Bathonian and Callovian (Middle Jurassic) dinoflagellate cysts and acritarchs from Franz Josef Land, Arctic Soviet

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Well preserved dinoflagellate cyst and acritarch assemblages are recorded from Upper Bathonian and Callovian deposits on Northbrook Island, Franz Josef Land. More than 45 species have been identified. Two new species are proposed: *Parvocysta bjaerkei* sp. nov., and *Meiourogonyaulax spongiosa* sp. nov. The recorded marine microfloras are compared with assemblages reported from contemporaneous strata in Svalbard.

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Franz Josef Land is a group of about 75 islands situated in the northeastern part of the Barents Sea (Fig. 1). Geologically the group bears a close relation to eastern Svalbard, whereas it is distinctly different from Novaya Zemlya. The samples included in this study are from Northbrook Island, one of the southernmost islands within the archipelago.

Jurassic and Early Cretaceous palynomorph assemblages have been recorded from Franz Josef Land by Romanovskaya (in Dibner & Shulgina 1960) and Smelror (1986). Romanovskaya described assemblages characterized by high abundance of conifer pollen and large quantities of Bennetittalean and Ginkgophytes pollen from argillaceous rocks containing *Arcticoceras* sp. (*Macrocephalites* sp.). Only the spore-pollen composition of these Middle Jurassic deposits on Hocker Island were listed, and no marine palynomorphs were mentioned. Smelror (1986) listed 41 species of dinoflagellate cysts, acritarchs, pollen, and spores contained in six samples from Cape Flora and Windy Gully on Northbrook Island. However, this study had no stratigraphic control of the Jurassic erratic samples which the author suggested were of Callovian and possibly Lower Oxfordian age. The objectives of the present study have been to elucidate more data concerning the marine microflora (partly recovered from well-dated strata) from the Late Middle Jurassic of Franz Josef Land, and to compare the dinoflagellate cyst and acritarch assemblages with time-equivalent assemblages recorded from the Svalbard archipelago in the western Barents Sea region.

The Jurassic strata of Northbrook Island

The Jurassic deposits are chiefly situated in the southern part of the Franz Josef Land group. A stratigraphic survey of the marine Middle and Upper Jurassic deposits in Franz Josef Land was given by Dibner & Shulgina (1960). At Cape Flora on Northbrook Island the Middle Jurassic strata reach a maximum thickness of 157 m. A sketch of the Cape Flora section was published already in 1900 by F. Nansen (Fig. 2). However, Dibner & Shulgina (1960) argued that some of the fossils of the Nansen collection from Cape Flora were misidentified by Pompeckj (1900), and consequently that the proposed ages for the strata were erroneous.

On Cape Flora, Upper Aalenian and Bathonian deposits rest with small angular unconformity on continental arenaceous sediments of Lower Jurassic age (Dibner & Shulgina 1960). The light-grey Aalenian alearolites and aleuropelites show a visible thickness of 3 m. Apparently resting immediately on these deposits is soft clay with nodules of sandy marls exposed at an interval 7–10 m above sea level (Nansen 1900; Dibner & Shulgina 1960). From these deposits a fossil fauna

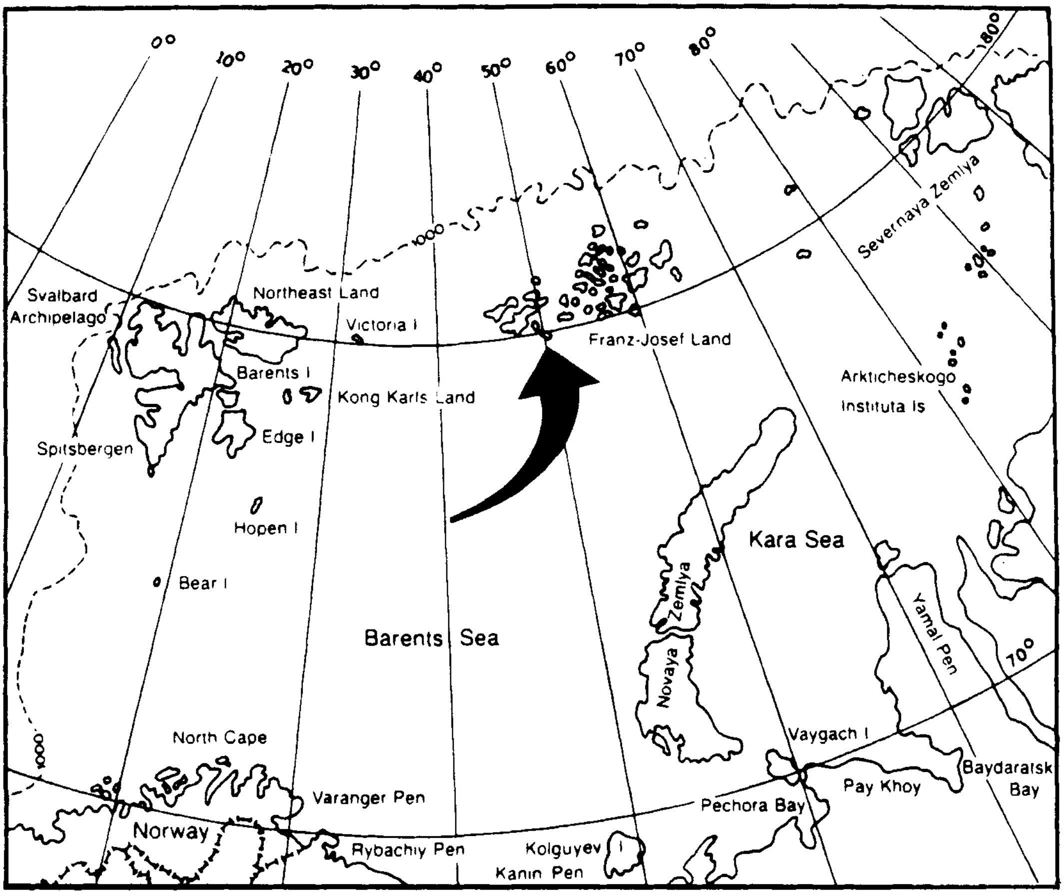


Fig. 1. Map of the Barents Sea Region. Location of Northbrook Island within the Franz Josef Land archipelago is indicated by arrow.

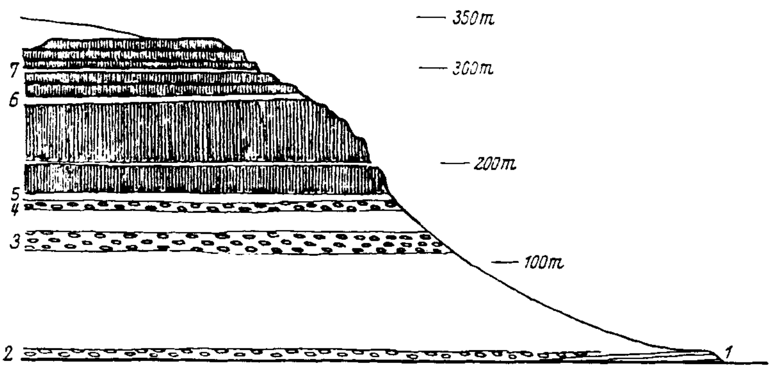


Fig. 2. Sketch of the Cape Flora section. 1. Thin alternating strata of sand with black carboniferous seams, 2. Lowermost fossiliferous horizon of soft clay with nodules of sandy marl, 3. Middle fossiliferous horizon of soft stratified clay with bands of phosphatic and calcareous nodules, 4. Upper fossiliferous horizon of soft clay, with band of nodules of clay-sandstone, 5. Horizon of soft clay, 6 and 7. Plant-bearing beds of shale and sandstone between beds of shale and sandstone between the successive layers of basalt (from Nansen 1900).

containing *Lingula beani, Discina reflexa, Oxytoma (Pseudomonotis) jacksoni,* and *Hibolites (Belemnites)* cf. *beyrichi* is recorded. Pompeckj (1900) suggested a Lower Bajocian age for this unit, but Dibner & Shulgina (1960) argued that since these listed fossils occur together with Aalenian species, these forms should be classed as Aalenian.

From about 10 to 113 m the section at Cape Flora is covered by scree, but the succeeding 24 m consist of soft, stratified horizontal clays packed with phosphoritic concretions and calcareous nodules. The concretions contain fossil faunas consisting basically of bivalves and, to a lesser degree, ammonites and belemnites. Unidentifiable plant remains also occur. Among the fauna recorded from this unit, Pompeckj (1900) identified *Macrocephalites kaettlitzi, M. ishamea* var. *arctica, M. pila, Cadoceras frearsi, Cadoceras* sp., and *Belemnites* sp. According to Pompeckj, these fossils date the clays as Lower Callovian. Later these fossils were reexamined by Spath (1932), who placed the ammonites described as *Macrocephalites* within the Bathonian genus *Arctocephalites*, and also questioned the identification of the ammonites described as *Cadoceras* by Pompeckj (1900). According to Spath (1947), the genus *Arctocephalites* is characteristic of the Upper Bathonian, while Arkell (1956) regarded both *Arctocephalites* and *Cranocephalites* as Lower Callovian forms. However, the definition of *Arctocephalites* as distinctly Upper Bathonian seems to be widely accepted (Dibner & Shulgina 1960; Smith et al. 1976), and the described interval from 113–137 m above sea level at Cape Flora is here regarded as Upper Bathonian.

The next mappable sedimentary strata are seen at a height of 150–172 m a.s.l., above the scree that has covered the Bathonian deposits. Here clays are exposed with numerous structures of the 'cone-in-cone' variety and intercalations of large arenaceous concretions (Nansen 1900; Dibner & Shulgina 1960). From these beds, Pompeckj (1900) identified the bivalves *Pseudomonotis* cf. *ornata, Pecten lindstroemi, Pecten* cf. *demissens, Lima* cf. *duplicata, Leda* cf. *nuda*, and the ammonites *Cadoceras tschefkini, Cadoceras stenolobum, Pseudocadoceras nanseni, Cylindroteuthis subextensa* and *Pachyteuthis panderi*. This fauna was placed in the Middle Callovian by Pompeckj (1900), but V. I. Bodylyevsky (Dibner & Shulgina 1960, p. 73) later suggested that species assignable to the genus *Cadoceras*, together with *Pseudocadoceras nanseni*, are more likely to indicate an early Upper Callovian age.

Just beneath the lowermost basalt, Nansen (1900) recognized two thin non-fossiliferous bands of black shale. A specimen of the Upper Callovian ammonite *Quenstediceras lamberti* was found enclosed in the basalt, and a specimen of *Quenstediceras vertumnum* was found in the scree close to the uppermost sedimentary layers and the basalt covering them (Nansen 1900).

According to Newton & Teall (1897), the Jurassic strata found at Cape Gertrude, 3–4 km east of Cape Flora, show great similarities to those at Cape Flora, even though some more sandy beds occur (Horn 1932). Windy Gully is located between Cape Flora and Cape Gertrude, but G. Horn who collected the examined material from Windy Gully gave no descriptions of the sedimentary strata in that area.

Material and methods

The samples investigated in the present study are from Cape Flora and Windy Gully on Northbrook Island. The samples from Cape Flora were collected by Dr. F. Nansen in 1896 at the end of the Norwegian North Polar Expedition 1893–96. The samples from Windy Gully were collected by G. Horn during the Norwegian Expedition to Franz Josef Land in 1930. All samples were later deposited in the collections of Paleontologisk Museum, Oslo. Details of stratigraphic levels and proposed ages of the samples investigated are given in Table 1.

The samples were prepared by standard techniques (see Barss & Williams 1973) at IKU in Trondheim. Slides with the figured specimens are kept in the collections of Paleontologisk Museum, Oslo.

Dinoflagellate cyst and acritarch assemblages

All processed samples yielded well preserved palynomorphs. In general, terrestrially derived palynomorphs are the most common, except in the samples CF-2 and CF-U from Cape Flora, where dinoflagellate cysts dominate the total microflora. The number of marine species recorded in each sample varies from between 15 and 32, except in the uppermost sample WG-3 from

Table 1. Stratigraphic levels and proposed ages of the investigated samples.

Sample	Locality	Macrofossil assemblage	Proposed ages Pompeckj 1900	Dibner & Shulgina 1960	This study
WG1	Windy Gully, 99 m				Upper Bathonian
WG2	Windy Gully, 151 m				Upper Bathonian
WG3	Windy Gully, 165 m				Callovian
CF1	Cape Flora, 130 m	*Arctocephalites kaettlitzi* *A. pilaeformis*	Lower Callovian	Upper Bathonian	Upper Bathonian
CF2	Cape Flora, 135 m	*A. ellepticus*			
CF3	Cape Flora, 168 m	*Cadoceras tschefhini* *Cadoceras stenolobum* *Pseudocadoceras nanseni*	Middle Callovian	Early Upper Callovian	Early Upper Callovian
CFU	Cape Flora, erratic				Early Upper Callovian

Windy Gully, which yielded only three dinoflagellate cyst species and two species of acritarchs. A list of the marine microplankton taxa recorded is shown in Table 2.

Upper Bathonian assemblages

The Upper Bathonian samples yielded moderately rich assemblages of dinoflagellate cysts and acritarchs, with 15 to 20 taxa being observed. The most common dinoflagellate cyst taxa in the two samples WG-1 and WG-2 from Windy Gully and sample CF-1 from Cape Flora are *Sirmiodinium grossii* (10–15% of the total microflora), *Sentusidinium* spp. (5–10%) and *Escharisphaeridia* spp. (5–10%). *Pluriarvalium osmingtonense* and *Chytroeisphaeridia chytroeides* are also relatively common (approximately 5% of the total microflora), while each of the remaining species of marine organic-walled microplankton represents less than 4%. In sample CF-2 from Cape Flora, *Chlamydophorella* sp. A and *Pluriarvalium osmingtonense* are most abundant (approximately 18%), while *Ctenidodinium* spp. and *Chytroeisphaeridia chytroeides* are present in significant amounts (9 and 7% of the total microflora). The remaining taxa, including *Sirmiodinium grossii*, *Escharisphaeridia* spp. and *Pareodinia* spp. are more subordinate, each representing less than 5%.

Callovian assemblages

The Callovian assemblages recorded from Cape Flora are more diverse than the assemblages registered from the Upper Bathonian strata, with 29 species observed in sample CF-3 and 32 in erratic sample CF-U. As for the Upper Bathonian samples, terrestrial palynomorphs are the most abundant elements in the early Upper Callovian sample CF-3, while sample CF-U is characterized by a dominance of marine species. The most prominent marine taxa in sample CF-3 are *Meiourogonyaulax* spp. together with *Lithodina* spp. (12% of the total microflora), *Chlamydophorella* sp. A., *Nannoceratopsis pellucida*, and *Valensiella ovula* (each representing approximately 5%). Sample CF-U is characterized by a high abundance of *Meiourogonyaulax* spp. (35%) and *Sirmiodinium grossii* (15%). *Chlamydophorella* sp. A and *Valensiella* spp. represent approximately 5% each of the total microflora assemblage in sample CF-U, while the remaining recorded species are less abundant.

The uppermost sample investigated from Windy Gully, WG-3, is dominated by spores including *Laevigatosporites* sp., *Exesipollenites tumulus*, and *Sphaeripollenites subgranulatus*. The only recorded marine species are the dinoflagellate cysts *Ellipsoidictyum cinctum*, *Escharisphaeridia pocockii*, *Valensiella ovula*, the acritarchs *Micrhystridium* sp., and the prasinophycean algae *Pterospermopsis* sp., which are present in low numbers.

Biostratigraphy

Dinoflagellate cyst zonation schemes covering the Upper Bathonian–Callovian of the Canadian Arctic have been published by Johnson & Hills (1973) and Davies (1983), offshore southeast Canada by Williams (1977), and northwest Europe by Herngreen & de Boer (1978), Sarjeant (1979), Riley & Fenton (1982), and Woollam & Riding (1983). The most detailed zonation schemes are

Table 2. List and numerical distribution of the recorded dinoflagellate cysts and acritarchs.

Taxon	Samples: Windy Gully WG1	WG2	WG3	Cape Flora CF1	CF2	CF3	CFU
Ambonosphaera calloviana Fensome 1979						2	3
Caddasphaera halosa (Filatoff) Fenton et al. 1980	6	8		5	4	3	4
Cassiculosphaeridia dictydia (Sarjeant) Riley & Fenton 1982	1	2		1	1	1	
Chlamydophorella sp. A of Davies 1983		5			35	9	11
Chytroeisphaeridia chytroeides (Sarjeant) Downie & Sarjeant 1965	10	11		10	15	4	
Ctenidodinium continuum Gocht 1970					6	2	2
Ctenidodinium ornatum (Eisenack) Deflandre 1938					11	3	3
Cymatiosphaera spp.	2	3		1		1	1
Diacanthum filapicatum (Gocht) Stover & Evitt 1978	1			1			1
Ellipsoidictyum cinctum Klement 1960	2		1	4			
Escharisphaeridia pocockii (Sarjeant) Erkmen & Sarjeant 1980	11	14	2	17		3	1
Escharisphaeridia sp. of Riding et al. 1985	4			6		1	2
Fromea tornatilis (Drugg) Lentin & Williams 1981					2	2	3
Gonyaulacysta jurassica (Deflandre) Norris & Sarjeant 1965						2	3
Gonyaulacysta jurassica var. *longicornis* (Deflandre) Gitmez 1970							1
Hystrichogonyaulax cladophora (Deflandre) Stover & Evitt 1978							3
Jansonia jurassica Pocock 1972							2
Leiofusa jurassica Cookson & Eisenack 1958	1	1					
Kylindrocysta spinosa Fenton et al. 1980	2	1		3			
Lithodinia jurassica Eisenack 1935					3	3	4
Meiourogonyaulax cf. *callomonii* Sarjeant 1972						1	1
Meiourogonyaulax deflandrei Sarjeant 1968						2	
Meiourogonyaulax spongiosa sp. nov.						23	67
Meiourogonyaulax valensii Sarjeant 1966						2	9
Micrhystridium spp.	2	4	2	5	3	4	1
Nannoceratopsis pellucida Deflandre 1938		5		3	3	11	12
Paragonyaulacysta calloviense Johnson & Hills 1973						2	2
Pareodinia alaskensis Wiggins 1975	3			2			
Pareodinia ceratophora Deflandre 1947	2	3			4		1
Pareodinia brachythelis Fensome 1979					2		
Pluriarvalium osmingtonense Sarjeant 1962	9	12			36	3	2
Parvocysta bjaerkei sp. nov.	3	5			4	3	
Pterospermopsis spp.	1		1	3			
Scriniocassis dictyotus (Cookson & Eisenack) Beju 1971							2
Scriniocassis pirum (Gitmez) Davies 1983	1			1			
Sentusidinium baculatum (Dodekova) Sarjeant & Stover 1978							
Sentusidinium pelionense Fensome 1979	11	15		18			
Sentusidinium pilosum (Ehrenberg) Sarjeant & Stover 1978							1
Sentusidinium sp. B of Fensome 1979						1	
Sirmodinium grossii Alberti 1961	22	32		21	5	3	35
Susadinium? sp. A							1
Tubotuberella eisenackii (Deflandre) Stover & Evitt 1978						2	2
Tubotuberella cf. *whatleyi* (Sarjeant) Stover & Evitt 1978							1
Valensiella ampulla Gocht 1970						3	1
Valensiella ovula (Deflandre) Eisenack 1963			2		3	10	13
Veryhachium spp.	2					1	1
Bisaccates	89	77	5	76	21	90	20
Other pollen + spores	13	21	42	32	68	34	18

those of Riley & Fenton (1982) and Woollam & Riding (1983), who correlated the boundaries of their dinoflagellate cyst zones with the boreal ammonite zonations. Riley & Fenton (1982) divided the Callovian and Oxfordian of north-west Europe into four zones and five subzones, while Woollam & Riding (1983) proposed six zones and nine subzones for the Bathonian, Callovian, and

Oxfordian Stages. It is clear that none of the existing zonation schemes can be used precisely within the Barents Sea Region, but some rough correlations with the British Jurassic are discussed here.

The Late Bathonian assemblages

The dinoflagellate cyst assemblages recorded from the Cape Flora samples CF-1 and CF-2, and the Windy Gully samples WG-1 and WG-2, can be correlated with the *Ctenidodinium combazii–Ctenidodinium sellwoodii* (Ccb/Cs) Zone of Woollam & Riding (1983). The age of this zone is Bathonian to early Callovian. The presence of *Sirmiodinium grossii* in the samples listed above indicates that the recorded assemblages can be placed within the Ccb/Cs subzone B, which is dated as Late Bathonian (middle *Discus* ammonite zone) to early Callovian (middle *Macrocephalus* zone). This correlation of the beds at 130–135 m a.s.l. at Cape Flora, and 99–151 m a.s.l. at Windy Gully, is in agreement with the earlier proposed age based on the macrofauna (Table 1).

Taxa known both from the Late Bathonian dinoflagellate cyst assemblages from Franz Josef Land and from the Ccb/Cs Zone of the British Jurassic include *Diacanthum filapicatum, Ctenidodinium continuum, C. ornatum, Chytroeisphaeridia chytroeides, Escharisphaeridia* spp., *Kylindrocysta spinosa, Nannoceratopsis pellucida, Pareodinia ceratophora, Sentusidinium* spp., and representatives of the *Ellipsoidictyum–Valensiella* complex. However, the key species *Ctenidodinium combazii* and *Ctenidodinium sellwoodii*, which dominate within the Ccb/Cs Zone in England, have so far not been recorded from Franz Josef Land. Data from Kong Karls Land (Bjærke 1977; Smelror 1988) and Spitsbergen (Bjærke 1980) seem to indicate that these species are very rare within the Barents Sea Region.

The early Upper Callovian assemblages

The samples CF-3 and CF-U from Cape Flora contain rich and diverse distinct Callovian dinoflagellate cyst assemblages, but based on the palynological data alone it is difficult to give more precise correlations. Several of the species recorded are well-known from the *Ctenidodinium ornatum–Ctenidodinium continuum* (Co/Ccn) Zone and the *Wanaea thysanota* (Wt) Zone of Woollam & Riding (1983), but the key species used to define the boundaries of these zones have not been observed from Franz Josef Land. As seen in the Co/Ccn and Wt zones of the British Jurassic, the Callovian assemblages from Franz Josef Land are more diverse than those in the Ccb/Cs zone below. In addition to *Ctenidodinium ornatum* and *C. continuum*, important taxa known from this interval both in England and Franz Josef Land include *Hystrichogonyaulax cladophora, Gonyaulacysta jurassica, Lithodinia jurassica*, and *Tubotuberella* spp.

The macrofauna suggests that the deposits from 150–172 m a.s.l. at Cape Flora are of early Upper Callovian age. The presence of *Ambonosphaera calloviana* suggests that the samples CF-3 (168 m) and CF-U (erratic) are of pre-*Lamberti* ammonite Zone age (according to the range reported by Berger (1986) for this species). This assumption is further supported by the absence of *Acanthaulax senta*, a species known from the *Athleta* Zone to the *Densiplicatum* Zone of the British Jurassic, and which is known to be abundant in Svalbard (Bjærke 1980; Smelror 1988). Thus, the samples CF-3 and CF-U from Cape Flora can probably be correlated with the *Wanaea thysanota* subzone A of Woollam & Riding (1983), i.e. the *Athleta* ammonite zone.

Comparisons with Bathonian–Callovian microfloras from Svalbard

In Svalbard, marine microplankton assemblages comparable with the Bathonian and Callovian assemblages from Franz Josef Land have been reported from Kong Karls Land (Bjærke 1977; Thusu 1978; Smelror 1988) and from central Spitsbergen (Bjærke 1980).

In Kong Karls Land Bjærke (1977) recognized 'Association' D of Callovian age within the lower part of the Retziusfjellet Member of the Janusfjellet Formation. Characteristic species of Bjærke's 'Association' D also recorded from Franz Josef Land include: *Tubotuberella eisenackii, Nannoceratopsis pellucida, Sirmiodinium grossii, Fromea tornatilis, Hystrichogonyaulax cladophora, Gonyaulacysta jurassica, Chytroeisphaeridia chytroeides*, and *Pareodinia ceratophora*.

In his stratigraphic paper on Aptian to Toarcian dinoflagellate cysts from Arctic Norway, Thusu (1978) listed several species recognized within the Franz Josef Land assemblages. However, only two samples from Upper Bathonian–Callovian deposits of the Retziusfjellet Member were included in his study. A more detailed palynological study of the Middle Jurassic of Kong Karls Land was carried out by Smelror (1988) who outlined the distribution of 79 dinoflagellate cyst and acritarch taxa through the Hårfagrehaugen section on Kongsøya. Excluding *Kylindrocysta spinosa* and *Leiofusa jurassica*, all of the species recognized from the Upper Bathonian of Franz Josef Land were also recorded from contemporaneous strata in Kong Karls Land. As observed within the Upper Bathonian samples from Franz Josef Land, *Sentusidinium* spp., *Escharisphaeridia* spp., and *Sirmiodinium grossii* are the most common taxa within the Upper Bathonian to lowermost Callovian part of the Retziusfjellet Member on Kongsøya, Kong Karls Land.

Several of the species recorded from the early Upper Callovian assemblages from Franz Josef Land are also present within the Callovian strata of Kong Karls Land. Most of these species are forms occurring below and/or above the early Upper Callovian interval on Kongsøya (Smelror 1988). Species exclusively known from the Callovian of both areas are *Ambonosphaera calloviana, Paragonyaulacysta calloviense, Hystrichogonyaulax cladophora, Tubotuberella eisenackii,* and *Valensiella ovula*. The three latter species are known from pre-Callovian strata elsewhere in northwest Europe.

The frequency distribution of the various dinoflagellate cyst taxa does not show directly equivalent patterns within the time-equivalent assemblages from Franz Josef Land and Kong Karls Land, although there are some similarities. Most prominent taxa within the Callovian Franz Josef Land assemblages are *Chlamydophorella* spp., *Sentusidinium* spp., *Escharisphaeridia* spp., *Pareodinia* spp., and *Sirmiodinium grossi*. However, the genera *Meiourogonyaulax, Lithodina,* and *Valensiella*, which are most common within the Franz Josef Land assemblages, are represented by relatively fewer specimens within the early Upper Callovian microfloras recorded from Kong Karls Land.

In central Spitsbergen, Bjærke (1980) recognized three assemblage zones within the Agardhfjellet Member of the Janusfjellet Formation. His Zone 1 was characterized by *Nannoceratopsis pellucida, Tubotuberella eisenackii, Gonyaulacysta jurassica* var. *longicornis*, and several species of the genera *Pareodinia, Ellipsoidictyum, Pluriarvalium*, and *Ctenidodinium*. The Assemblage Zone 1, which was recognized within the lower few metres at Knorringfjellet and Festningen, was regarded as uppermost Bathonian or Lower Callovian by Bjærke (1980). This author further defined an Assemblage Zone 2 characterized by *Acanthaulax senta, Stephanelytron redcliffense, Lithodinia jurassica, Tubotuberella dangeardii,* and *Wanaea* sp. Zone 2, which covers a 20–40 m thick interval immediately above Zone 1, was regarded as Middle or Upper Callovian age.

Bjærke (1980) suggested that the Assemblage Zone 1 of the Agardhfjellet Member in central Spitsbergen may be correlated with his 'Association D' defined in Kong Karls Land. Several of the species listed from Zone 1 of the Agardhfjellet Member by Bjærke (1980) are classified within open nomenclature, and it is not possible to give detailed comparisons. None of the species show equivalent restricted occurrence on both Spitsbergen and in Franz Josef Land.

The presence of *Acanthaulax senta* within Zone 2 of the Agardhfjellet Member indicates that these assemblages are slightly younger than the early Upper Callovian assemblages recorded from Franz Josef Land. *Acanthaulax senta* is known to have its earliest occurrence within the Late Callovian *Lamberti* zone within the English Jurassic (Woollam & Riding 1983), although it may first appear within the underlying *Athleta* zone in East Greenland (Piasecki 1980; Poulsen 1985). Several of the species known from the Upper Bathonian and early Upper Callovian assemblages of Franz Josef Land and from Zone 1 of the Agardhfjellet Member, also occur within Zone 2 of the Agardhfjellet Member, and are thus of limited use in correlations. Additional data are needed to give more detailed comparisons.

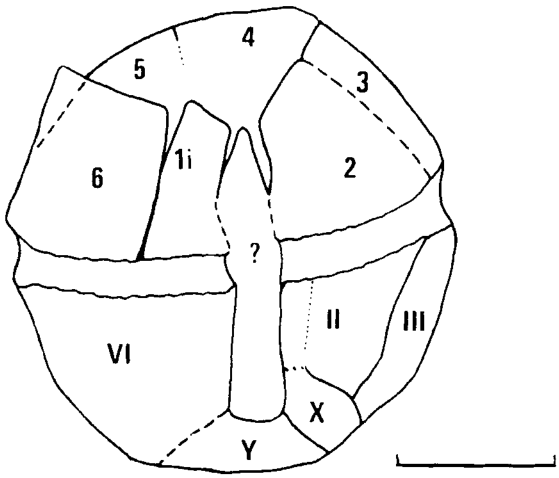
Systematic palynology

Class *Dinophyceae* Fritsch 1929
Order *Peridiniales* Haeckel 1894

Genus *Parvocysta* Bjærke 1980
Type species: *Parvocysta bullula* Bjærke 1980

Parvocysta bjaerkei sp. nov. Figs. 4G, 8C & D, Text-fig. 9 (see p. 237)

Description.– Dinoflagellate cysts basically subpentagonal in outline, with a more or less



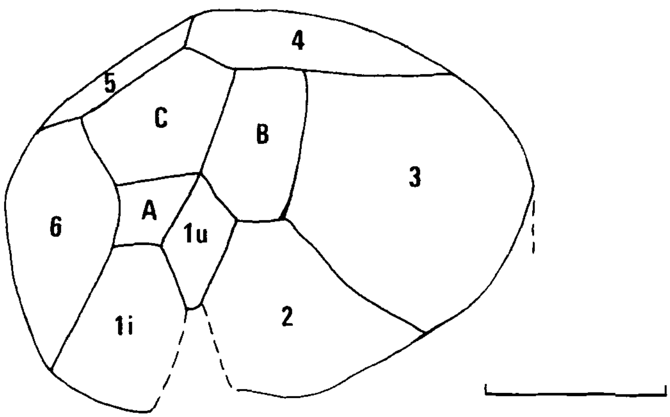


Fig. 3. Meiourogonyaulax spongiosa sp. nov. (scale bar = 10 μm). Schematic line drawings labelled in the terms of the Taylor-Evitt notation system (see Evitt 1985).

Fig. 4. Upper Bathonian and early Upper Callovian dinoflagellate cysts and acritarchs from Franz Josef Land.

A–C: *Ambonosphaera calloviana* Fensome 1979. A & B: CF-U. F57/1. PA4386. Length 32 μm. C: CF-3, SEM CF-3 (I). Length 34 μm.

D & E: *Caddasphaera halosa* (Filatoff) Fenton et al. 1980. D: WG-2 (B). A47/1. PA4387. Total width 60 μm. E: SEM CF-3 (I). Width central body 28 μm.

F: *Escharisphaeridia pocockii* (Sarjeant) Erkmen & Sarjeant 1980. CF-1. M52/4. PA4392. Width 50 μm.

G: *Parvocysta bjaerkei* sp. nov. SEM CF-3 (II). Width 45 μm.

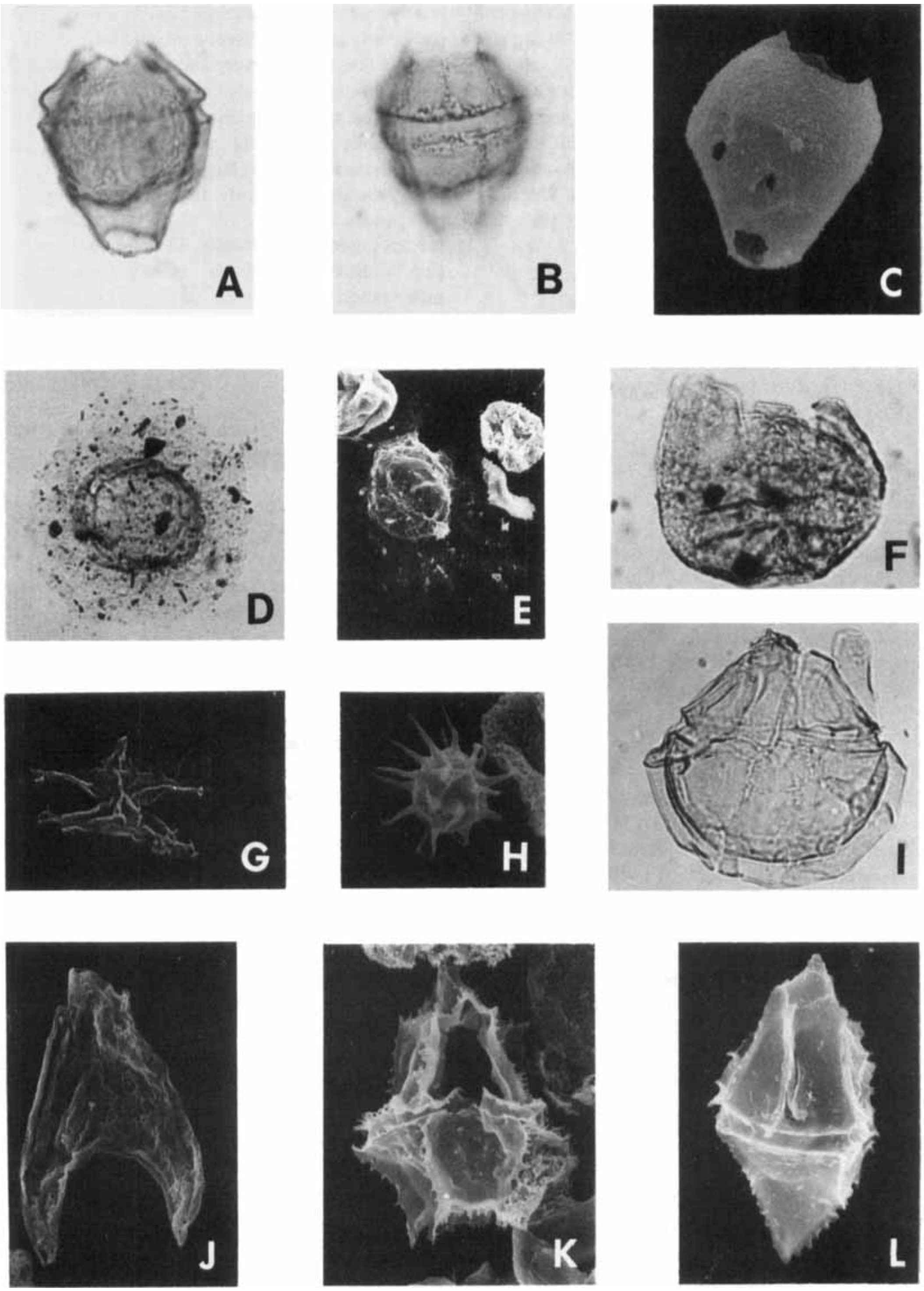
H: *Micrhystridium* sp. SEM CF-3 (I). Width central body 30 μm.

I: *Sirmiodinium grossii* Alberti 1961. CF-U. F57/1. PA4386. Width 54 μm.

J: *Nannoceratopsis pellucida* Deflandre 1938. SEM CF-3 (I). Length 65 μm.

K: *Gonyaulacysta jurassica* (Deflandre) Norris & Sarjeant 1965. SEM CF-3 (I). Length 55 μm.

L: cf. *Tubotuberella eisenackii* (Deflandre) Stover & Evitt 1978. SEM CF-3 (I). Length 60 μm.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narrow paracingular region. A prominent apical horn and two precingular and two postcingular horn-like processes in lateral positions are present. Each of the lateral horns has a main branch and 3 to 5 fingerlike branches, sometimes with bifurcate distal tips. The cyst wall is single layered, smooth, sometimes with scattered short spines in the apical and antapical areas. The archeopyle appears to be intercalary, but the exact outline is not known.

Holotype. – SEM CF-3 (II), Figure 4G.

Dimensions. – Length including apical horn 38–54 µm, length of lateral processes 13–32 µm (15 specimens measured).

Derivation name. – Named in honour of T. Bjærke.

Type stratum and locality. – Early Upper Callovian strata, 168 m a.s.l., Cape Flora, Northbrook Island.

Occurrence. – Northbrook Island, Cape Flora, samples CF-2 and CF-3, Windy Gully, samples WG-1 and WG-2.

Remarks. – *Parvocysta bjaerkei* sp. nov. was first described under open nomenclature as *Parvocysta* sp. B from the Toarcian of Spitsbergen by Bjærke (1980). Earlier, Bjærke (1977) recorded this species as Sp. Indet. (Pl. 10, Fig. 5) in his 'Association' D of Callovian age from Kong Karls Land. According to Haq et al. (1987, Fig.), representatives of the *Parvocysta*-complex became extinct within the Aalenian, while Woollam & Riding (1983) regard the Early Bajocian as the stratigraphic top of these species. However, Smelror (1988) reported *Parvocysta bjaerkei* sp. nov. in both Toarcian deposits and strata ranging from Late Bathonian to Early Oxfordian in Kong Karls Land. The consistent distribution of this species throughout the Early and Middle Callovian deposits on Kongsøya (Kong Karls Land) suggests that reworking is unlikely. In addition, this species also occurs in Lower Callovian dinoflagellate cyst assemblages from eastern England and within the Callovian offshore mid-Norway (pers. observation).

Genus *Meiourogonyaulax* Sarjeant in Davey et al. 1966

Type species: *Meiourogonyaulax valensii* Sarjeant in Davey et al. 1966

Meiourogonyaulax spongiosa sp. nov. Figs. 5A–F, Text-fig. 3

Description.– Dinoflagellate cysts subspherical in outline. Autophragm is thick, spongy. The ornamentation appears irregular and variously developed, sometimes as a low reticulum or as more or less fossulate or even foveolate. A gonyaulacoid paratabulation is indicated by parasutural lines ranging from roughened to irregularly punctatoreticulate. The archeopyle appears to be composed of four apical paraplates, and is probably of type (4A).

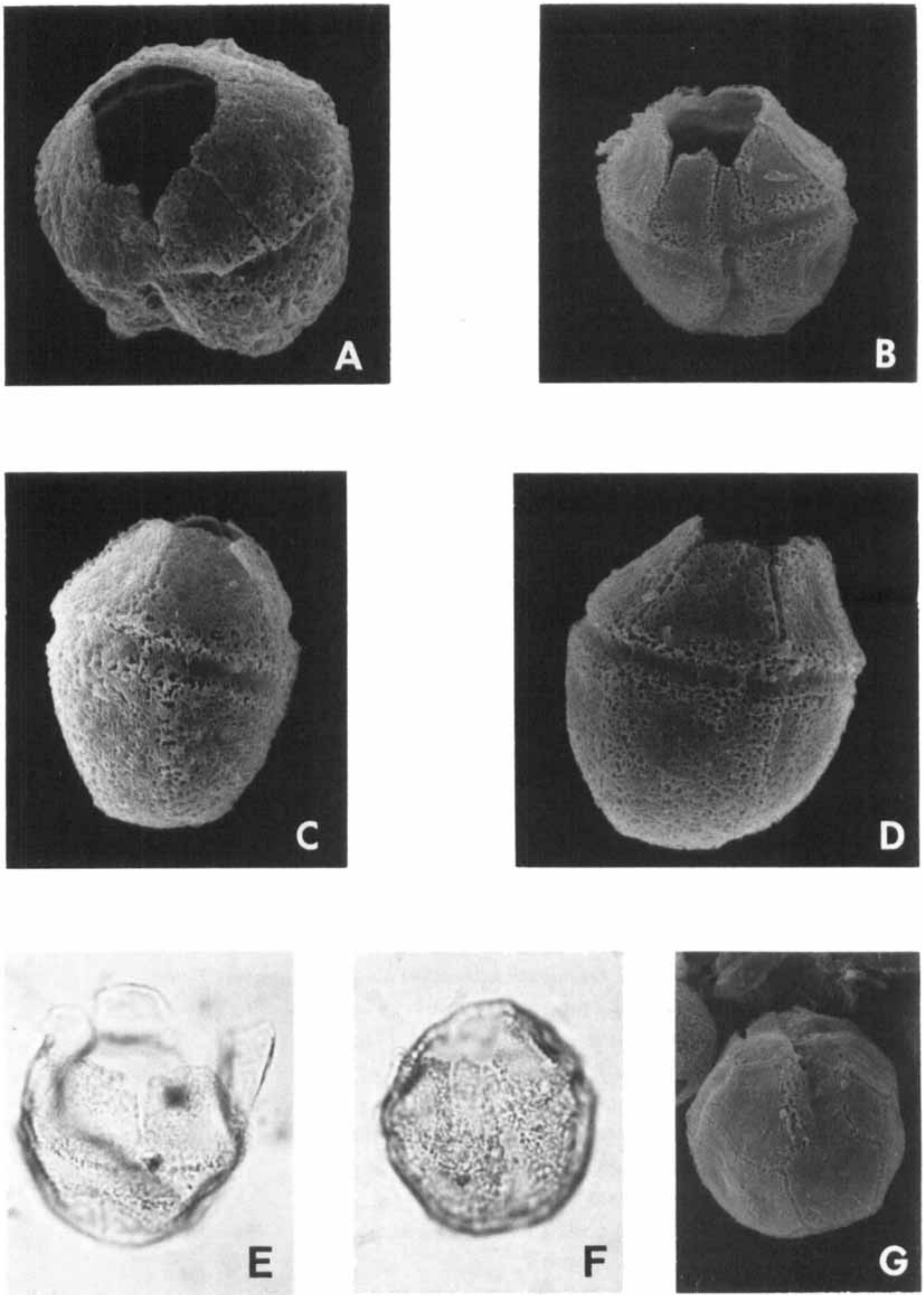
There are six precingular paraplates. The number of paracingular plates are not known. The parasulcus is expressed as a relatively deep and broad sinerous depression. The parasulcal tabulation pattern is not known. Including the Iu, which rarely is clearly expressed, six postcingular paraplates are present. A posterior intercalary

Fig. 5. *Meiourogonyaulax spongiosa* sp. nov. Early Upper Callovian, Franz Josef Land.

A–D & G: SEM CF-3 (I). A: Width 40 µm. B: Width 45 µm. C: Length 54 µm. D: Length 48 µm. G: Width 40 µm.

E: CF-U, N56/1. PA4386. Width 38 µm.

F: CF-U, X53 1. PA4386. Width 32 µm.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paraplate (X/1pV) is present on the left side of the sulcus. The antapical paraplate is 6-sided and contacts VI (5'''') (i.e. the pattern is sexiform).

Holotype. – SEM CF-3(I), Figure 5B.

Dimensions. – Length (excluding apical paraplates) 35–52 μm, width 30–49 μm (20 specimens).

Derivation of name. – 'Spongiosa', referring to the spongy autophragm.

Type stratum and locality. – Early Upper Callovian strata, 168 m a.s.l., Cape Flora, Northbrook Island.

Occurrence. – Northbrook Island, Cape Flora, sample CF-3 (168 m a.s.l.) and CF-U (erratic). Early Upper Callovian.

Remarks. – *Meiourogonyaulax spongiosa* sp. nov. seems comparable with *Meiourogonyaulax reticulata* Dodekova 1975. However, the Callovian specimens from Franz Josef Land differ from the Bulgarian Upper Bathonian specimens described by Dodekova (1975) in lacking well-developed reticulum. Specimens which most probably are conspecific with *Meiourogonyaulax spongiosa* sp. nov. have also been observed in Early Callovian dinoflagellate cyst assemblages from eastern England by the present author.

Genus *Susadinium* Dörhöfer & Davies 1980

Type species: *Susadinium scrofoides* Dörhöfer & Davies 1980

Susadinium? sp. A. Fig. 6H

Description.– Dinoflagellate cyst, elongated hour-glass shaped in outline, with a short apical horn and slightly concave antapical area. Autophragm generally smooth and with short spines aligned in generally ?parasutural rows and with well-developed denticles on the pre- and postcingular protuberances. Epicyst and hypocyst separated by a deeply constricted paracingular area. Archeopyle formed by one or more intercalary paraplates.

Dimensions. – Length 35 μm, width paracingular area 13 μm (1 specimen measured).

Occurrence. – Northbrook Island, erratic Callovian sample CF-U. Early Upper Callovian.

Remarks.– Only one specimen has been observed. This differs from other species of the genus *Susadinium* in having a very deeply constricted paracingular region, and having well-

Fig. 6. Upper Bathonian and early Upper Callovian dinoflagellate cysts and acritarchs from Franz Josef Land.

A: *Paragonyaulacysta calloviense* Johnson & Hills 1973. SEM CF-U (C). Length 50 μm.

B & D: *Ctenidodinium* sp. SEM CF-3 (II). B: Width 96 μm. D: Width 90 μm.

C: cf. *Chlamydophorella* sp. A of Davies 1983. SEM CF-3 (I). Width 34 μm.

E: *Meiourogonyaulax* sp. SEM CF-3 (I). Length 58 μm.

F: *Fromea tornatilis* (Drugg) Lentin & Williams 1981. CF-2. V58/4. PA4389. Length 60 μm.

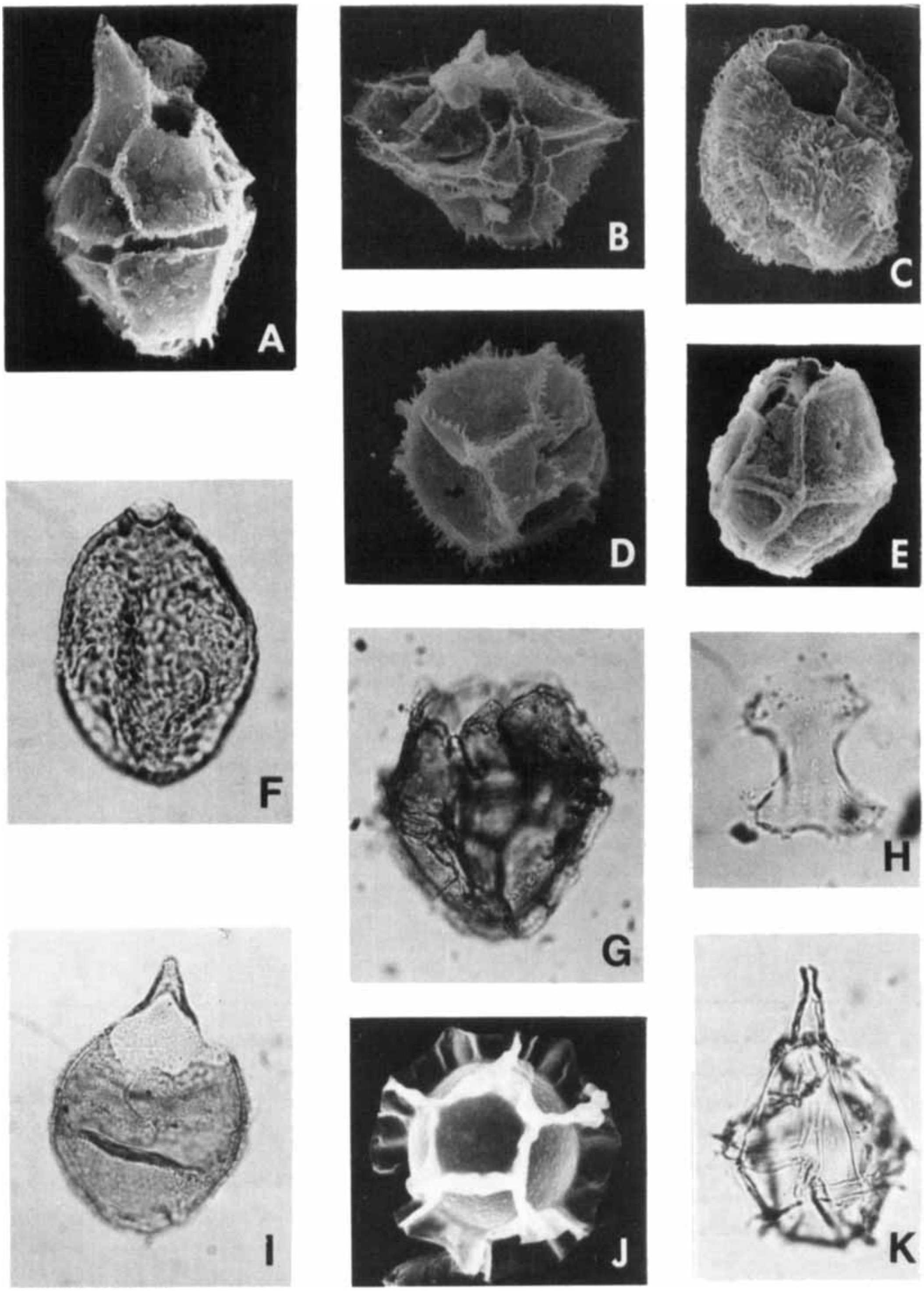
G: *Meiourogonyaulax valensii* Sarjeant 1966. CF-U. K46/1. PA4386. Length 66 μm.

H: *Susadinium*? sp. A. CF-U. K58/1. PA4386. Length 35 μm.

I: *Pareodinia alaskensis* Wiggins 1975. CF-1. M52/4. PA4392. Length 70 μm.

J: *Cymatiosphaera* sp. SEM CF-U (C). Width 40 μm.

K: *Gonyaulacysta jurassica* var. *longicornis* (Deflandre) Gitmez 1970. CF-U. M52/3. PA4386. Length 95 μm.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developed denticles on the pre- and postcingular protuberances.

This species is also recorded within the Lower Callovian *Nordenskjoeldi* ammonite zone on Jameson Land, East Greenland (pers. observations).

Algae Incertae Sedis
Group *Acritarcha* Evitt 1963

Genus *Baltisphaeridium* (Eisenack) Eisenack 1969

Type species: *Baltisphaeridium longispinosum* (Eisenack) Eisenack 1959

?*Baltisphaeridium* sp. A. Fig. 8B

Description. – The vesicle is spherical in outline, hollow and thin-walled (less than 1 µm). The wall appears to consist of two layers, of which only the outer layer forms the processes. The processes (20–30 in number) are homomorphic acuminate, and are shorter than the vesicle diameter. Both vesicle and processes are smooth. The excystment structure is circular (cyclopyle) and the operculum apparently consists of 3 or 4 pieces.

Dimensions. – Diameter (excluding processes) 9 µm (1 specimen measured).

Occurrence. – Northbrook Island, Cape Flora, sample CF-3 (Upper Callovian).

Remarks. – This species is here questionably placed in the genus *Baltisphaeridium* since there appears to be no solid plug at the base of the processes, separating the process interiors from the vesicle cavity. ?*Baltisphaeridium* sp. A seems comparable with *Micrhystridium*. However, representatives of the latter genus usually have epityche or median splitting excystment apertures.

Genus *Micrhystridium* (Deflandre) Downie & Sarjeant 1963

Type species: *Micrhystridium inconspicuum* Deflandre 1937

Micrhystridium sp. A. Fig. 7F

Description. – The vesicle is subspherical in outline, hollow, with more than 25 short, broad acuminate processes. The vesicle wall and processes bear granulate to blunt echinate, well spaced ornamentation. Excystment by splitting of vesicle wall.

Dimensions. – Overall diameter 12 µm (1 specimen measured).

Occurrence. – Northbrook Island, Cape Flora, sample CF-3 (Upper Callovian).

Remarks. – This species appears somewhat similar to the specimen illustrated as *Micrhystridium* sp.

Fig. 7. Upper Bathonian and early Upper Callovian dinoflagellate cysts and acritarchs from Franz Josef Land.

A: *Meiourogonyaulax* cf. *callomonii* Sarjeant 1972. SEM CF-3 (III). Width 62 µm.

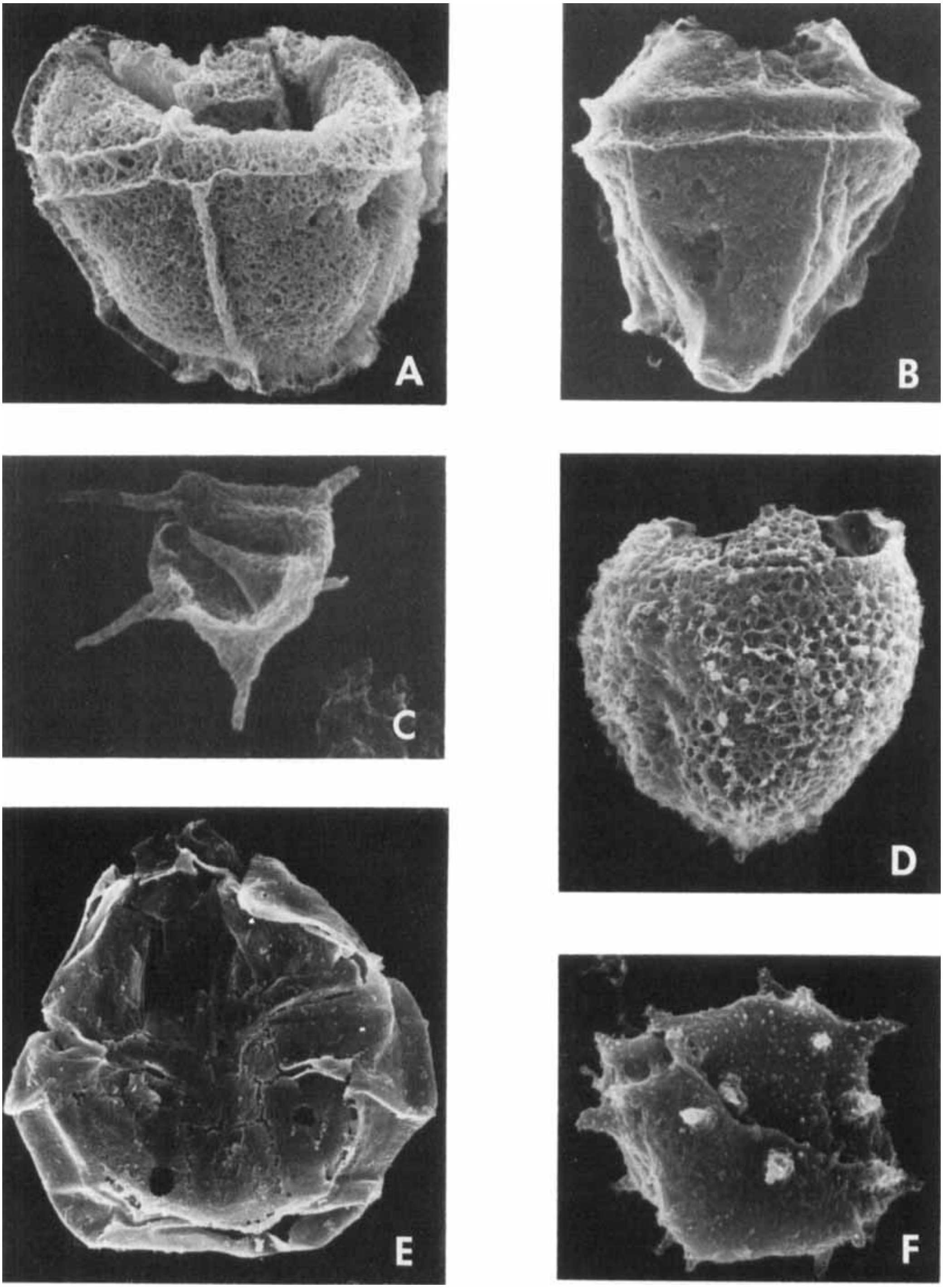
B: *Meiourogonyaulax valensii* Sarjeant 1966. SEM CF-3 (III). Length 65 µm.

C: *Veryhachium* sp. SEM CF-3 (I). Width (excluding process) 18 µm.

D: *Valensiella* sp. SEM CF-3 (III). Width 40 µm.

E: *Sirmiodinium grossii* Alberti 1961. SEM CF-3 (III). Width 60 µm.

F: *Micrhystridium* sp. A. SEM CF-3 (III). Width 12 µm.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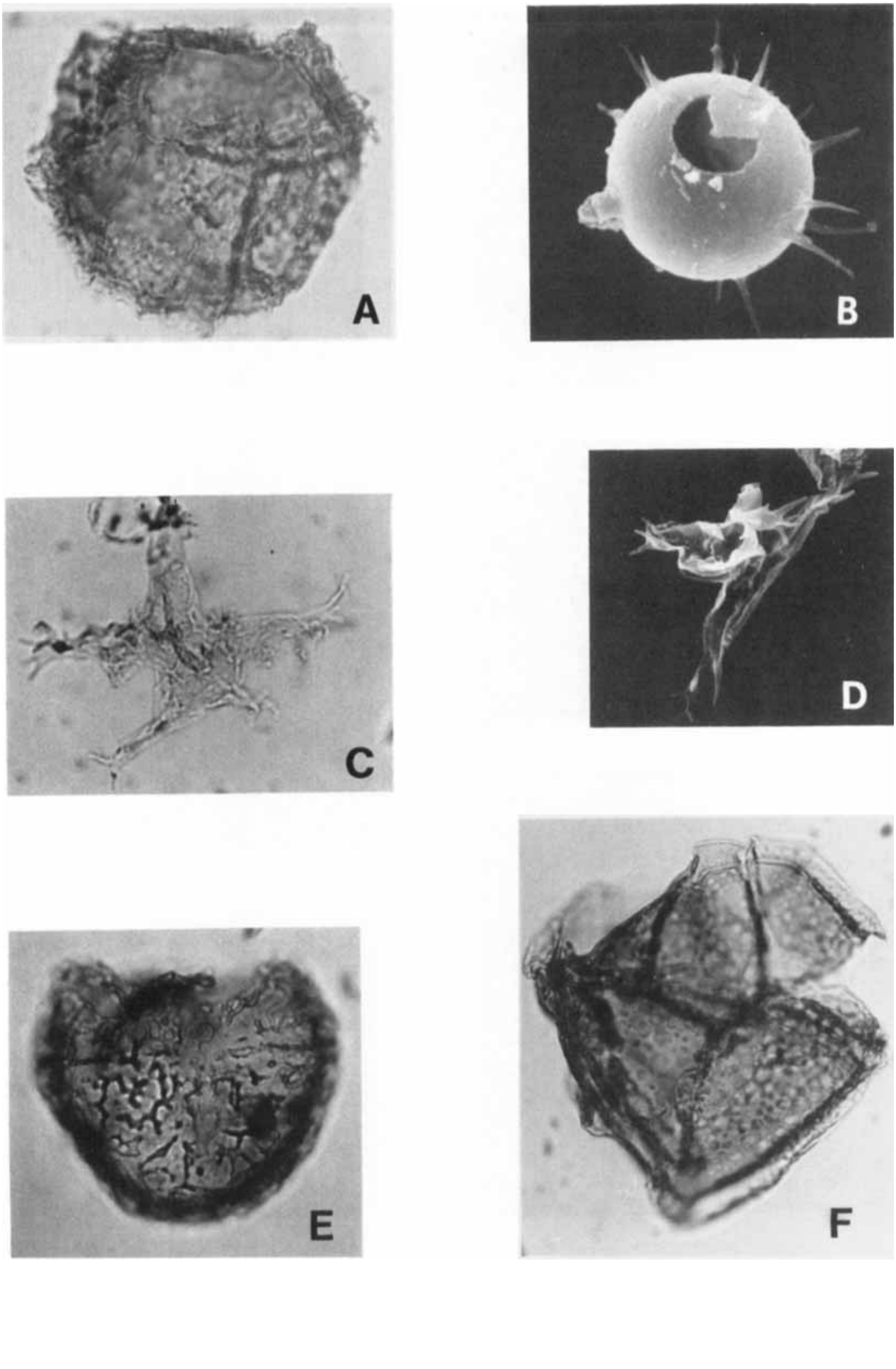
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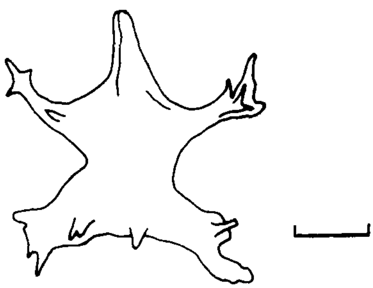

Fig. 9. Parvocysta bjaerkei sp. nov. (scale bar = 10 µm). Schematic line drawing (from Bjærke 1980).

from Toarcian deposits in NW Scania, Sweden, by Guy-Ohlson (1986, Pl. 18, Fig. 2). However, *Micrhystridium* sp. A from Franz Josef Land has relatively shorter processes and is less densely ornamented.

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Fig. 8. Upper Bathonian and early Upper Callovian dinoflagellate cysts and acritarchs from Franz Josef Land.

A: *Meiourogonyaulax spongiosa* sp. nov. CF-U, S27/0. PA4386. Width 42 µm.

B: *Baltisphaeridium* sp. A. SEM CF-3 (II). Width 9 µm (excluding processes).

C: *Parvocysta bjaerkei* sp. nov. WG-2 (B), A47/1. PA4387. Width 38 µm.

D: *Parvocysta bjaerkei* sp. nov. SEM CF-3 (II). Width 40 µm.

E: *Valensiella ovula* (Deflandre) Eisenack 1963. CF-3, L49/0. PA4388. Width 58 µm.

F: *Scriniocassis dictyotus* (Cookson & Eisenack) Beju 1971. CF-U, S49/0. PA4386. Width 69 µm.

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