium* sp. (delicate specimen with well developed paratabulation) MGUH 24916 from GGU 220349, MI 5479; **g**: *Senegalinium obscurum* MGUH 24917 from GGU 424196, MI 5339; **h**: *Senegalinium obscurum* MGUH 24918 from GGU 424195, MI 5346; **i**: ?*Senegalinium obscurum*/*Trithyrodinium evittii*? MGUH 24919 from GGU 424196, MI 5337; **j**: *Laciniadinium arcticum* MGUH 24920 from GGU 220351, MI 5501; **k**: *Laciniadinium arcticum* MGUH 24921 from GGU 196271, MI 5080; **l**: ?*Laciniadinium* sp. (long apical horn) MGUH 24922 from GGU 220349, MI 5633.

Genus *Palaeocystodinium* Alberti 1961

***Palaeocystodinium lidiae* (Górka 1963) Davey 1969**
Fig. 7a, b

Comments. Specimens of *Palaeocystodinium* with the endocoel filled with dark brown organic matter. As noted by Lindgren (1984), this taxon has the same structure between the wall layers as *Trithyrodinium fragile* Davey (1969), i.e. it is broken up into irregular, angular pieces.

Occurrence in the Thyra Ø Formation. Palaeocystodinium lidiae is found in samples from Prinsesse Thyra Ø and from the southern part of Prinsesse Ingeborg Halvø.

Previous occurrences. Górka (1963) originally described this species from the Maastrichtian of Poland and Davey (1969) reported it from sediments of the same age in South Africa. Lindgren (1984) reported it from the Maastrichtian of Sweden and Denmark. Similar, dark specimens are known from Paleocene deposits of the North Sea (G. Mangerud & L. Søyseth, personal communication 1996).

Genus *Senegalinium* Jain & Millepied 1973; emend. Stover & Evitt 1978

***Senegalinium microgranulatum* (Stanley 1965) Stover & Evitt 1978**
Fig. 6a, b, d

Comments. Specimens recorded as *Senegalinium microgranulatum* are very thin walled, with a finely granular endocyst, which gives the cyst a slightly greyish appearance. They have well-defined, small apical and equal or unequal antapical horns and a single-plate intercalary archaeopyle. The paracingulum is indicated by low ridges and an ambital bulge. The endocyst is rarely discernible. Paratabulation is generally better developed than in specimens of *Senegalinium obscurum* recorded in the material. Stanley (1965) mentioned that *Senegalinium microgranulatum* may be synonymous with *Subtilisphaera ventriosa*, and Ioannides (1986) did not exclude the possibility that *Senegalinium obscurum* (and probably *Subtilisphaera ventriosa*) may be conspecific with *Senegalinium microgranulatum*.

Occurence in the Thyra Ø Formation. Senegalinium microgranulatum is found in the southern part of Prinsesse Thyra Ø (GGU 424196) and southern Prinsesse Ingeborg Halvø.

Previous occurrences. Stanley (1965) described this species from a Paleocene sample from South Dakota, USA. Kurita & McIntyre (1995) reported it from the Paleocene of Manitoba, Canada.

***Senegalinium obscurum* (Drugg 1967) Stover & Evitt 1978**
Fig. 6g–i

Comments. Small, sac-like, thin-walled peridinioid cyst with a single-plate I archaeopyle. A small apical horn is often developed, in addition to one or two distinct to poorly developed antapical horns. An endocyst may or may not be discernible. In some specimens the paracingulum is well marked by low ridges resulting in an ambital notch, in others it is hardly visible. Other parts of the paratabulation are rarely expressed. In deformed, non-tabular specimens the single-plate intercalary archaeopyle may be misidentified as a 3I archaeopyle (characteristic of the genus *Trithyrodinium*, especially the smooth, thin-walled *T. evittii*, specimens of which are often found as isolated endocysts). In specimens of *S. obscurum* where the endocyst is not visible, it may be difficult to tell the two cyst genera apart, but usually the narrower (single plate) archaeopyle will identify the *Senegalinium*.

Occurrence in the Thyra Ø Formation. Senegalinium obscurum is the most common and consistently occurring dinoflagellate cyst taxon in the material studied.

Previous occurrences. Drugg (1967) described the species from the Maastrichtian–Paleocene of California, USA; he reported it to be abundant in the Danian part of the section, while occurring only sporadically in what he interpreted as being of Maastrichtian age. Kurita & McIntyre (1995) reported it from the Lower Paleocene of Manitoba, Canada.

Genus *Spinidinium* Cookson & Eisenack 1962; emend. Lentin & Williams 1976

Comments. There is much confusion in the literature concerning what characters to rely on and accept for

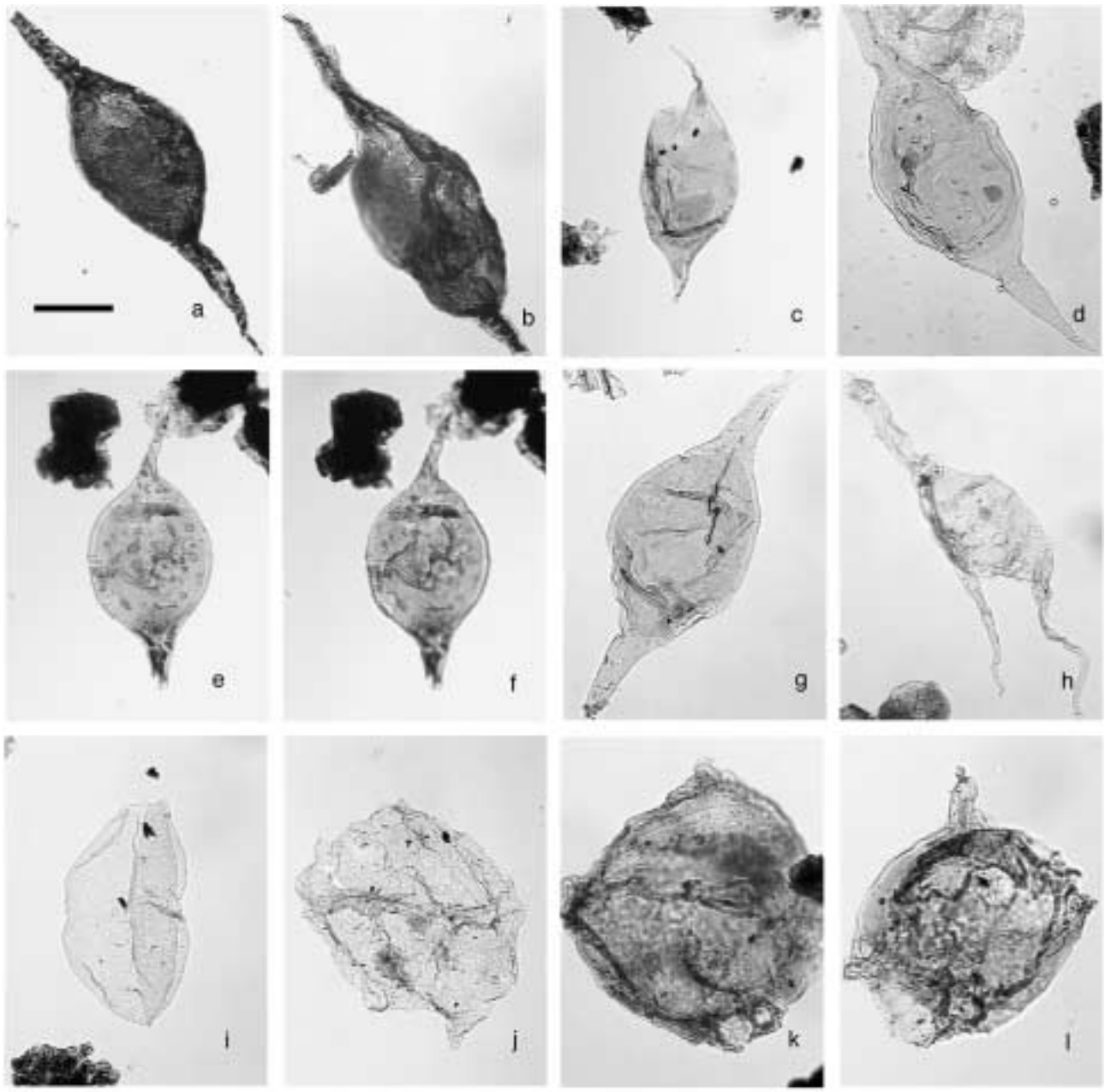


Fig. 7. *Palaeocystodinium* spp. Scale bar is 30 µm; all figures are the same size. **a**: *Palaeocystodinium lidiae* MGUH 24948 from GGU 196274, MI 5622; **b**: *Palaeocystodinium lidiae* MGUH 24949 from GGU 220351, MI 5539; **c**: *Palaeocystodinium* ?*bulliforme* MGUH 24950 from GGU 220345, MI 5294; **d**: *Palaeocystodinium* ?*australinum* MGUH 24951 from GGU 220351, MI 5527; **e**, **f**: *Palaeocystodinium* ?*bulliforme* (with initial '*P. lidiae*-like' charcoal-like structure in antapical horn) MGUH 24952 from GGU 220345, MI 5295; **g**: *Palaeocystodinium* ?*australinum* MGUH 24953 from GGU 220349, MI 5001; **h**: *Odontochitina operculata* MGUH 24954 from GGU 256621, MI 5640; **i**: *Fromea fragilis* MGUH 24955 from GGU 220349, MI 5632; **j**: *Palaeoperidinium pyrophorum* MGUH 24956 from GGU 220349, MI 5630; **k**: *Spongodinium delitiense* MGUH 24957 from GGU 220347, MI 5849; **l**: *Spongodinium delitiense* MGUH 24958 from GGU 220347, MI 5850.

each species within the *S. densispinatum – S. echinoideum – S. microceratum –* ?*S. pilatum –* ?*S. clavus – S. essoi* group of cysts (*S. essoi* has as yet only been reported from the southern hemisphere). A revision is needed, as in several cases the same character is said to be specific for several species. Furthermore, poor preservation of the present material renders identification to the species level somewhat uncertain. Here, the following criteria have been used to distinguish between the members of the group: size and development of the horns, distribution of the spines, and the size and form of spines.

?*Spinidinium pilatum* (Stanley 1965) Costa & Downie 1979
Fig. 8d–f, l

Comments. Specimens assigned to this taxon are elongate (approximately 60 µm long and 30–35 µm wide) with a moderately sparse cover of 2–3 µm long, robust, capitate spines. The distribution of the spines is uncertain due to poor preservation, but is nontabular as well as penitabular. The antapical horns are unequally developed, the left horn being markedly longer than the very reduced right one. The apical horn is 5–8 µm long, box-shaped, slightly tapering and concave at the tip, which bears a few spines.

Occurrence in the Thyra Ø Formation. ?*Spinidinium pilatum* occurs in most of the sections studied. The best preserved specimens are found in samples from the southern part of Prinsesse Ingeborg Halvø.

Previous occurrences. Stanley (1965) described this species from the Paleocene of South Dakota, USA, Benson (1976) reported rare specimens from Maryland, USA, and Kurita & McIntyre (1995) reported it from Paleocene deposits of Manitoba, Canada. The specimens illustrated by Kurita & McIntyre (1995, plate 2, figs 9, 10) bear penitabular spines only, a character which, according to the original description, is more characteristic of ?*Spinidinium clavus*.

***Spinidinium sagittula* (Drugg 1970) Lentin & Williams 1976**
Fig. 8a–c

Comments. A large, extremely thin-walled species with paratabulation indicated by penitabular echinae.

Occurrence in the Thyra Ø Formation. The species is only found in the southern part of Prinsesse Ingeborg Halvø where it is rare.

Previous occurrences. Spinidinium sagittula was described by Drugg (1970) from Lower Eocene sediments of the American Gulf Coast.

Genus *Spongodinium* Deflandre 1936; emend. Stover & Evitt 1978; emend. Lucas-Clark 1987

***Spongodinium delitiense* (Ehrenberg, 1838) Deflandre 1936; emend. Lucas-Clark 1987**
Fig. 7k, l

Comments. This species is very large, 110–120 µm long and 105–110 µm wide. It is thick walled, irregularly shaped with a large precingular archaeopyle. An apical horn, antapical and paracingular flanges are developed to a variable extent. The cyst wall is never as delicately spongy as seen in the specimens illustrated by Lucas-Clark (1987) and Ioannides (1986), but loose opercula seen in the preparations resemble those illustrated by Ioannides (1986) in shape and degree of sponginess.

Occurrences in the Thyra Ø Formation. This species occurs in samples from Prinsesse Thyra Ø, Prinsesse Dagmar Ø and southern Prinsesse Ingeborg Halvø.

Previous occurrences. Lucas-Clark (1987) reported *Spongodinium delitiense* in deposits of Late Campanian age in Montana, USA, in Maastrichtian sediments of the Arctic Ocean and in Paleocene deposits of New Jersey, USA. McIntyre (1974) reported the species from Santonian to Maastrichtian deposits from the Canadian Arctic, and has seen it in abundance in Maastrichtian deposits of southern Manitoba, Canada (D.J. McIntyre, personal communication 1997). Ioannides (1986) reported *Spongodinium delitiense* from Santonian to Paleocene sediments from the Canadian Arctic. Morgenroth (1968) reported the species from Danian deposits of Northern Europe. It occurs in abundance in a thin Early Paleocene interval on Nuussuaq, West Greenland (Nøhr-Hansen & Dam 1997).

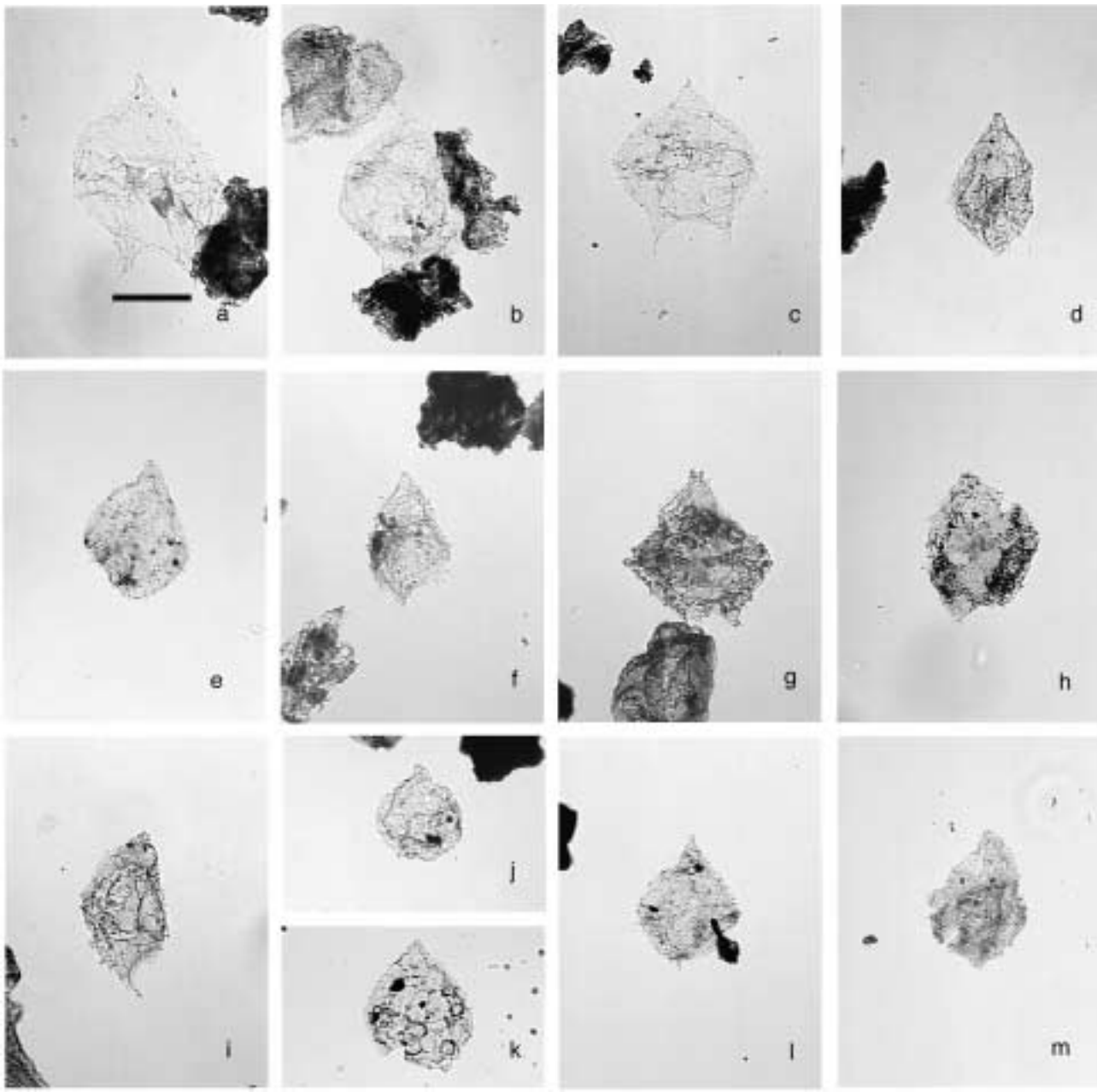


Fig. 8. *Spinidinium* spp. Scale bar is 30 µm; all figures are the same size. **a**: *Spinidinium sagittula* MGUH 24923 from GGU 220349, MI 5467; **b**: *Spinidinium sagittula* MGUH 24924 from GGU 220349, MI 5468; **c**: *Spinidinium* ?*sagittula* MGUH 24925 from GGU 220345, MI 5280; **d**: ?*Spinidinium pilatum* MGUH 24926 from GGU 220345, MI 5843; **e**: ?*Spinidinium pilatum* MGUH 24927 from GGU 424205, MI 5841; **f**: ?*Spinidinium pilatum* MGUH 24928 from GGU 220345, MI 5842; **g**: *Spinidinium* sp. MGUH 24929 from GGU 424196, MI 5654; **h**: ?*Spinidinium* sp. MGUH 24930 from GGU 424196, MI 5648; **i**: *Spinidinium* ?*essoi* MGUH 24931 from GGU 424206, MI 5847; **j**: *Spinidinium* sp. MGUH 24932 from GGU 424202, MI 5845; **k**: *Spinidinium* ?*clavus* MGUH 24933 from GGU 424206, MI 5846; **l**: ?*Spinidinium pilatum* MGUH 24934 from GGU 196271, MI 5081; **m**: *Spinidinium* ?*densispinatum* MGUH 24935 from GGU 196271, MI 5079.

Genus *Trithyrodinium* Drugg 1967

***Trithyrodinium evittii* Drugg 1967**
Fig. 9a–c

Comments. Species with a delicate periphragm with pointed, broad-based horns, and a slightly more robust, granular, rounded endocyst. The species is often found as isolated endocysts due to the fragile nature of the periphragm. Length of complete specimens 65–100 µm, width 50–90 µm, i.e. rather variable. Paraplates 1a and 3a are often seen to be fused in the midline anterior to plate 2a, as noted by Benson (1976, p. 197). This feature was neither shown by Drugg (1967, plate 9, fig. 2) nor Evitt (1985, p. 131) in their schematic representations of the *Trithyrodinium* archaeopyle.

Some specimens from the southern part of Prinsesse Thyra Ø have more thick-walled endocysts than usual, like the specimen described by Drugg, (1967, plate 3, fig. 3), as 'heavily encysted'.

Occurrence in the Thyra Ø Formation. *Trithyrodinium evittii* is common in samples from the southern part of Prinsesse Thyra Ø (e.g. GGU 424196) and from southern Prinsesse Ingeborg Halvø.

Previous occurrences. This species was originally described by Drugg (1967) from Danian deposits of California, and it has been reported from many Late Cretaceous – Early Paleocene sections (e.g. Benson 1976; Kurita & McIntyre 1995).

***Trithyrodinium fragile* Davey 1969**
Fig. 9g–i

Comments. This species has a thick-walled, ovoidal, nearly opaque endocyst and a very thin periphragm produced into short, box-like apical and antapical horns. The endocyst is dark brown and cracked in the few recorded specimens. The 3I archaeopyle, when discernible, is large.

In a large (90 µm) and a smaller (60 µm) partially broken down specimen, irregular scales of semi-opaque brown material seems to adhere to the otherwise translucent endocysts. This observation seems to support Davey's (1969) suggestion that the wall of the endocyst is two-layered, an observation which was contested by Lindgren (1984). Similar cysts have been recognised by Nøhr-Hansen & Dam (1997) in lowermost Paleocene sediments from West Greenland. The degradation of the semi-opaque layer may be due either to natural processes or to the chemical processing of the samples.

Occurrence in the Thyra Ø Formation. This species occurs in Prinsesse Dagmar Ø, the southern part of Prinsesse Thyra Ø and in a single sample from southern Prinsesse Ingeborg Halvø.

Previous occurrences. Trithyrodinium fragile was originally described by Davey (1969) from Maastrichtian–?Danian sediments of South Africa. Lindgren (1984) has recorded it from the Maastrichtian of Scania, southern Sweden.

***Trithyrodinium* sp.**
Fig. 9d–f

Comments. This rather inconspicuous species is smaller and more diffuse than *Trithyrodinium fragile*. It has a brownish endocyst and a thin pericyst, which may be essentially shapeless or relatively well defined, with small apical and antapical protrusions. The 3I archaeopyle, when discernible, is narrower than usual for the genus.

Occurrence in the Thyra Ø Formation. This species occurs in samples from Prinsesse Dagmar Ø, the southern part of Prinsesse Thyra Ø and Prinsesse Ingeborg Halvø.

Spores and pollen

Genus *Caryapollenites* Raatz & Potonié 1960; emend. Krutzch 1961

***Caryapollenites* sp.**
Fig. 11i, k, l

Comments. Relatively large, almost featureless, rounded, ?oblate grains, a few possibly with indications of three simple pores on the same hemisphere. In a few grains, a slight thinning of the polar area is suggested.

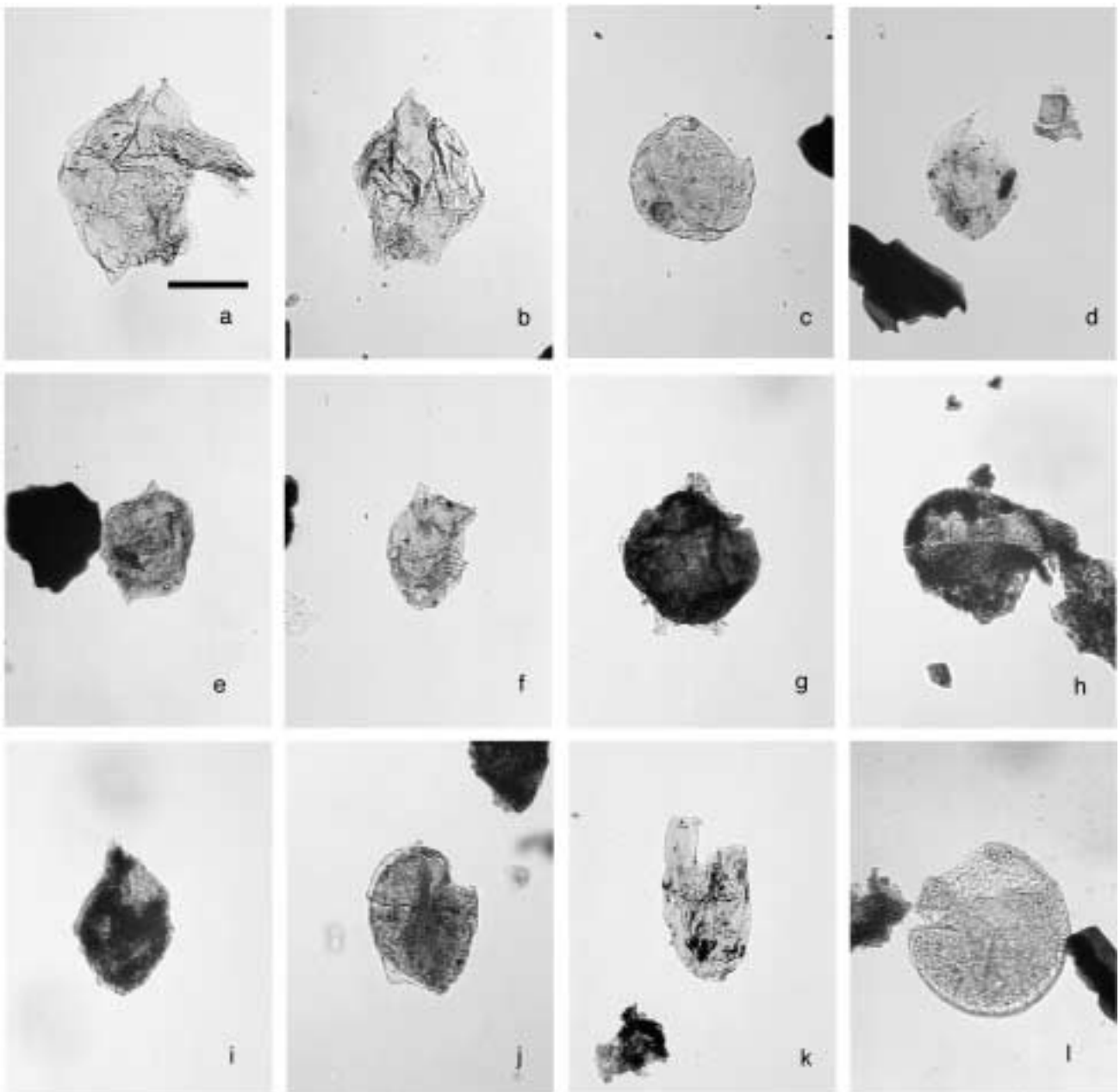


Fig. 9. *Trithyrodinium* spp. Scale bar is 30 µm; all figures are the same size. **a**: *Trithyrodinium evittii* MGUH 24936 from GGU 424196, MI 5643; **b**: *Trithyrodinium evittii* MGUH 24937 from GGU 424199, MI 5650; **c**: *Trithyrodinium evittii* (endocyst) MGUH 24938 from GGU 424196, MI 5334; **d**: *Trithyrodinium* sp. MGUH 24939 from GGU 220345, MI 5253; **e**: *Trithyrodinium* sp. MGUH 24940 from GGU, MI 5621; **f**: *Trithyrodinium* sp. MGUH 24941 from GGU 196271, MI 5155; **g**: *Trithyrodinium fragile* MGUH 24942 from GGU 196274, MI 5178; **h**: *Trithyrodinium fragile* MGUH 24943 from GGU 424196, MI 5647; **i**: *Trithyrodinium fragile* MGUH 24944 from GGU 424196, MI 5644; **j**: *Trithyrodinium* aff. *fragile* MGUH 24945 from GGU 424206, MI 5851; **k**: *Trithyrodinium* sp. MGUH 24946 from GGU 196269, MI 5886; **l**: *Trithyrodinium suspectum* MGUH 24947 from GGU 220351, MI 5571.

Occurrence in the Thyra Ø Formation. Rare in samples from southern Prinsesse Ingeborg Halvø.

Genus *Extratriporopollenites* Pflug 1953; emend. Skarby 1968

Extratriporopollenites sp.

Fig. 11b

Comments. This species is oblate, slightly rounded triangular in ambitus, with open pore invaginations and a diameter of 35–40 µm. It resembles *Extratriporopollenites* sp. 2 of McIntyre (1974) in overall appearance and size, but has less pronounced sculptural elements. The species also has some morphological affinity with *Trudopollis rotundus* of Manum (1962, plate XII, fig. 30) and the *Momipites* group, especially *Momipites wyomingensis* of Nichols & Ott (1978), but is considerably larger than the illustrated specimens. Nichols & Ott (1978), on the other hand, mention that their specimens are smaller than the very similar *Momipites coryloides* described by Wodehouse (1933) from the Eocene Green River Shale. *Momipites* sp. 2 of Gregory & Hart (1995) from Paleocene sediments of Louisiana resembles *Extratriporopollenites* sp. in outline and size (45 µm) but seems to be less sculptured.

Occurrence in the Thyra Ø Formation. Southern part of Prinsesse Ingeborg Halvø.

Genus *Hazaria* Srivastava 1971

Hazaria sheopiariae Srivastava 1971

Fig. 12a

Comments. Thick-walled monolete spore with an echino-foveolate appearance due to its tectate wall.

Occurrence in the Thyra Ø Formation. The species is practically confined to the samples from the southern part of Prinsesse Ingeborg Halvø, and is common in GGU 220351.

Previous occurrences. Srivastava (1971) described the species from Maastrichtian deposits of Alberta, Canada. Jerzykiewicz & Sweet (1986) reported it as spanning the Maastrichtian–Paleocene boundary in Alberta, Canada, and McIntyre (1994) reported it from the Paleocene of the Canadian Arctic Archipelago. D.J. McIntyre (personal communication 1997) has not seen the taxon in material older than the Early Campanian.

Genus *Myricipites* Wodehouse 1933

Myricipites speciosus Manum 1962

Fig. 11a, d

Comments. Scabrate, triporate pollen, oblate with a rounded triangular ambitus and slightly protruding pore areas with annular thickenings situated at the corners of the triangle. Equatorial diameter approximately 30 µm.

Occurrence in the Thyra Ø Formation. This species is never common, but occurs more commonly in the southern part of Prinsesse Ingeborg Halvø than further north.

Previous occurrences. Manum (1962) described the species from Palaeogene deposits of Spitsbergen, but several records of this (or very similar) species exist in the literature. Samoilovitch (1967) and Bratzeva (1967) both illustrated similar specimens as *Comptonia sibirica* and *Comptonia* sp. from Upper Senonian to Danian, and Paleocene–Eocene deposits of Siberia. Stanley (1965) erected the new species *Carpinus subtriangula* for similar pollen, allegedly without annular thickenings in the pore areas, even though those seem to be present on his illustrations. Russell & Singh (1978) reported *Carpinus subtriangula* as characterising (together with *Wodehouseia fimbriata* and *Alnus trina*, and without *Aquilapollenites* spp.) the Paleocene interval in Alberta, Canada. Hjortkjær (1991) recorded rather similar forms as *Triatriopollenites bituitus* and *Triporopollenites* sp. 1 from the Paleocene deposits of Disko and Nuussuaq, West Greenland. Kalkreuth *et al.* (1993, 1996) reported similar triporate pollen as *Triporopollenites mullensis* from the Paleocene – Early Eocene of Arctic Canada and Jerzykiewicz & Sweet (1986, plate 3, fig. 3) illustrated a similar type as 'Betulaceae–Myricaceae pollen' and reported it to span the Cretaceous–Tertiary boundary in Alberta, Canada.

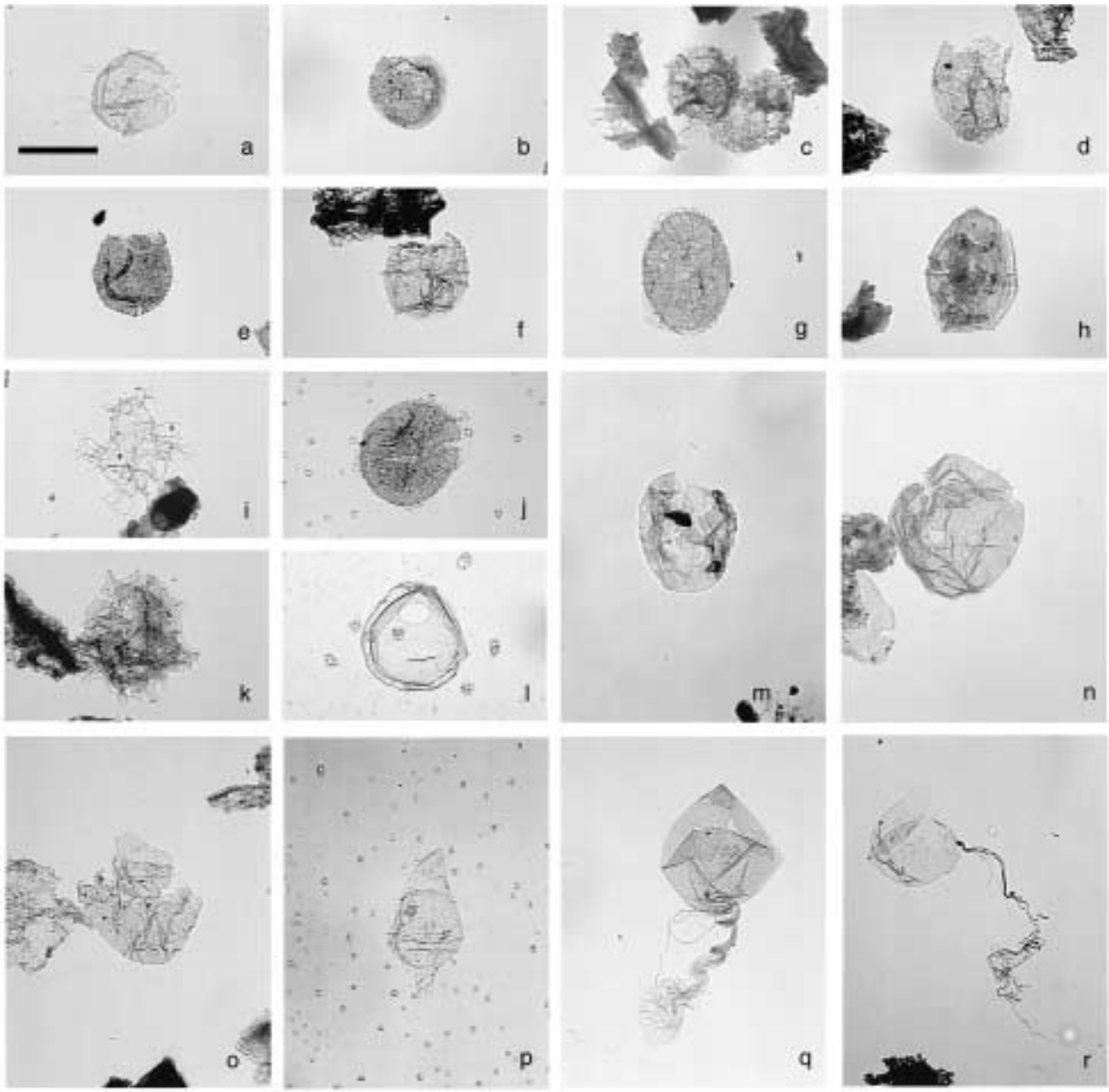


Fig. 10. Miscellaneous dinoflagellate cysts. Scale bar is 30 µm; all figures are the same size. **a**: ?*Trithyrodinium* sp. MGUH 24970 from GGU 220345, MI 5254; **b**: *Kallosphaeridium helbyi* MGUH 24971 from GGU 220349, MI 5018; **c**: ?*Microdinium* sp. MGUH 24972 from GGU 220345, MI 5281; **d**: *Membranosphaera* sp. of Drugg (1967) MGUH 24973 from GGU 220345, MI 5424; **e**: ?*Cerebrocysta* sp. MGUH 24974 from GGU 220345, MI 5258; **f**: *Microdinium ornatum* MGUH 24975 from GGU 220349, MI 5463; **g**: Dinoflagellate Type D of Ioannides (1986) MGUH 24976 from GGU 220351, MI 5546; **h**: *Microdinium ornatum* MGUH 24977 from GGU 220351, MI 5587; **i**: Aff. *Quadrina pallida* MGUH 24978 from GGU 220345, MI 5260; **j**: Dinoflagellate Type D of Ioannides 1986 MGUH 24979 from GGU 220351, MI 5556; **k**: *Pterodinium* sp. MGUH 24980 from GGU 220345, MI 5286; **l**: *Paralecaniella indentata* MGUH 24981 from GGU 220346, MI 5627; **m**: Smooth proximate sp. MGUH 24982 from GGU 220349, MI 5472; **n**: ?*Escharisphaeridia* sp. MGUH 24983 from GGU 220349, MI 5464; **o**: ?*Escharisphaeridia* sp. MGUH 24984 from GGU 220349, MI 5259; **p**: *Palaeohystrichophora infusorioides* MGUH 24985 from GGU 220351, MI 5505; **q**: *Desmocysta plekta* MGUH 24986 from GGU 220346, MI 5857; **r**: *Desmocysta plekta* MGUH 24987 from GGU 220345, MI 5287.

Genus *Trivestibulopollenites* Pflug 1953

***Trivestibulopollenites betuloides* Pflug 1953**
Fig. 11c

Comments. Triangular, triporate pollen with protruding pore areas. The pollen wall is smooth and hyaline.

Occurrence in the Thyra Ø Formation. This species is very rare in samples from northern Prinsesse Thyra Ø (GGU 420963) and in the southern part of Prinsesse Ingeborg Halvø (GGU 220345).

Previous occurrences. Similar pollen were reported by Lund (1989) from deposits of Late Paleocene age from the Faeroe Islands and by Hjortkjær (1991) from mid-Paleocene sediments of West Greenland. The species recorded as *Triporopollenites* sp. 1 (cf. *Betula*) by McIntyre (1974, plate 22, fig. 13) from the Campanian and Maastrichtian of the Canadian Arctic appears very similar, and it may be wiser to see it as a general type simply implying a Late Cretaceous or younger age.

Genus *Trudopollis* Pflug 1953

***Trudopollis* sp.**
Fig. 11f

Occurrences in the Thyra Ø Formation. A few representatives of this genus were found in samples from the southern part of Prinsesse Thyra Ø and Prinsesse Dagmar Ø.

Previous occurrences. Manum (1962, p. 92) reported the very common occurrence of *Trudopollis* spp. in material from Spitsbergen. He stated the stratigraphical range of this group of pollen to be Late Cretaceous to Middle Eocene.

Triprojectacites Group (*Aquilapollenites sensu lato*)

Comments. This characteristic group, consisting of the genera *Aquilapollenites*, *Mancicorpus*, *Integricorpus*, and *Pseudointegricorpus* is a conspicuous constituent of the Thyra Ø Formation microflora. Members of the group are never numerically prominent in the samples, but commonly occur in numbers from 2 to 10 specimens per slide. Preservation is somewhat variable, but a general trait is that the original features of the grains are blurred, a fact which mostly hampers determination to the species level. Preservation is immensely better, however, than the charred material reported by Batten (1982) from the Kap Washington Group of volcanics further to the north-west in Greenland, and the characteristic outline of the grains allows a tentative determination. This pollen group is characteristic of Upper Campanian to Maastrichtian deposits, consequently, specimens occurring in the Thyra Ø Formation are considered to be reworked from deposits of this age.

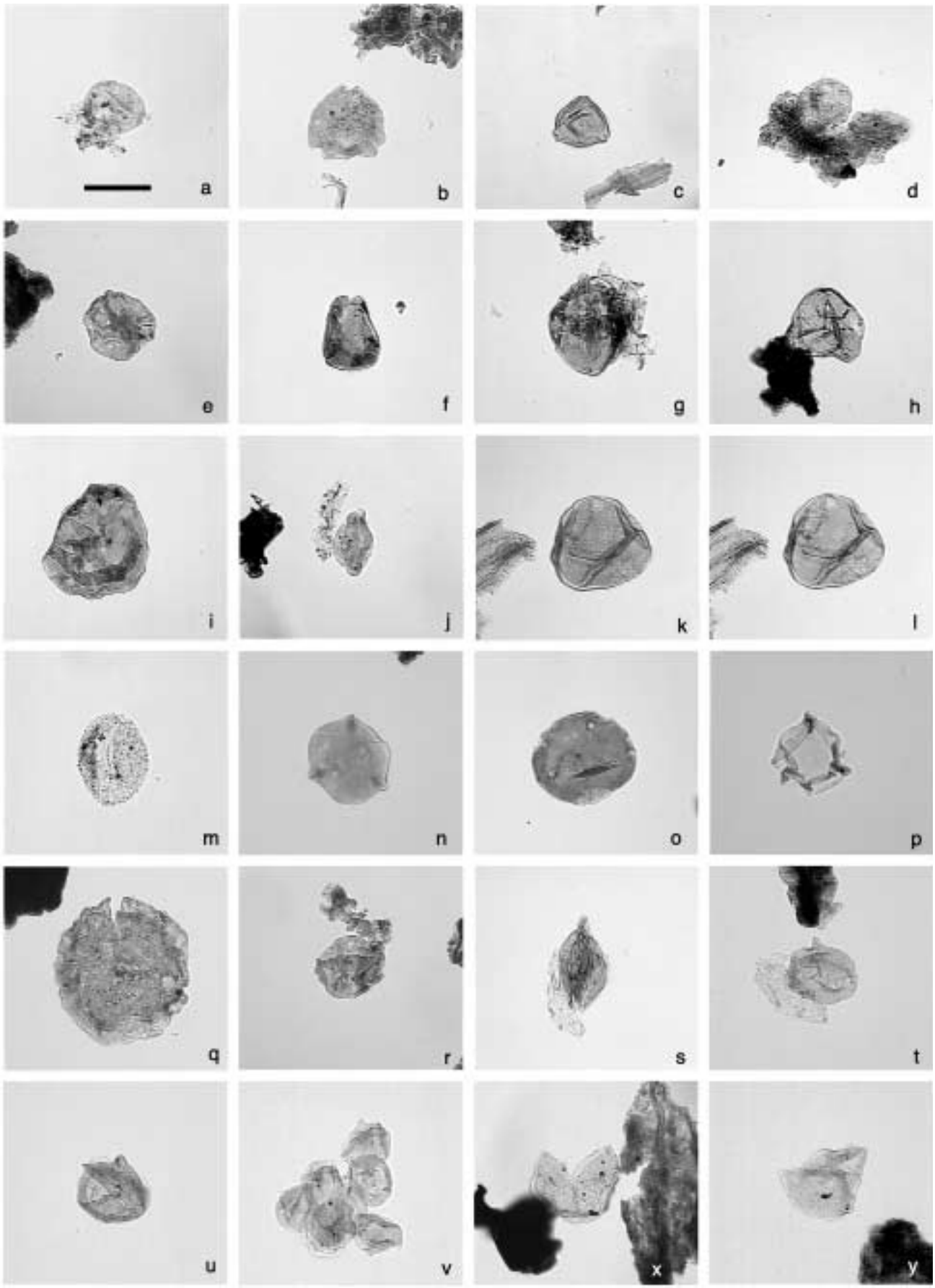
Genus *Aquilapollenites* Rouse 1957; emend. Funkhouser 1961

***Aquilapollenites conatus* Norton 1965**
Fig. 13f

Occurrence in Thyra Ø Formation. Prinsesse Dagmar Ø as a single broken specimen in GGU 256621.

Previous occurrences. Sweet (1986) ascribes it to his

Fig. 11. Pollen. Scale bar is 30 µm; all figures are the same size. **a**: *Myricipites speciosus* MGUH 25000 from GGU 220345, MI 5293; **b**: *Extratriporopollenites* sp. MGUH 25001 from GGU 220345, MI 5292; **c**: *Trivestibulopollenites betuloides* MGUH 25002 from GGU 220345, MI 5660; **d**: *Myricipites speciosus* MGUH 25003 from GGU 196274, MI 5662; **e**: Porate sp. MGUH 25004 GGU 220345, MI 5658; **f**: *Trudopollis* sp. MGUH 25005 from GGU 196269, MI 5883; **g**: ?*Rugubivesiculites* sp. MGUH 25006 from GGU 220345, MI 5257; **h**: ?*Triporopollenites* sp. MGUH 25007 from GGU 196268, MI 5060; **i**: ?*Caryapollenites* sp. MGUH 25008 from GGU 424203, MI 5316; **j**: Aff. *Tricolporopollenites villensis* MGUH 25009 from GGU 220345, MI 5661; **k**, **l**: *Caryapollenites* sp. MGUH 25010 from GGU 424199, MI 5663; **m**: ?*Ilexpollenites* sp. MGUH 25011 from GGU 220351, MI 5873; **n**: *Kurzipites trispissatus* MGUH 25012 from GGU 220351, MI 5879; **o**: *Caryapollenites* sp. MGUH 25013 from GGU 256621, MI 5681; **p**: *Alnipollenites* sp. MGUH 25014 from GGU 220351, MI 5872; **q**: *Inaperturopollenites magnus* MGUH 25015 from GGU 196271, MI 5074; **r**: *Triporopollenites* sp. MGUH 25016 from GGU 220345, MI 5657; **s**: *Metasequoia papillapollenites* MGUH 25017 from GGU 220349, MI 4988; **t**: *Sequoiapollenites* sp. MGUH 25018 from GGU 220351, MI 5875; **u**: *Taxodiaceaepollenites* sp. MGUH 25019 from GGU 220351, MI 5876; **v**: *Sequoiapollenites* spp. MGUH 25020 from GGU 220351, MI 5874; **x**: *Taxodiaceaepollenites hiatus* MGUH 25021 from GGU 220351, MI 5877; **y**: *Taxodiaceaepollenites hiatus* MGUH 25022 from GGU 220351, MI 5878.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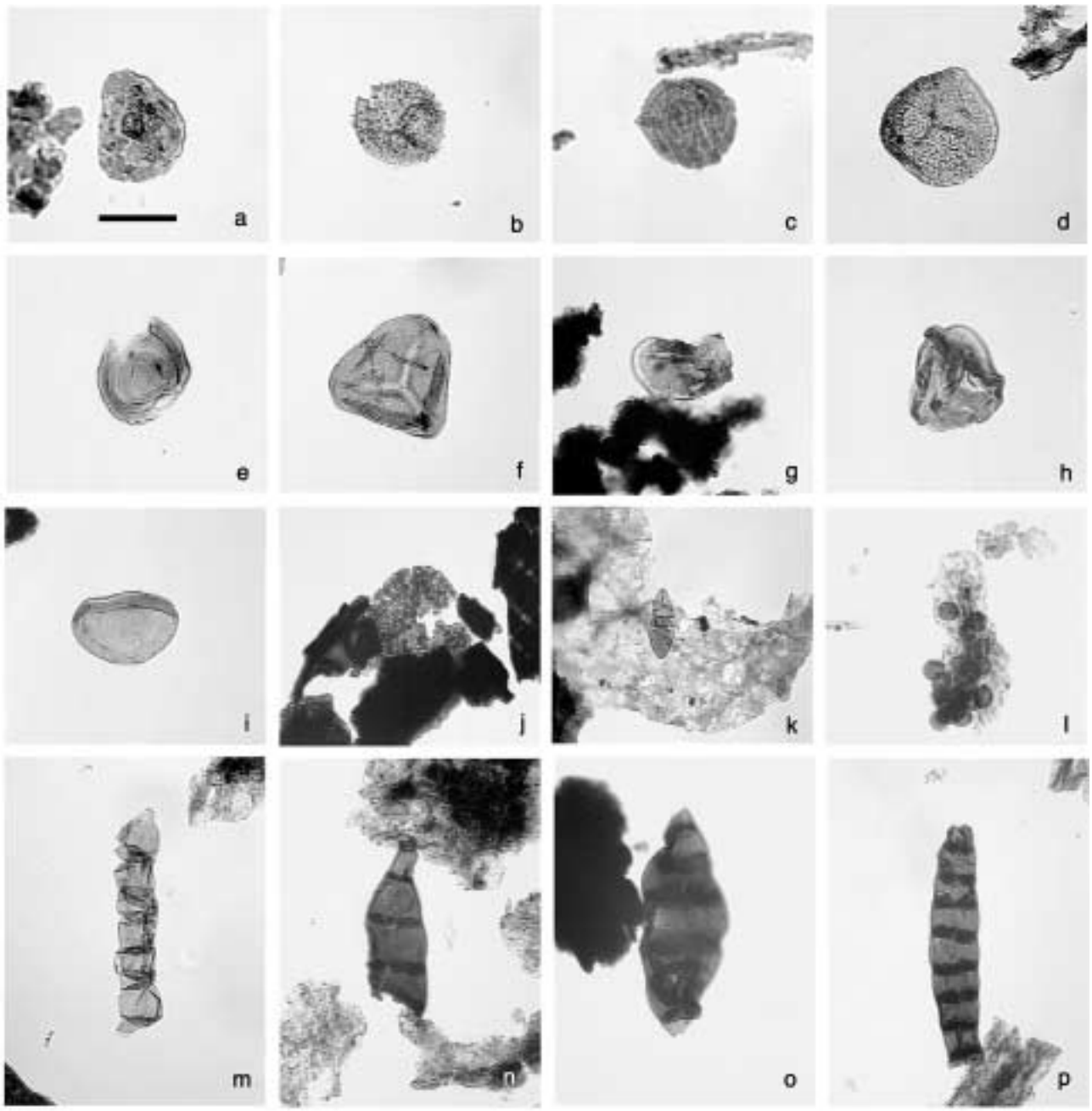

Fig. 12. Spores, fungal palynomorphs. Scale bar is 30 µm; all figures are the same size. **a**: *Hazaria sheopiariae* MGUH 25023 from GGU 220345, MI 5882; **b**: ?*Osmundacidites wellmanii* MGUH 25024 from GGU 220349, MI 4996; **c**: *Radialisporis radialis* MGUH 25025 from GGU 220349, MI 4998; **d**: *Osmundacidites* ?*coumauensis* MGUH 25026 from GGU 196268, MI 5059; **e**: Aff. *Chomotriletes minor* MGUH 25027 from GGU 220349, MI 5000; **f**: *Gleicheniidites* sp. MGUH 25028 from GGU 220349, MI 4997; **g**: Mono?colpate, gemmate sp. MGUH 25029 from GGU 196268, MI 5061; **h**: *Triplanosporites* sp. MGUH 25030 from GGU 196268, MI 5063; **i**: *Laevigatosporites* sp. MGUH 25031 from GGU 196268, MI 5067; **j**: *Foveotriletes subtriangularis* MGUH 25032 from GGU 196271, MI 5072; **k**: ?*Dicellaesporites* sp. MGUH 25033 from GGU 220345, MI 5667; **l**: *Inapertisporites* spp. MGUH 25034 from GGU 220345, MI 5668; **m**: *Multicellaesporites* sp. MGUH 25035 from GGU 220345, MI 5669; **n**: ?*Pleuricellaesporites* sp. MGUH 25036 from GGU 220345, MI 5670; **o**: Aff. *Diporicellaesporites reticulatus* MGUH 25037 from GGU 220345, MI 5672; **p**: ?*Pleuricellaesporites* sp. MGUH 25038 from GGU 220345, MI 5671.

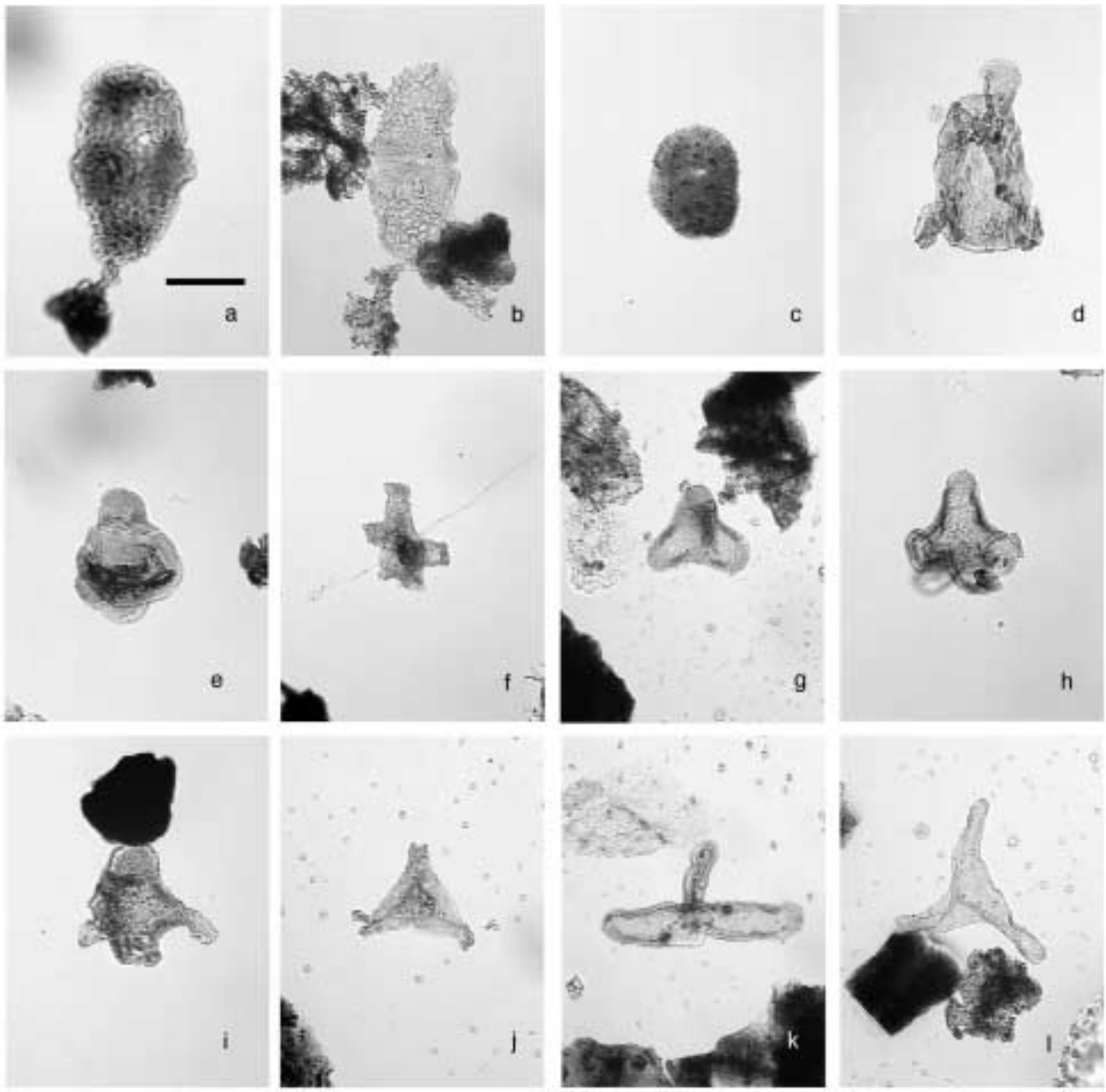

Fig. 13. *Aquilapollenites* spp. (*sensu lato*). Scale bar is 30 µm; all figures are the same size. **a**: *Pseudointegricorpus protrusum* MGUH 24988 from GGU 196274, MI 5620; **b**: *Pseudointegricorpus protrusum* MGUH 24989 from GGU 220347, MI 5459; **c**: *Wodehouseia spinata* MGUH 24990 from GGU 196271, MI 5071; **d**: ?*Grevilloideaepites* sp. MGUH 24991 from GGU 424205, MI 5678; **e**: ?*Grevilloideaepites* sp. MGUH 24992 from GGU 220347, MI 5461; **f**: *Aquilapollenites conatus* MGUH 24993 from GGU 256621, MI 5682; **g**: *Mancicorpus* sp. MGUH 24994 from GGU 220351, MI 5683; **h**: *Aquilapollenites* sp. MGUH 24995 from GGU 220347, MI 5460; **i**: *Aquilapollenites* ?*sentus* MGUH 24996 from GGU 424205, MI 5679; **j**: *Mancicorpus* ?*notabile* (polar view) MGUH 24997 from GGU 220351, MI 5685; **k**: *Mancicorpus notabile* MGUH 24998 from GGU 220351, MI 5684; **l**: *Mancicorpus notabile* MGUH 24999 from GGU 220351, MI 5687.

latest Maastrichtian *Wodehouseia spinata* assemblage. The species has been recorded from many localities in western Canada.

Genus *Mancicorpus* Mtchedlishvili 1961, emend. Srivastava 1968

Mancicorpus notabile Mtchedlishvili 1961
Fig. 13j–l

Comments. This is a large, smooth, thin-walled member of the genus, with three well-defined projections and triangular in polar view.

Occurrence in the Thyra Ø Formation. The species is a very conspicuous and common element in GGU 220351 from the southern part of Prinsesse Ingeborg Halvø.

Previous occurrences. Mtchedlishvili (1961) described the species from Upper Cretaceous deposits of western Siberia. Batten (1981) reported it from sediments of Late Campanian age from the northern North Sea and McIntyre (1974) reported it from the Maastrichtian of Arctic Canada.

Genus *Pseudointegricorpus* Takahashi & Shimono 1982

Pseudointegricorpus protrusum Takahashi & Shimono (Samoilovitch 1967)
Fig. 13a, b

Comments. Most recorded specimens of this characteristic taxon are dark brown, a few are light yellow.

Occurrences in the Thyra Ø Formation. Rare, dark brown specimens occur on southern Prinsesse Ingeborg Halvø and southern Prinsesse Thyra Ø. In GGU 420963 from northern Prinsesse Thyra Ø, a couple of well-preserved, yellow specimens were found.

Previous occurrences. Samoilovitch (1967) originally described the species as *Integricorpus* sp. 1 from Siberia. McIntyre (1974) reported it from the Maastrichtian of the Horton River section, Canada as *Integricorpus* sp., referring to Samoilovitch (1967). He also recorded the species from the Canadian Arctic Islands (McIntyre 1994). Nøhr-Hansen (1996) reported *Pseudointegricorpus protrusum* from West Greenland from his Late Maastrichtian *Wodehouseia spinata* zone.

Genus *Wodehouseia* Stanley 1961

Wodehouseia spinata Stanley 1961
Fig. 13c

Comments. Specimens of this characteristic oculate angiospermous taxon are all dark brown, and the features are somewhat blurred due to chemical or physical degradation.

Occurrence in Thyra Ø Formation. The species was found sporadically in samples from Prinsesse Thyra Ø and Prinsesse Dagmar Ø, but in only one sample were more than two specimens recorded.

Previous occurrences. This species is a well established Maastrichtian marker, but is known also from the latest Campanian. It was originally described by Stanley (1961) from South Dakota. Later, it has been reported by numerous other authors from Late Maastrichtian sections in North America, (e.g. Norton & Hall 1967; Evitt 1973; Sweet *et al.* 1990; Nichols & Brown 1992). McIntyre (1974) reported it from Arctic Canada, Batten (1981) from Maastrichtian strata from west of the Shetland Islands. Croxton (1980) and Nøhr-Hansen (1994b, 1996) reported *Wodehouseia spinata* from the Maastrichtian of West Greenland. Nøhr-Hansen (1994a) also reported a few, probably reworked specimens from sediments in West Greenland dated as Paleocene.

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