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# Dinoflagellate Cysts from Surface Sediments of the Bransfield Strait, Antarctica

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# 남극 브랜스필드 해역의 표층퇴적물에서 산출된 와편모충 미화석

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**ABSTRACT** : A total of 31 dinocyst and acritarch species and 1 dinocyst subspecies belonging to 25 genera, are first described from surface sediments of the Bransfield Strait, Antarctica. The cyst assemblage is characterized by good preservation, and relatively low abundance and diversity, although they considerably vary with sample station. It indicates that dinoflagellate productibity has been primarily variable depending locality, and modified by secondary factors such as postmortem transportation and fossilization. The species association is similar to some extent to that of Bering Sea(Bujak, 1984). Frequently found are species which are known from the Miocene or even late Cretaceous. Therefore, the reworking possiblity of older sediments and mixture with Holocene ones can not be excluded.

**KEY WORD** : Dinoflagellate cysts, Holocene sediment, Bransfield Strait, Antarctica.

**요 약** : 총 25속 31종 1아종의 와편모충류와 아크리타르히를 포함한 유기질 미화석이 남극의 해협 Bransfield Strait 표층퇴적물에서 처음으로 추출, 분류, 기재되었다. 전반적으로 보존상태는 양호한 반면 풍도와 다양도는 떨어지는 편이다. 종의 낮은 다양도는 와편모충류 군집이 몇종에 의해 독점되므로 다른 종들의 수가 줄어들었기 때문인데 이는 와편모충류 생존에 열악한 환경에서 흔히 나타나는 현상이다.

와편모충류의 분포는 Antarctic Peninsula에서 일정거리가 떨어진 난류의 영향을 받는, 북쪽해구에 연한지역에 많은데 특히 해류의 하류쪽에 집중되어 있다. 따라서 와편모충류의 풍도와 분포는 육지에서의 거리, 온도 및 2차적으로 운반작용 등의 함수에 의해 영향을 받는다고 간주할 수 있다. 본 조사지역에서는 기대하기 어려운 초기 3기의 고기종들이 다수 산출되는데 이는 일부 퇴적물의 침식과 재이동에 의한 것으로 해석된다.

## Introduction

Korea Ocean Research and Development Institute(KORDI) has studied natural environments in the Bransfield Strait located between Antarctic Peninsula and South Shetland Islands around the Korean Antarctic Station(Sejong Station), Antarctica from December, 1989 to January 1990 and published research reports(KORDI, 1991, 1992). In the reports, various phytoplankton have been studied showing usefulness as the simplest and best tool for interpretation on biological production of the water-mass, paleoceanography, stratigraphy, and sedimentation rate of the area. However, investigation on neither thecate nor cyst dinoflagellates was accompanied. We consider dinoflagellate might also be very valuable for the uses mentioned above. Therefore, this study aims to describe the dinoflagellate cysts from the 18 surface samples collected in 1989 and to provide basic information to infer the paleoceanographic condition of the area.

## Systematic Description

Division PYRRHOPHYTA Pascher 1914
Class DINOPHYCEAE Fritsch 1929
Order PERIDINIALES Haesckel 1894

### Genus *Alisocysta* Stover and Evitt 1978

Type Species : *A. circumtabulata* (Drugg 1967) Stover and Evitt 1978.

*Alisocysta* sp.
pl. 2, fig. 6

Remarks : This species is characterized by having pandasutural area and short ridge. However, only one brokened specimen is observed in station 11.

### Genus *Apteodinium* Eisenack 1958

Type Species : *A. granulatum* Eisenack 1958.

*Apteodinium maculatum* subsp. *grande*
(Cookson and Hughes, 1964)
Below, 1981
pl. 1, fig. 9

1964 *Apteodinium grande* sp. nov. – Cookson & Williams, p. 14, pl. 6, fig. 8–9 (Cenomanian).
1973 *A. grande* – Davey & Verdier, pl. 5, fig. 1 ; text – fig. 8–9 (Vraconnien).
1973 *A. grande* – Lentin & Williams, p. 14.
1975 *A. grande* – Williams & Brideaux, fig. 9 (Santonian).
1978 *A. grande* – Bujak & Williams, text – fig. 6 (Cenomanian).
1981 *A. maculatum* subsp. *grande* – Below, p. 25 (L Hauterivian-E. Santonian).
1987 *A. maculatum* subsp. *grande* – Lucas – Clark, p. 176.

Materials : Rare.

Remarks : This species is characterized by circular central body with one apical horn and smooth surface. Archeophyle is precingular. Only one specimen is found.

### Genus *Aquadulcum* Harland and Sarjeant 1970

Type Species : *A. serpense* Harland and Sarjeant 1970.

*Aquadulcum myalupense*
(Churchill and Sarjeant 1962)
Harland and Sarjeant 1970
pl. 2, figs. 7a–b.

1962 *Paleohystrichophora myalupense* n. sp. – Churchill and Sarjeant, p. 38–40, fig. 5, 22–2.
1970 *Aquadulcum myalupense* n. comb. – Harland and Sarjeant, p. 221–222. (Holocene).

Remarks : This species has numerous short spines, which are arranged along the plate boundary. Archeopyle of this cyst is uncertain because of a incomplete preservation.

Stratigraphic Range : Holocene.

### Genus *Batiacasphaera* Drugg 1970

Type Species : *B. compta* Drugg 1970.

*Batiacasphaera* sp.
pl.4, fig.8

Remarks : This species is characterized by subspheroidal central body. Six precingular plates are indicated by plate sutures. The archeopyle is formed by loss of apical plates. This species differs from other species of Batiacasphaera in absence of baculate or reticulate surface structure. Only one specimen is observed in station 25.

### Genus *Beringiella* Bujak 1984

Type Species : *B. fritilla* Bujak 1984.

*Beringiella fritilla* Bujak 1984
pl.3, figs.6–9 ; pl.9, figs.5–6.

1984 *Beringiella fritilla* – Bujak, p.195, pl.4, figs.12–14 ; pl.4, figs.12–13 (Late Pleistocene).

Materials : Common.

Remarks : *B. fritilla* is characterized by a disebox shape and by thick foveolate wall structure. Bujak (1984) first discovered this species from the Late Pleistocene sediments of Bering Sea which had been controlled by very cold water mass. In the study area, this species commonly encountered in nearly all stations. Therefore, the distribution of this species seems to be influenced by the water temperature.

Stratigraphic Range : Late Pleistocene.

*Beringiella* sp. A
pl.3, figs.1–5 ; pl.9, figs.1–3.

Materials : Common.

Remarks : This cyst is similar to *B. fritilla* in having a ovoidal to ellipsoidal central body. However, *Beringiella* sp. A has smooth surface and thin wall feature. This species shows continuous appearance throughout the surface sediments.

*Beringiella* sp. B
pl.3, figs.4–5 ; pl.9, fig.7.

Materials : Rare.

Remarks : This species is similar to *Beringiella* sp. A having a smooth oval to ellipsoidal cyst, but *Beringiella* sp. B possesses pores which are irregularly distributed on the surface.

*Beringiella* sp. C
pl.9, fig.4.

Materials : Common.

Remarks : The peculiar morphological characteristics of this species is thick collor developed around the opening. The cyst wall is very thick and has rough corrugate surface.

### Genus *Deflandrea* Eisenack 1938

Type Species : *D. phosphorittica* Eisenack 1938.

*Deflandrea* sp.
pl.1, fig.7.

Materials : Rare.

Remarks : The cavate cyst possesses thick-walled sphaeroidal endocyst and thin transparent pericyst with apical horn. Triangular intercalarly archeopyle(hexa 2a) is distinct.

### Genus *Gelatia* Bujak 1984

Type Species : *G. inflata* Bujak 1984.

*Gelatia inflata* Bujak 1984
pl.5, figs.8–9.

1984 *Gelatia inflata*–Bujak, p.185–186, pl.1, figs. 13–20 ; text–fig. 2, pl. 1, fig. 16 (Late Eocene-Late Oligocene).

Materials : Rare.

Remarks : The circular body is transparent, microgranulated and faintly tabulated. In this study this species is rare being restructed to station 6, 7.

### Genus *Gippslandia* Stover and Williams 1987

Type Species : *G. extensa*(Stover 1974) Stover and Williams 1987.

*Gippslandia extensa* (Stover 1974) Stover and Williams 1987
pl. 7, figs. 4–5.

1974 *Deflandrea extensa*–Stover, p. 178–179, pl. 5, figs. 4a-c, 5a-d, 6(Middle-Late Eocene).
1987 *Gippslandia extensa*–Stover and Williams, p. 107.

Materials : Rare.

Remarks : The cyst is pentagonal to circular in outline. The surface is occupied by numerous short acuminate spines. Occasionally two small antapical and one apical horns are developed. The paratabualtion is indicated by the arrangement of spines.

### Genus *Gonyaulacysta* Deflandre 1964

Type Species : *G. jurassica*(Deflandre 1938) Norris and Sarjeant 1965.

*Gonyaulacysta* sp.
pl. 2, figs. 1a-b ; pl. 7, fig. 9.

Materials : Rare.

Remarks : This species is typical gonyaulacoid species characterized by large prominent apical horn and well developed tabulation. Paraplates are bounded by denticulated crests. This species together other several species seems to be non-endemic and suggests possible reworking process in this area.

### Genus *Thalassiphora* Eisenak & Gocht 1960

Type Species : *T. pelagica*(Eisenack 1954) Eisenack & Gocht 1960.

*Thalassiphora* sp.
pl. 5, figs. 2–3.

Materials : Rare.

Remarks : The species shows thin inflaged pericyst, which is faintly tabulated. Due to complicated folds the tabulation is hardly determined. The characteristics of the species fall within the range of definition of the genus Thalassiphora. However, the endocyst is not yet observed in this species, what makes generic allocation difficult. Therefore, this species is tentatively placed under this genus.

### Genus *Lejeunecysta* Artzner and Dörhöfer 1978

Type Species : *L. hyalina*(Gerlach 1961) Artzner and Dörhöfer 1978.

*Lejeunecysta* sp.
pl. 5, figs. 1–4, 6.

Materials : Rare.

Remarks : This species is very variable in morphological characteristics. The wall surface is transparent, granulate and sometimes thick. The apical and antapical horns are also diversely developed.

### Genus *Operculodinium* Wall 1967

Type Species : *O. centrocarpum*(Deflandre and Cookson 1955) Wall 1967.

*Operculodinium centrocarpum*
(Deflandre and Cookson 1955) Wall 1967.
pl. 6, figs. 1a-b, 3 ; pl. 8, figs. 1-2.

1955 *Hystrichosphaeridium centrocarpum* sp. nov. -Deflandre & Cookson, p. 272-273, pl. 8, fig. 3-4. (Middlen Miocene).
1959 *H. centrocarpum*-Maier, p. 314, pl. 31, fig. 7. (Middle-Upper Oligocene, Middle-Upper Miocene).
1961 *Baltisphaeridium centrocarpum*-Gerlach, p. 192, pl. 28, fig. 9. (Middle-Upper Oligocene, Middle-Upper Miocene).
1967 *Operculodinium centrocarpum* comb. nov. -Wall, p. 111, pl. 16, figs. 1-2, 5. (Pleistocene).
1967 *O. centrocarpum*-Wall & Dale, p. 352, pl. 1, fig. M. (Recent).
1968 *O. centrocarpum*-Harland, p. 546-548, figs. 11, 11a, 25, 26. (post-Pleistocene).
1973 *Protoceratium reticulatum*-*Operculodinium centrocarpum*-Harland, p. 236-239, pl. II, fig. 4, 7-16 ; pl. III, figs. 1-6 ; pl. IV, figs. 1-2. (Upper Campanian).
1974 *O. centrocarpum*-Reid, p. 594-595, pl. 2, figs. 10-11. (Recent).
1975 *O. centrocarpum*-Williams & Bideaux, pl. 15, fig. 6. (Late Eocene-Pleistocene).
1976 *O. centrocarpum*-Eaton, p. 278, pl. 15, figs. 1-2. (Eocene).
1976 *O. centrocarpum*-Jux, pl. 1, fig. 4 ; pl. 4, figs. 1-3 ; pl. 5, figs. 1-4. (Holocene).
1977 *O. centrocarpum*-Jan du Chêne, p. 106, pl. 2, figs. 1-2. (Upper Eocene).
1977 *O. centrocarpum*-Harland, p. 96-97, pl. 1, fig. 19 ; pl. 4, figs. 9-10.
1980 *O. centrocarpum*-Piasecki, pl. 6, fig. 1. (Miocene).
1982 *O. centrocarpum*-Harland, pl. 1, figs. 1-4. (Recent).
1983 *O. centrocarpum*-Matsuoka, p. 124-125, pl. 9, figs. 10-12. (Late Cenozoic).
1984 *O. centrocarpum*-Bradford & Wall, p. 32-33, pl. 1, figs. 10-11 ; pl. 2, fig. 6. (Recent).
1985 *O. centrocarpum*-Matsuoka, p. 41-43, pl. 7, figs. 1-6. (Pleistocene).

Materials : Rare.

Remarks : The perforate body surface and numerous small spines distinct.

## Genus *Pheopolykrikos* Chatton 1933

Type Species : *P. beauchampii* Chatton 1933. =*Polykrikos beauchampii*(Chatton) Loeblish 1980.

*Pheopolykrikos hartmannii* Matsuoka
and Fukuyo 1985
pl. 6, figs. 5-8.

1968 ? Resting spore of naked dinoflagellates-Wall and Dale, p. 281, pl. 4, fig. 27.
1982 Cyst of *Polykrikos hartmannii*-Fukuyo, p. 208, pl. III, figs. 1-6.
1982 Cyst of *Polykrikos hartmannii*-Matsuoka, pl. 2, fig. 13.
1985 Cyst of *Polykrikos hartmannii*-Matsuoka, pl. 3, figs. 1-4, fig. 1D.
1985 Cyst of *Pheopolykrikos hartmannii*-Matsuoka, p. 63, pl. 17, figs. 1-4.

Materials : Abundant.

Remarks : The cyst body is circular in outline and occupied by numerous, very short, acuminated solid spines. The cyst wall is very thin and transparent.

*Pheopolykrikos* sp. B.
pl. 6, fig. 4.

Materials : Rare.
Remarks : This species is characterized by epicystal archeopyle, numerous solid fibrous processes of intermediate length. This species differs from all of genus Operculodinium in having epicystal archopyle and acuminate solid processes.

### Genus *Pyxidiella* Cookson and Eisenack 1958

Type Species : *P. pandora* Cookson and Eisenack 1958.

*Pyxidiella simplex* Harland 1979
pl. 1, figs. 1-3, 6 ; pl. 8, fig. 4.

1979 *Pyxidiella simplex* sp. nov.-Harland, p. 537-538, pl. 3, figs. 12-15.
1984 *P. simplex*-Edward, pl. 5, figs. 8a-b, 10a-b.
Materials : Rare.
Remarks : This species which is characterized by single wall and intercalary is frequently found in the study area. The morphological characteristics are similar to those of *Pyxidiella* species, but trapezoidal archeopyle shape and stratigraphic range are different from most species of *Pyxidiella*.

? *Pyxidiella* sp.
pl. 1, figs. 4-5.

Materials : Rare.
Remarks : This central body is circular in outline and differs from rounded-gonal shape of *Pyxidiella simplex*.

### Genus *Selenopemphix* Benedek 1972

Type Species : *S. nephroides* Benedek 1972.

*Selenopemphix nephroides* Benedek 1972
pl. 7, fig. 7.

1972 *Selenopemphix nephroides*-Benedek, p. 47-48, pl. 11, fig. 13 ; pl. 16, figs. 1-4.
1980 *S. nephroides*-Bujak in Bujak *et al.*, p. 84, pl. 21, fig. 6 ; text-fig. 23A (Middle - Late Oligocene).
1982 *Protoperidinium subinerme*-Harland, p. 396.
Materials : Rare.
Remarks : This is reported from the Bering Sea. Therefore, its distribution is presumed to be chiefly influenced by water temperature.

### Genus *Spinidinium* Cookson and Eisenack 1962

Type Species : *S. styloniferum* Cookson and Eisenack 1962.

*Spinidinium* cf. *pulchrum* (Benson 1976)
Lentin and Williams 1977
pl. 2, fig. 2.

1976 *Deflandre pulchrum*-Benson, pl. 9, figs. 4-7 (Early Paleocene).
1977 *Spinidinium pulchrum*-Lentin and Williams, p. 147.
Materials : Rare.
Remarks : The surface is covered by short spines. The antapical horns are distinct and cingulum zone is free of spines.

*Spinidinium* sp.
pl. 2, figs. 3-5 ; pl. 7, figs. 1, 7.

Materials : Rare.
Remarks : The single antapical horn is characteristic of the species. Numerous short spines are regularly distributed over the whole central body.

### Genus *Spiniferites* Mantell 1850

Type Species : *S. ramosus* (Ehernberg 1838) Loeblich 1966.

*Spiniferites* sp.
pl.4, figs.1-2a,b ; pl.8, fig.9.

Materials : 7.

### Genus *Trinovantedinium* Reid 1977

Type Species : *T. capitatum* Reid 1977.

*Trinovantedinium capitatum* Reid 1977
pl.7, fig.8.

1977 *Trinovantedinium capitatum*-Reid, p.47-49, fig.2 : 1-8(Recent).
1981 *T. capitatum*-Harland, p. 68, tab.1.
1984 *Protoperidinium pentagonum*-Lewis *et al.*, p.31.

Materials : Rare.
Remarks : The pentagonal central body is covered by penitabular and intratabular processes. The processes are hollow and tubiform.

### Genus *Votadinium* Reid 1977

Type Species : *V. calvum* Reid 1977

*Votadinium calvum* Reid 1977
pl.8, fig.5.

1977 *Votadinium calvum*-Reid, p.444-445, pl. 2, figs.21-23(Recent).
1981 Encysted stage of *Protoperidinium oblongum* (Aurivillius) Parke and Dodge-Harland, p.68, tab.1.

Materials : Rare.
Remarks : The surface of central body is smooth. Archepyle is intercalary.

### Genus *Wallodinium* Loeblich and Loeblich 1968

Type Species : *W. glaessneri*(Cookson and Eisenack 1960) Loeblich and Loeblich 1968.

*Wallodinium* sp.
pl.4, fig.6 ; pl.8, figs.7-8.

Materials : Common.
Remarks : Smooth transparent surface and elongate shape are characteristic for the species. One pole is always is broken with irregular margin forming apical archeopyle.

### Lineage indet.

Dinoflagellate cyst type A of Matsuoka 1985
pl.6, figs.1a-b,3

1982 Cyst of *Diplopsalis* sp. ? -Matsuoka, pl.2, fig.11.
1985 Dinoflagellate cyst type A-Matsuoka, pl. 15, fig.11.

Materials : Very abundant.
Remarks : This species is very similar to dinoflagellate cyst type A of Matsuoka 1985. However, our specimens show more numerous spines which are basally connected.

## Conclusion

A total of 31 dinocyst and acritarch species and 1 dinocyst subspecies belonging to 25 genera, are first described from surface sediments of the Bransfield Strait, Antarctica. Generally, the dinoflagellate assemblage shows relatively low diversity and richness, which is credited to predominance of one or two species. For example, Dinoflagellate cyst A(sensu Matsuoka 1985) comprises approximately 62% of the dinoflagellate flora and floral abundance is mainly dependent on this species.

Figure 1 shows that the abundance increases

Table 1. Occurrence chart of dinoflagellate cysts from surface sediments of the Bransfield Strait, Antarctica.

| Species \ Stations | 2 | 6 | 7 | 8 | 9 | 11 | 14 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 28 | 29 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alisocysta* sp. | | | | | | 1 | | | | | | | | | | | | | 1 |
| *Apectodinium maculatum* subsp. *grande* | | | | | | | | | 1 | | | | | | | | | 1 | 2 |
| *Aquadulcum myalupense* | | | | | | | | | | | | | | | | 1 | | | 1 |
| *Batiacasphaera* sp. | | | 6 | | | | 1 | | | | | | | | | | | | 7 |
| *Beringiella fritilla* | | 2 | 2 | | 2 | 4 | 1 | | 2 | 3 | | | | | | | | 1 | 17 |
| *Beringiella* sp. A | 6 | 7 | 2 | 1 | 1 | 5 | 1 | 1 | 2 | | 2 | | | | | | | 7 | 35 |
| *Beringiella* sp. B | | | | | 2 | 1 | | | 1 | 1 | | | 1 | | 1 | 1 | | | 8 |
| *Beringiella* sp. C | 1 | | | | | | | | | 13 | | | | | | | | 3 | 17 |
| *Deflandre* sp | | 1 | 1 | | | | | | | 1 | | | | | | 2 | | | 5 |
| *Dinoflagellate* cyst A | 87 | 26 | 191 | 4 | 18 | 32 | 74 | 5 | 12 | 48 | 12 | | 1 | | | 4 | 1 | 13 | 528 |
| *Gelatia inflata* | | 13 | 1 | | | | | | | | | | | | | | | | 14 |
| *Gippslandia extensa* | | | 1 | | | | | | | 1 | | | | | | | | | 2 |
| *Gonyaulacysta* sp. | | | | | | | | | | 1 | | | | | | | | | 1 |
| *Lejeunecysta* sp. | | | 1 | | | | | | 2 | | | | | | | | | | 3 |
| *Membranilarnacia* sp. | | | 2 | | | | | | | | | | | | | | | | 2 |
| *Operculodinium centrocarpum* | | 6 | | | 2 | 1 | | | | | | | | 2 | | | | | 11 |
| *Operculodinium echigoense* | | 1 | | | | | | | | | | | | | | | | | 1 |
| *Operculodinium israelianum* | | 1 | | | | | | | | | | | | | | | | | 1 |
| *Pheoplykrokos hartmannii* | 51 | 2 | 18 | 5 | 8 | | | | 1 | 2 | | | | | | | | 4 | 91 |
| *Pontadinium* sp. | | | | | | 1 | | | | | | | | | | | | | 1 |
| *Protoperidinium* sp. | | | | | | | | | | 1 | | | | | | | | | 1 |
| *Pthanoperidinium* sp. | | | | | | | | | | 1 | | | | | | | | | 1 |
| *Pyxidiella simplex* | | | 6 | | 1 | | | | | 3 | | | | | | | | 1 | 11 |
| *Pyxidiella* sp. | | | | | | 1 | 4 | | | | | | | | | | | | 5 |
| *Selenophempix nepheroides* | | 2 | 3 | | | | | | | | | | | | | | | | 5 |
| *Spinidinium* cf. *pulchrum* | | | | | | | | | | 1 | | | | | | | | | 1 |
| *Spinidinium* sp. | | | 1 | | | | | | | 3 | | | | | | | | | 4 |
| *Spiniferites* sp. | | | 2 | | | 4 | 1 | | | | | | | | | | | | 7 |
| *Thalassiphora* sp. | | | | | | | | | | | | | | | | 2 | | | 2 |
| *Trinovantedinium* sp. | 1 | | | | | | | | | | | | | | | | | | 1 |
| *Votadinium carvum* | | | | | | | | | | | | | | | | | | 2 | 2 |
| *Wallodinium* sp. | 27 | 6 | 14 | 4 | 5 | 1 | | 2 | 1 | 5 | | | | | | | | | 65 |
| Acritarch | 2 | | | | | | | | | | | | | | | 4 | | | 6 |
| Total | 175 | 67 | 251 | 14 | 39 | 51 | 82 | 8 | 22 | 84 | 14 | 0 | 2 | 2 | 1 | 14 | 1 | 32 | 859 |

in proportion toward deeper environment and reaches maximum on the border of central subbasin and around South Shetland Islands, where warm water mass prevails: specifically 1)along warm water mass from the Bellingshausen, 2)in downstream side of the warm current, and 3)in the area equal distant from the Antarctic Peninsula. Therefore, in the case of dinoflagellate, it has been regarded that abundance fluctuation is a factor of the distance from Antarctic Peninsula, water temperature and postmortem transport rather than of water depth.

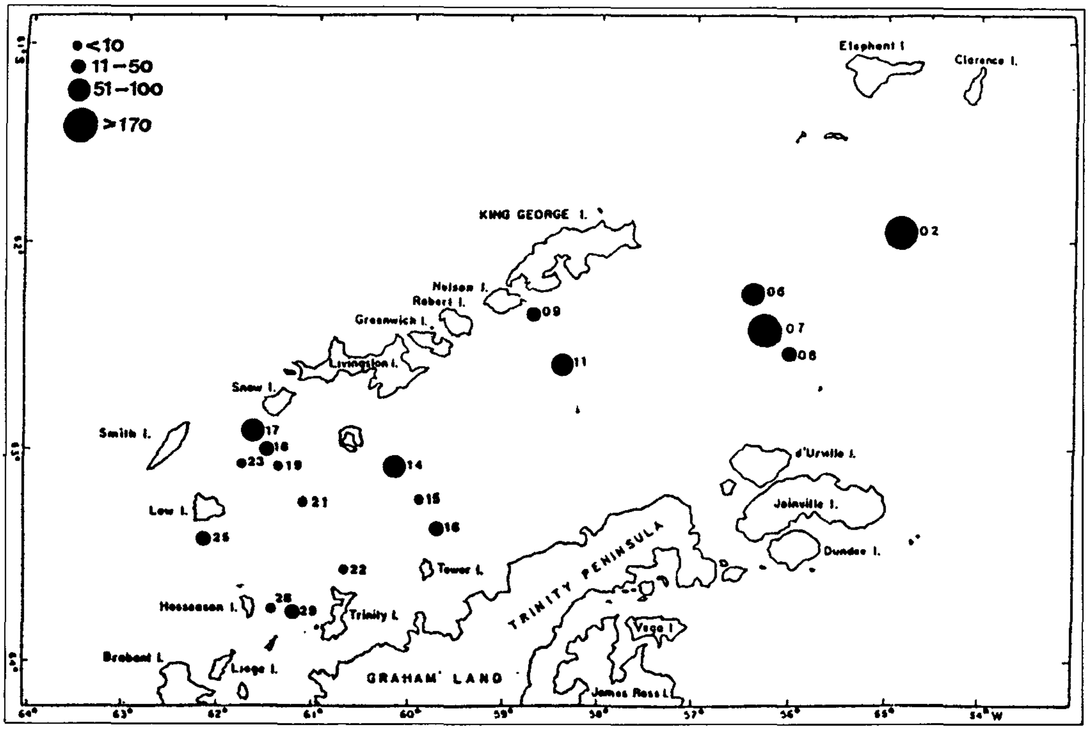


Fig. 1. Abundance of dinoflagellate cysts from surface sediments of the study area.

Some species such as *Apteodinium maculatum grande*, ?*Deflandrea* sp., *Gippslandia extensa*, *Spinidinium* cf. *pulchrum*, *Gonyaulacysta* sp., and *Thalassiphora* sp. are mainly known from early Tertiary. Therefore, it seems to regarded that older sediments are reworked and transported to the study area.

Based on *Beringiella fritilla*, *Pheopolykrikos hartmannii*, and *Votadinium carvum* the geological age is interpreted to be Late Pleistocene. However, detailed stratigraphic zonation and paleoenvironmental interpretation is left for further study, until more basic taxonomic descriptions and determinations have accumulated.

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## Plate 1

Figs. 1−3, 6 ? *Pyxidiella simplex*
1 : Dorsal view, 600X, st. 25.
2 : Dorsal view, trapizoidal archeopyle, 600X, st. 16.
3 : Dorsal view, 400X, st. 17.
6 : Dorsal view, 600X, st. 25.

Figs. 4−5 ? *Pyxidiella* sp.
4 : Dorsal view, 600X, st. 25.
5 : Dorsal view, spherical antapical part, 600X, st. 25.

Fig. 7 *Deflandrea* sp.
7 : Dorsal view, intercalary archeopyle, 400X, st. 16.

Fig. 8 *Deflandrea* sp.
8 : Dorsal view, 600X, st. 25.

Figs. 9 *Apteodinium* cf. *maculatum* subsp. *grande*(Cookson and hughes 1964) Below 1981
9 : Dorsal view, 500X, st. 29.

## Plate 2

Figs. 1a-b. *Gonyaulacysta* sp.
1a : Ventral view, low focus, 800X, st. 17.
1b : Ventral view, high focus, 800X, st. 17.

Fig. 2. *Spinidinium* cf. *pulchrum*(Benson 1976) Lentin and Williams 1977.
2 : Dorsal view, 600X, st. 17.

Figs. 3−5. *Spinidinium* sp.
3 : Dorsal view, 600X, st. 17.
4 : Apical view, 1000X, st. 17.
5 : 1000X, st. 17.

Figs. 7a-b. *Aquadulcum myalupense*(Churchill and Sarjeant 1962) Harland and Sarjeant 1970.
7a : Low focus, 800X, st. 25.
7b : High focus, 800X, st. 25.

Fig. 6 *Alisocysta* sp.
6 : Cingular plates, 1000X, st. 11.

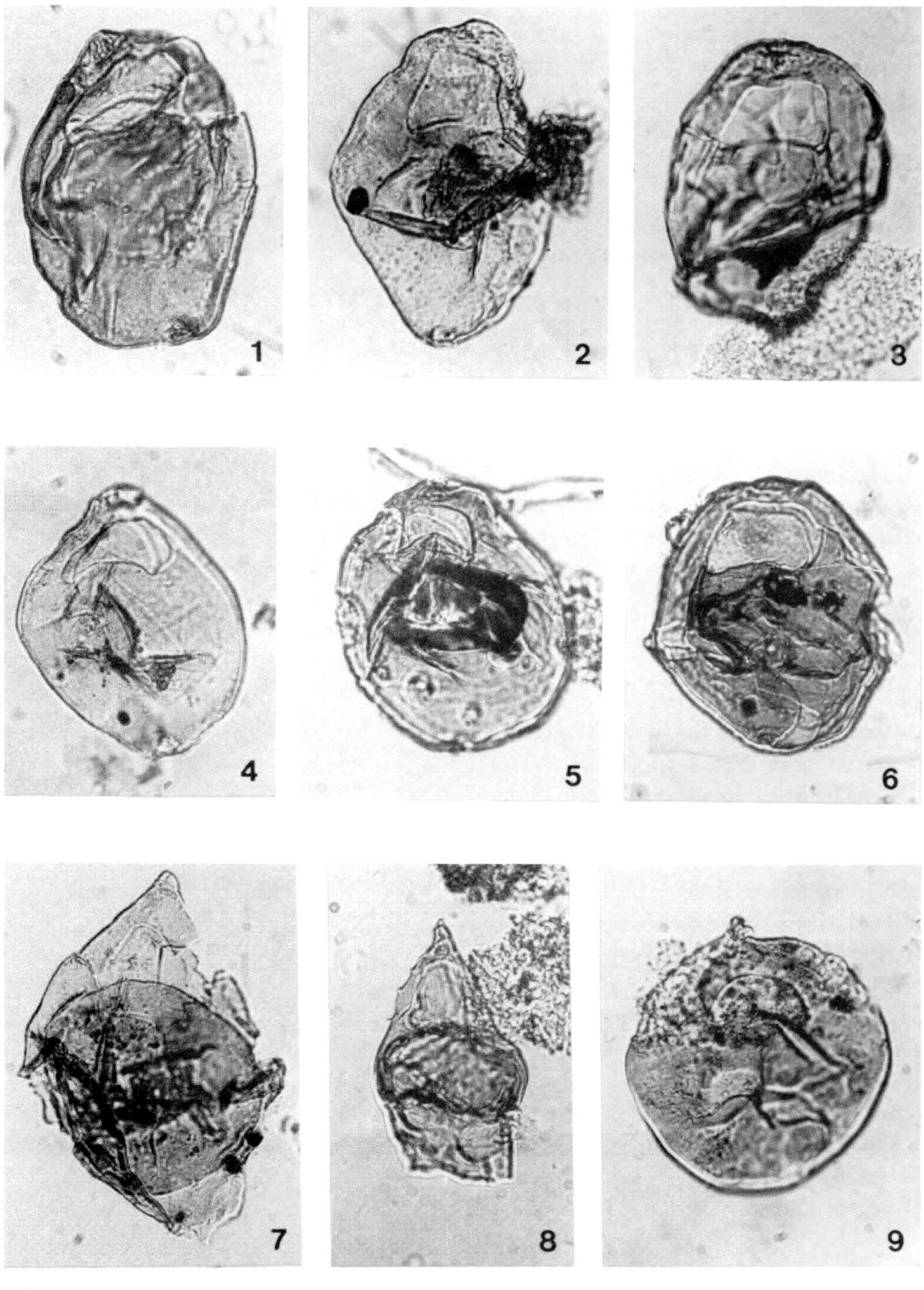
## Plate 3

Figs. 1−5. *Beringiella* sp. A.
1 : Lateral view, smooth surface ornamentation, 1000X, st. 25.
2 : Lateral view, attatched operculum, 800X, st. 29.
3 : Lateral view, subspheroidal cyst, 1000X, st. 17.

Figs. 4−5. *Beringiella* sp. B.
4 : Lateral view, periporate smooth surface ornamentation, 1000X, st. 9.
5 : Lateral view, ovoidal to ellipsoidal cyst, 1000X, st. 9.

Figs. 6−9. *Beringiella fritilla* Bujak 1984.
6 : Lateral view, subspheroidal cyst with a adnate operculum, 1000X, st. 25.
7 : Lateral view, granulate surface structure, 1000X, st. 17.
8 : Lateral view, 1000X, st. 17.
9 : Lateral view, 1000X, st. 25.

plate 1



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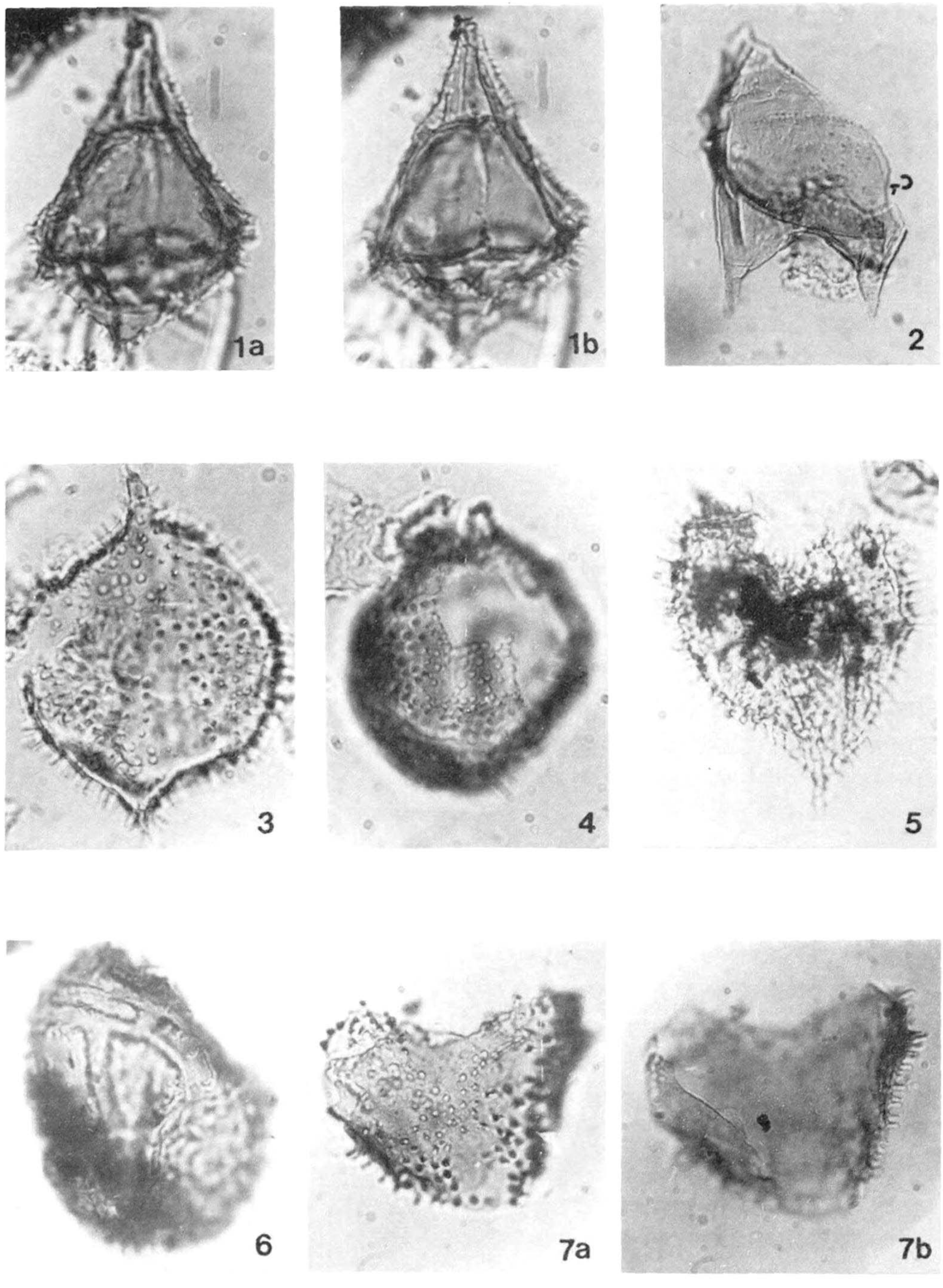

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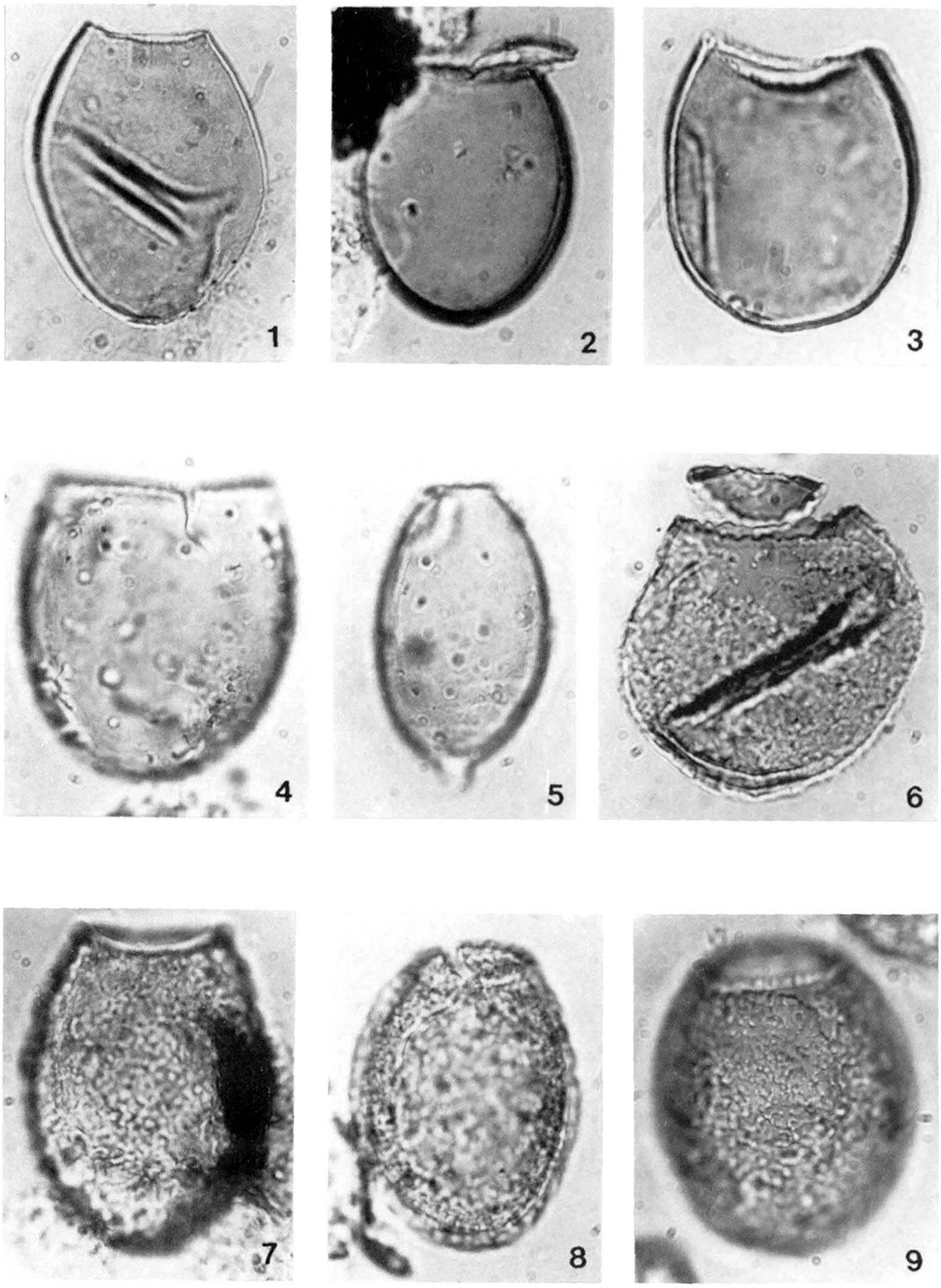


## Plate 4

Figs. 1–2a, b. *Spiniferites* sp.
1 : Multifurcate processes, 800X, st. 11.
2a : Gonal processes, 640X, st. 17.
2b : 640X, st. 17.
Figs. 3–5, 7. Acritarchs
3 : Lateral view, smooth surface ornamentation, 250X, st. 17.
4 : Lateral view, irregular opening, 250X, st. 25.
5 : Lateral view, conical antapical horn, 250 X, st. 25.
7 : Lateral view, attached operculum, 600X, st. 25.
Fig. 6. *Wallodinium* sp.
6 : Relatively large hypocyst and usually folded thin autophragm, 400X, st. 11.
Fig. 8. ? *Batiacasphaera* sp.
8 : 600X, st. 25.

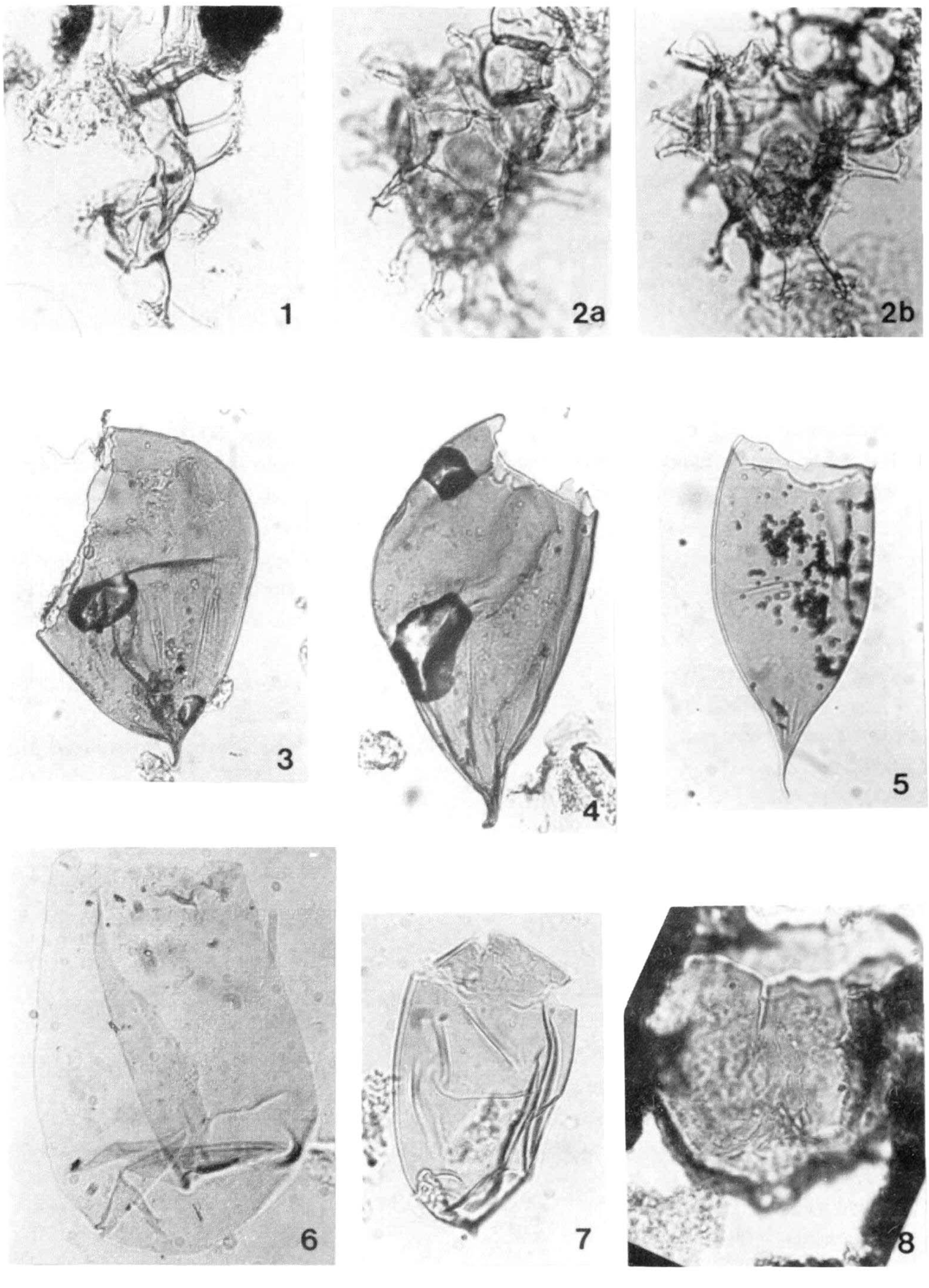
## Plate 5

Figs. 2–3. *Thalassiphora* sp.
2 : 600X, st. 25.
3 : 600X, st. 25.
Figs. 1, 4–6. *Lejeunecysta* sp.
4 : Ventral view, 400X, st. 17.
5 : Dorsal view, prominant apical horn and intercalary archeopyle, 640X, st. 17.
6 : 600X, st. 25.
Fig. 7. *Selenopemphix nephroides* Benedek 1972
7 : Antapical view, 400X, st. 29.
Figs. 8–9. *Gelatia inflata* Bujak 1984.
8 : 400X, st. 29.
9 : Large spherical cyst, 1000X, st. 2.
Figs. 10–11a, b. Genus and species indet.
10 : 400X, st. 17.
11 : High focus, 1000X, st. 16.
12 : Low focus, 1000X, st. 16.

## Plate 6

Figs. 1a-b, 3. *Operculodinium centrocarpum* (Deflandre and Cookson 1955) Wall 1967.
1a : Low focus, 800X, st. 25.
1b : Granulate surface structure, high focus, 800X, st. 25.
3 : 600X, st. 16.
Fig. 2. Dinoflagellate cyst type A Matsuoka 1985.
2 : Very short spines, 1000X, st. 17.
Fig. 4. *Operculodinium* ? *echigoense* Matsuoka 1983.
4 : Solid and long nontabular processes, 1000X, st. 6.
Figs. 5–8. *Pheopolykrikos hartmannii* Matsuoka and Fukuyo 1985.
5 : Acicular, Solid numerous and nontabular processes, 400X, st. 6.
4 : 1000X, st. 17.
7 : 1000X, st. 9.
8 : Spherical cyst, 1000X, st. 6.

plate 4



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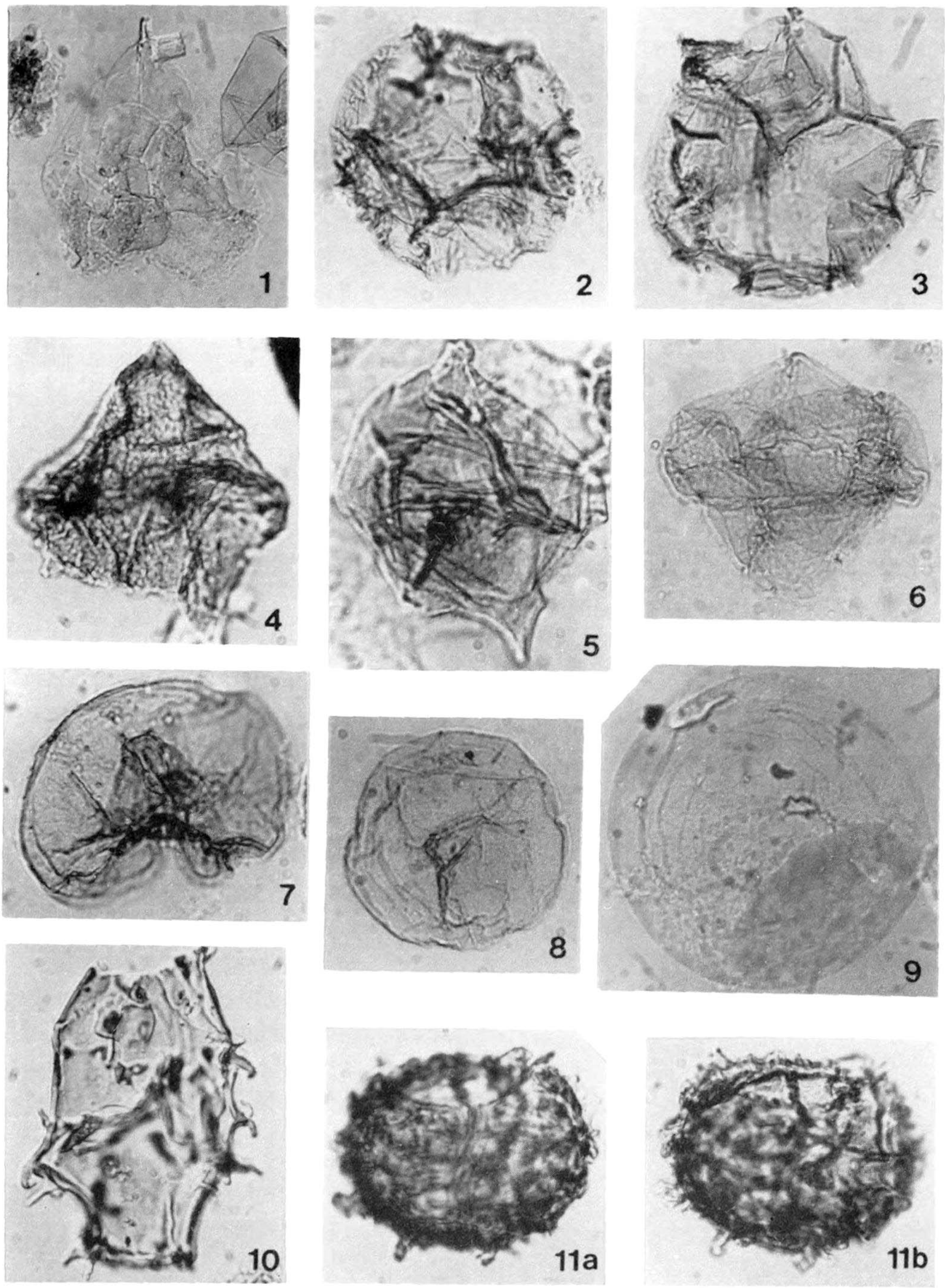

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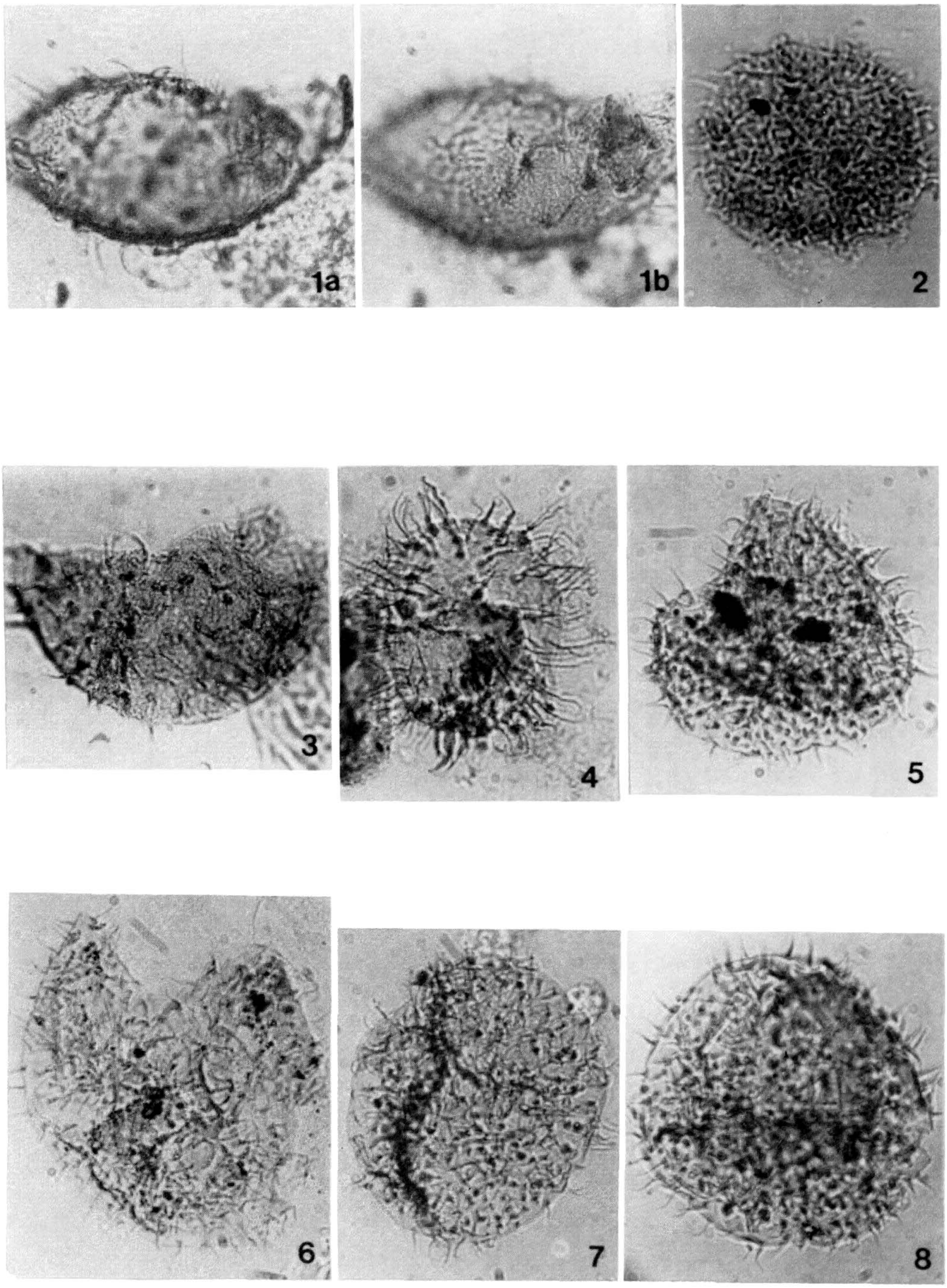

## Plate 7
(All scale bars = 10μm)

Fig. 1. *Spinidinium* sp.
1 : st. 17.
Fig. 2. *Protoperidinium* sp.
2 : st. 17.
Fig. 3. ? *Phthanoperidinium* sp.
3 : st. 17.
Figs. 4–5. *Gippslandia extensa* Stover and Williams 1987.
4 : Ventral view, st. 17.
5 : Dorsal view, st. 7.
Fig. 6. Genus and species indet.
6 : st. 29.
Fig. 7. *Spinidinium* sp.
7 : st. 2.
Fig. 8. Trinovantedinium capitatum Reid 1977.
8 : Dorsal view, st. 2.
Fig. 9. *Gonyaulacysta* sp.
9 : Apical view, st. 7.

## Plate 8
(All scale bars = 10μm)

Figs. 1–2. *Operculodinium centrocarpum* (Deflandre and Cookson 1955) Wall 1967.
1 : st. 5.
2 : Dorsal view, precingular(3˝) archeopyle, st. 25.
Figs. 3–6. *Pheopolykrikos hartmannii* Matsuoka and Fukuyo 1985.
3 : Chasmic archeopyle, st. 2.
6 : Solid processes, st. 2.
Fig. 4. ? *Pyxidiella simplex* Harland 1979.
4 : Dorsal view, st. 2.
Fig. 5. *Votadinium calvum* Reid 1977.
5 : Apical view, adnate apical archeopyle st. 2.
Figs. 7–8. *Wallodinium* sp.
7 : Lateral view, st. 2.
8 : Lateral view, st. 6.
Fig. 9. *Spiniferites* sp.
9 : Well developed parasutural septa, st. 17.

## Plate 9

(All scale bars = 10μm)

Figs. 1–3. *Beringiella* sp. A
1 : Lateral view, st. 6.
2 : Lateral view, st. 6.
3 : Lateral view, st. 7.
Fig. 4. *Beringiella* sp. C
4 : Lateral view, reticulate surface ornamentation and well developed collor, st. 7.
Figs. 5–6. *Beringiella fritilla* Bujak 1984.
5 : Lateral view, st. 17.
6 : Lateral view, st. 6.
Fig. 7. *Beringiella* sp. B
7 : Lateral view, periporate surface structure, st. 6.
Figs. 8–9. Acritarch.
8 : Lateral view, st. 2.
9 : Lateral view, st. 2.

plate 7

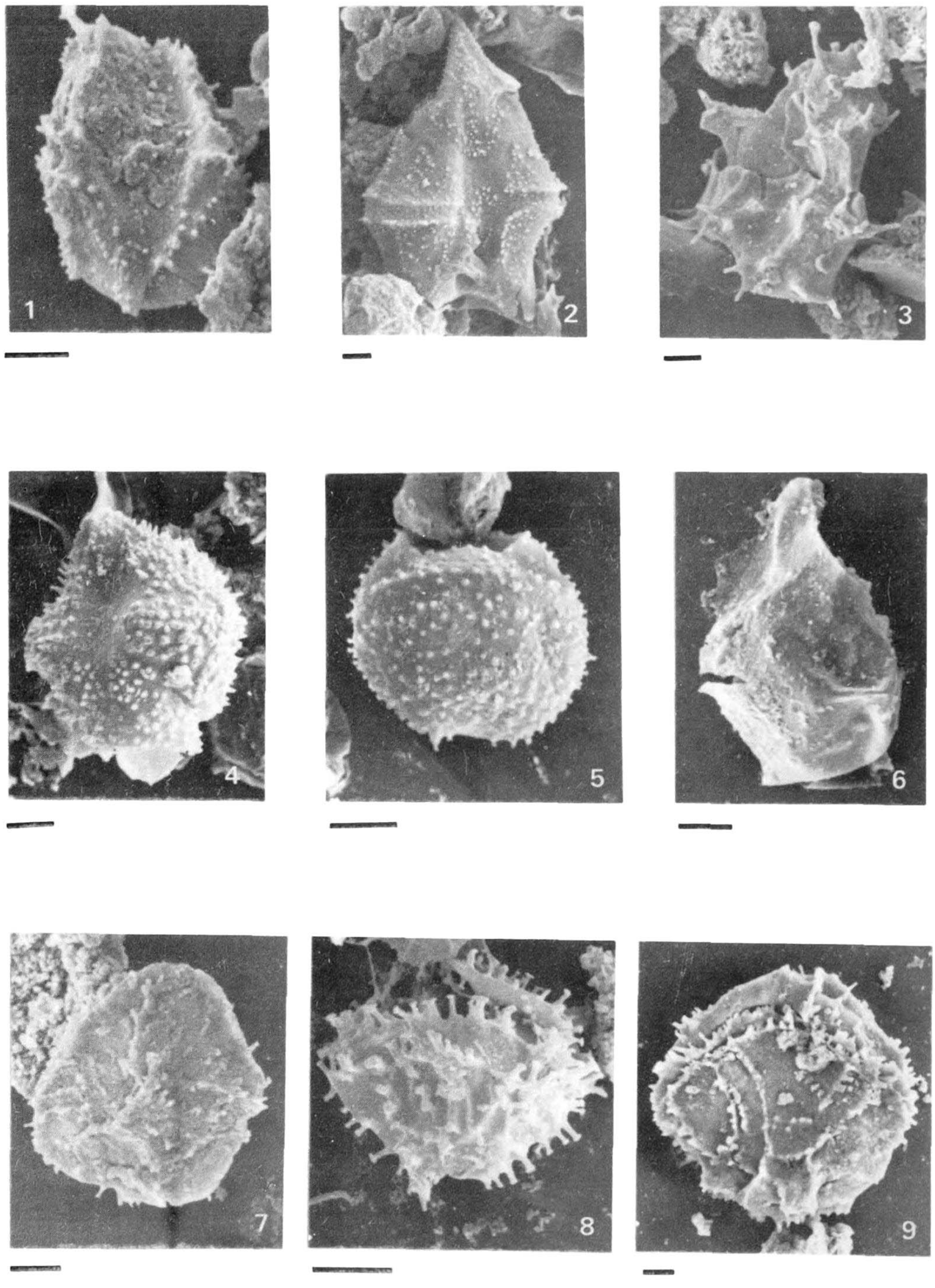

plate 8

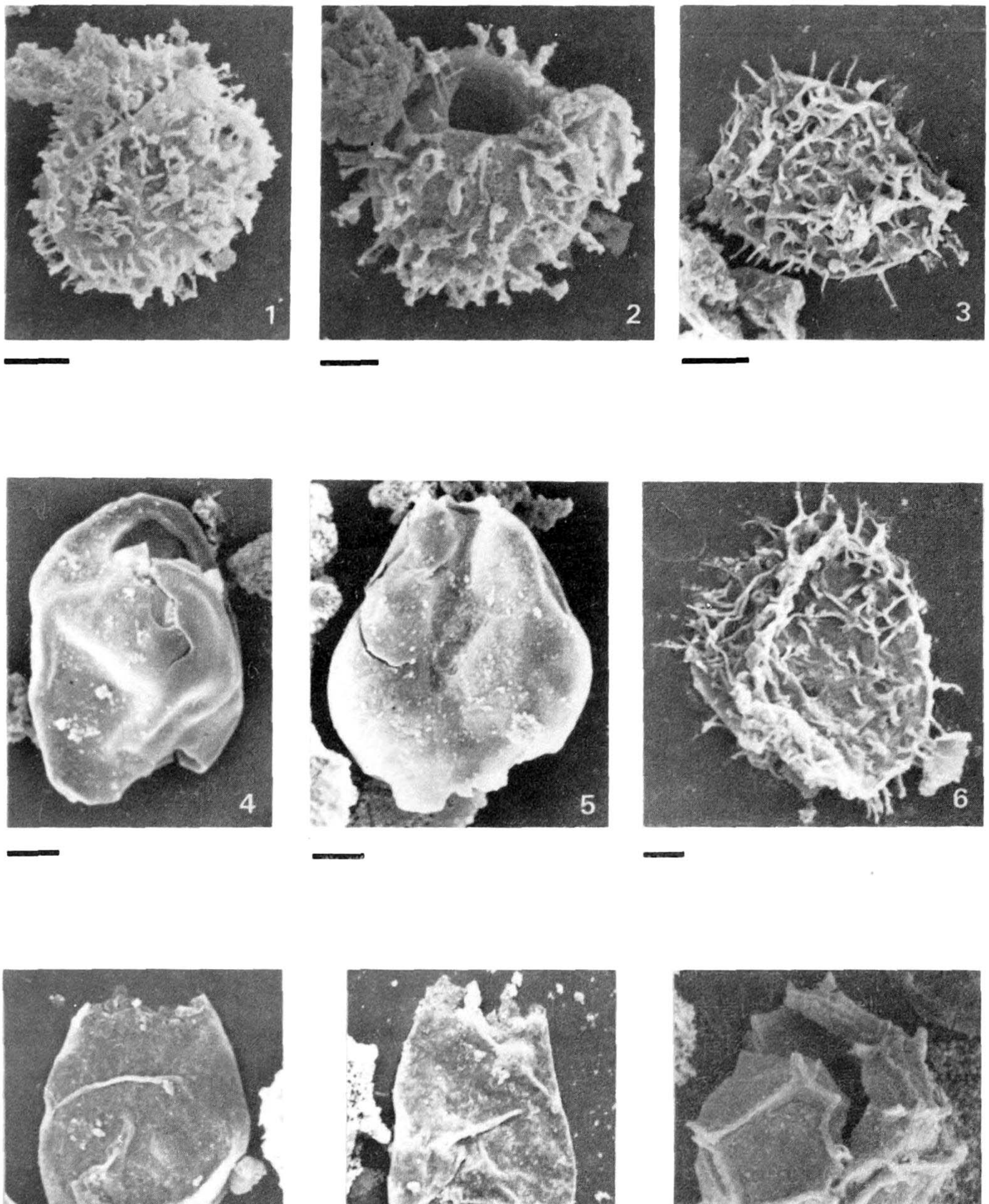

plate 9