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Organic-walled dinoflagellate cysts from surface sediments of Nagasaki Bay and Senzaki Bay, West Japan

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Abstract

Modern dinoflagellate cysts recovered from surface sediments of Nagasaki Bay and Senzaki Bay, West Japan are described under the cyst-based classification. The characteristics of both cyst assemblages are discussed in comparison with previous records around the Japanese Island. Consequently, the cyst assemblages of Nagasaki Bay and Senzaki Bay are similar to that of Omura Bay, West Japan and they are strongly influenced by the warm water Tsushima current, because *Spiniferites* spp. abundantly occur.

Contents

I) Introduction

The fossil dinoflagellate is an useful tool in the applied micropaleontology, especially a paleoenvironmental study as well as biostratigraphical one. The investigation of modern dinoflagellate cysts provides with fundamental data for above-mentioned study. From this view-point, the

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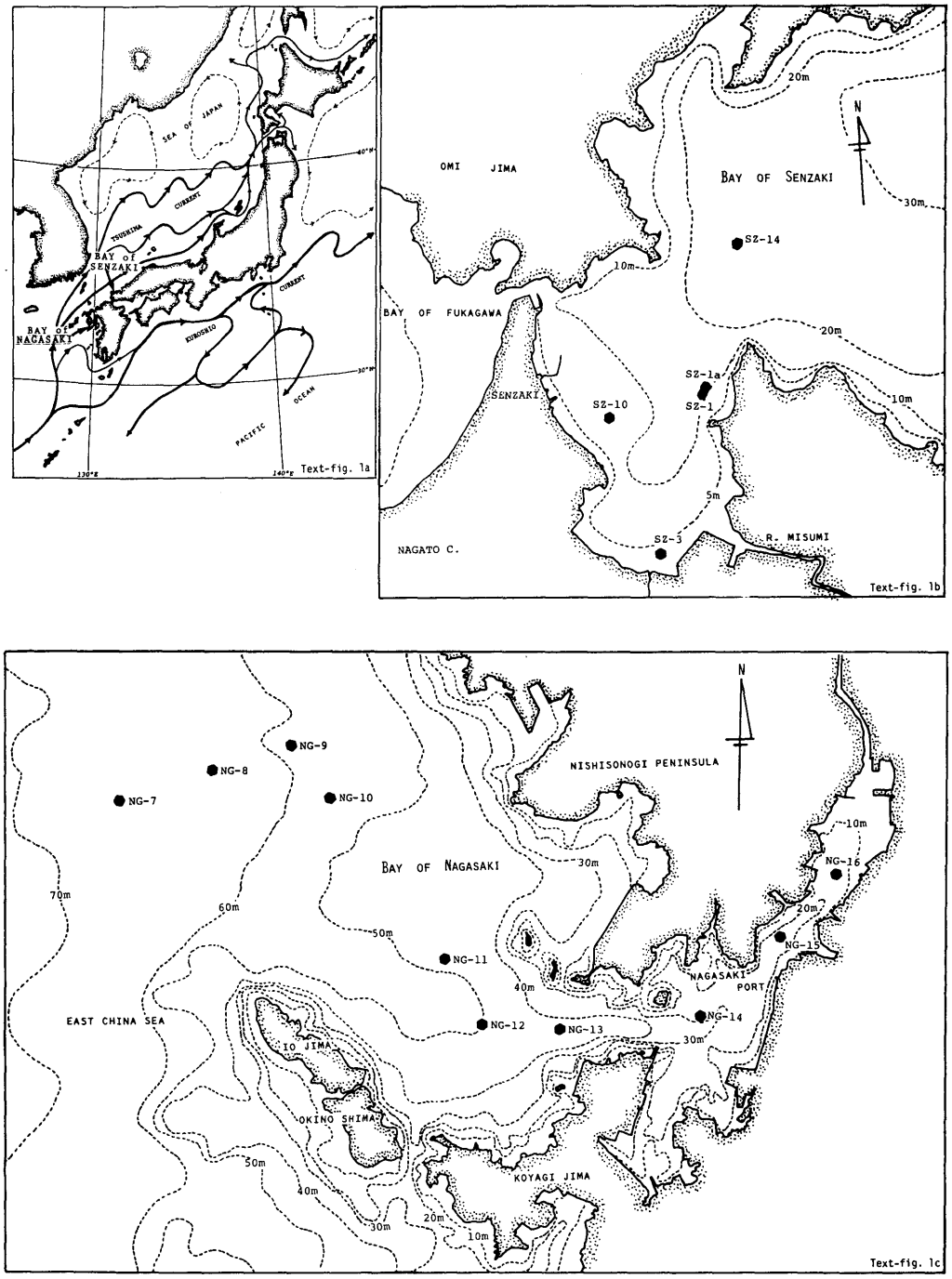


Text-figure 1. Location map. a ; locations of Senzaki Bay and Nagasaki Bay, showing modern current system around the Japanese Island. b ; sampling station in Senzaki Bay. c ; sampling station in Nagasaki Bay.

morphological description and distribution of modern dinoflagellate cysts recovered from surface sediments have been well investigated in the North Atlantic Ocean and the Persian Gulf by several authors (Wall 1967; Wall, Dale, Lohman and Smith 1977; Williams, D. M. 1971; Reid 1974, 1977; Harland 1977, 1981, 1983; Bradford 1975; Bradford and Wall 1984).

On the contrary, there are only a few studies of these purposes in the West Pacific. Harada (1974 M.S.) clarified the distribution of modern cysts in surface sediments along the Pacific coast of East Japan, but unfortunately he indentified cysts on only generic level. Matsuoka (1976, 1981, 1982) made the reports on species distribution in surface sediments of Hachinohe Coast of the Pacific side, north Philippine Sea and Omura Bay, West Kyushu respectively. But untill this moment, the general cyst distribution is not fully understood around the Japanese Island. Here I decribe 33 species belonging to 15 genera of modern dinoflagellate cysts in surface sediments collected from Nagasaki Bay and Senzaki Bay, West Japan. This paper will provide with basic descriptive data for investigating the geographical distribution of modern cysts around the West Pacific.

II) Environmental Condition

1) Nagasaki Bay

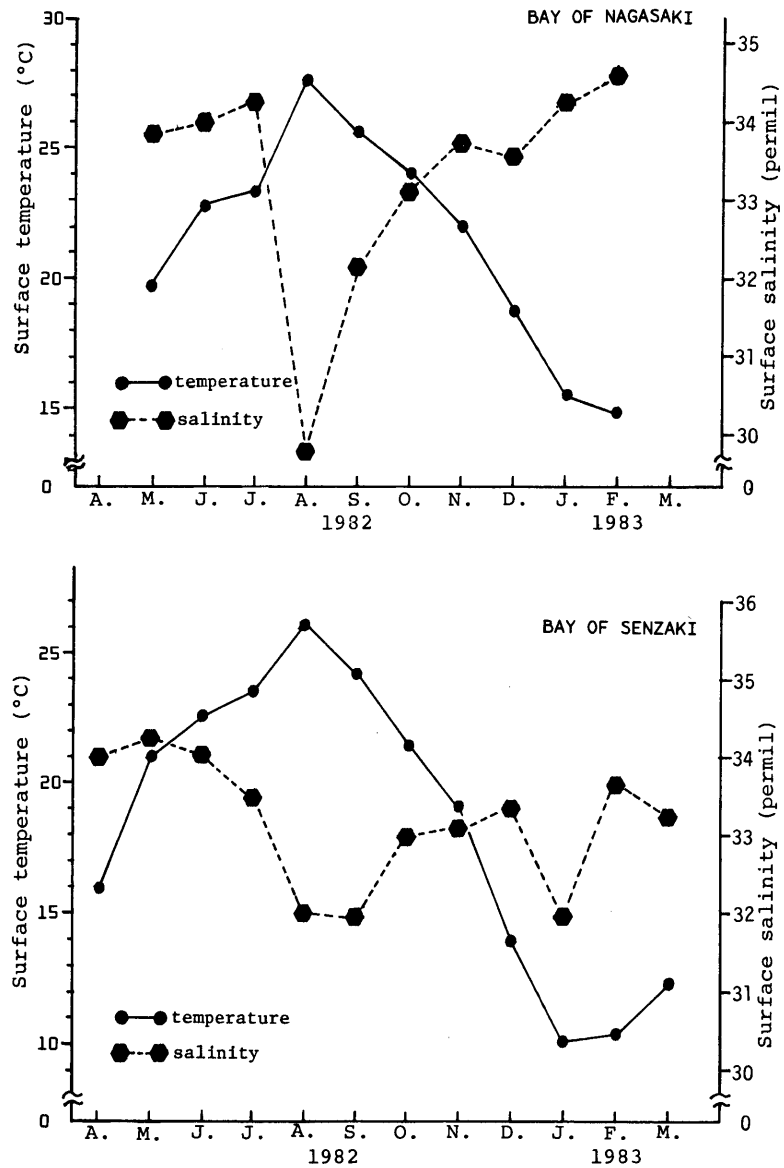
i) Topography and sediment type

Nagasaki Bay is situated at the western part of the Kyushu Island, Japan (appoximately Lat. 32°45′N, Long. 129°45′E) and is devided into two parts, outer part and inner part of the Nagasaki port. This bay is surrounded by Iō-jima, Okino-shima, and Kōyagi-jima at southern part and by the Nishisonogi Peninsula at the northern part, and opens the mouth toward northwest. In water depth, the most outer part of this bay is about −65m, middle part about −50m and most inner part, the Nagasaki port, about −15m. According to Kamada et al. (1980), the sediment character in this bay comprises mainly two types. One of them is grayish olive mud distributed in the middle to inner parts. Another is olive black silt to silty-fine sand and is observed at the outer part. The most inner part is covered with fine black sapropel derived from artificial effects.

ii) Water condition

According to the Nagasaki Prefectural Government (1983), the water temperature at Fukuda, northern coast of this bay, is shown in Text-fig. 2. The maximum temperature was about 28°C in August and the minimum

was about 15°C in February in 1982. The salinity at this station was relatively constant and marked around 34 permil from 1982 to 1983. This indicates that the outer part of this bay is distinctively effected by the oceanic water. The most inner part of this bay is strongly influenced by artificial nutrient carried by the small rivers, Urakami-gawa, Nakashima-



Text-figure 2. Surface temperature and salinity of Nagasaki Bay and Senzaki Bay. Original data for Nagasaki Bay from Nagasaki Prefectural Government (1983) and for Senzaki Bay from Yamaguchi Prefectural Government (1983).

gawa and Ōura-gawa. Owing to this, the Nagasaki port is often covered by red-tides of diatom-blooming in late spring to summer. While the outer part of this bay hardly has a red-tide through a year.

2) Senzaki Bay

i) Topography and sediment type

Two small bays surrounded by Ōmi-jima are situated at the northwestern part of the Chūgoku district in the Honshu Island, Japan (Text-fig. 1). These bays, Fukagawa and Senzaki, are separated by a small peninsula going out from the Honshu Island. One of them, Senzaki Bay (appoximately Lat. 34°25'N, Long. 131°15'E) is investigated here. This bay, about 20km^2 in area, opens the mouth toward northeast and is subdivided into two parts by the narrow straite. According to Matsu'ura et al. (1981), the outer part with −20 to −30m in water depth is mainly covered with muddy sediments. The inner part is −5 to −20m in depth and also silty to clayey sediments are widely distributed.

ii) Water condition

Several elements of the water condition were investigated at Kojima near the station SZ. 1 in this bay from April in 1982 to March in 1983 by Yamaguchi Prefectural Government (1983). According to this report, the water temperature varied from 26°C in August to 10°C in February and salinity varied from 34.3 to 32 permil from 1982 to 1983 (Text-fig. 2). Based on this salinity, this bay is also influenced by oceanic water.

III) Sampling Location

Ten samples were collected from Nagasaki Bay with a small gravity corer on October, 1981. Six samples of them, station number from NG. 7 to NG. 12, were obtained from the outer part of this bay and others, NG. 13 to NG. 16, from the inner part (Text-fig. 1c). The samples are generally olive black to gray in color and sandy silt to silt occasionally containing small shell fragments. The basic physical date of these samples are given in Table 1.

Four samples obtained from Senzaki Bay were provided for the present study by Yamaguchi Prefectural Government. These samples were collected with a small gravity corer in 1982. These samples, SZ. 3 and SZ. 10 were collected from the inner part of this bay and another sample, SZ. 14, from the outer part. The physical data of these samples are given in

Table 1.

Table 1. Physical data of samples of Nagasaki Bay (NG) and Senzaki Bay (SZ).

Sample No.	Depth(m)	Temperature(°C)	Sediment character
NG−7	66	20.2*	olive black silty sand
NG−8	63	20.3*	olive black sandy silt
NG−9	59	21.1*	grayish olive silty sand
NG−10	57	21.1*	grayish olive silty sand
NG−11	48	21.2*	grayish olive sandy silt with shell fragments
NG−12	51	21.1*	grayish olive silt
NG−13	45	21.3*	grayish olive silt with fine shell fragments
NG−14	30	21.1*	gray silt with small shell fragments
NG−15	21	21.1*	gray silt with small shell fragments
NG−16	16	21.1*	olive black silt
SZ−1	12.5	14.4**	silt
SZ−1a	12	14.4**	silt
SZ−3	3	14.6**	silt
SZ−10	8	14.5**	silt
SZ−14	22	14.6**	sandy silt

* : temperature of bottom sediment on October 26, 1981.
** : temperature of bottom water on February 9, 1983.

IV) Preparation Method

The part of upper two centimeters of each core sample was prepared for the present analysis. The volume of processed material was about 3.8ml.

The original material was taken into 100cc beaker, and then a mixed solution of nitric and hydrochloric acids and distilled water was added to the beaker for removing calcium carbonate particles. The desolved material was repeatedly washed out with pure water. Then the material was taken into 15cc polyethylen tube and about 30 percent solution of fluoric acid was used to remove fine silicate mineral grains. The organic residure was sieved through 120μm-and 20μm-opening screens.

For the quantitative analysis, the remnant material on the 20μm-

opening screen, containing organic-walled micro-remains was mounted with water. The dinoflagellate cysts on the slide were immediately identified and counted. This process was repeated until more than 200 specimens of the dinoflagellate cyst were counted. Reid (1974) initialy counted about two hundreds specimens from each sample in Recent sediments around the British Isles. Bradford and Wall (1984) showed the specimen/species curve for two Recent Persian Gulf sediments, and they counted three hundreds dinoflagellate cysts. But according to their curve, the number of species was mostly satulated with around initial two hundreds specimens.

For taking further morphological observation and microphotographs, other remnant material was mounted on a glass slide with glycerine jelly. The cover slipes were sealed with transparent nail enamel.

These slides and other part of the original samples are deposited in Department of Geology, Faculty of Liberal Arts, Nagasaki University.

V) Systematic Description

Note on the classification of modern dinoflagellate cysts

There is an important problem on the classification of living cysts. Many cysts have two species names which have been independently given by both biological and paleontological study. Matsuoka (1983) classified these cysts into several lineages, nearly corresponding with the Order or Family in the modern motile dinoflagellate taxonomy by using the archeopyle type which is regarded as an important and diagnostic character in the cyst classification. Dale (1983) discussed the problem of the classification system in detail from both view points of biology and paleontology, and proposed the best possible compromise for the classification of living cysts. He devided the living cysts into four categories on the basis of the development of theca-cyst relationship, and recomended the using together of biological and paleontological names in the meantime without any more additional new name based on the paleontological system, because the new cyst-based artificial nomenclature is not fruitiful for understanding of the dinoflagellate classification and phylogeny.

In the present study, actually I encountered some species which have not been yet described and given the cyst name. These cysts belong to Category 1 and Category 4 of Dale (1983). In the case of Category 1 cyst, I adopt the name of the cyst form. In the case of Category 4, the most possible name of biological or paleontological systems are given. And I

used the cyst-based species name for peridinialean cyst, because we need more detailed and careful observation in order to confirm the cyst-theca relationship in this group. For example, Fukuyo et al. (1977) reported a different cyst form from that described by Wall and Dale (1968) in *Protoperidinium minutum* (Kofoid). Furthermore, Kobayashi and Matsuoka (1984) showed two different cyst forms in *Protoperidinium conicum* (Gran). In this circumstance, I think that we can not use the pertinent name which is based on the modern motile dinoflagellate classification system. Therefor, for palynological investigation done without any relation to motile forms, it is better to use the cyst-based classification system with appendex of the thecal affinity.

Order Gonyaulacales Taylor 1980 (Gonyaulacoid cyst)

Family Gonyaulacaceae Lindemann 1928

Genus *Spiniferites* Mantell 1854 emend. Sarjeant 1970

Type species ; *Spiniferites ramosus* (Ehrenberg 1837) Mantell 1970
= *Xanthidinium ramosus* Ehrenberg 1837
= *Hystrichosphaera ramosa* O. Wetzel 1933
= *Hystrichosphaera furcata* O. Wetzel 1933

Spiniferites asperulus Matsuoka 1983

Pl. 4, figs. 7, 8.

1983 *Spiniferites asperulus* Matsuoka, p. 131–132, pl. 12, figs. 2–4, text–fig. 17.

Description: Proximate cyst is intermediate in size and subspherical to roundly ovoidal in shape without any apical boss. Cyst wall consists of two layers, the smooth and relatively thick endophragm and the coarsely granular and thin periphragm adpressed between processes. Processes derived from the periphragm are mostly gonal and rarely intergonal, and tapering with membranous and granular stalk and with slender trifurcate or bifurcate extremities. The antapical paraplate is incompletely surrounded by well developed parasuture forming large and hollow box-like processes. Parasuture is clear, but weak and waving. Paracingulum is relatively narrow, about one-tenth to one-twelfth of the cyst length. Parasulcus is also clearly defined, but not examined in detail. Paratabulation may be typical for the genus with four apical paraplates. Archeopyle is a precingular

type derived from displacement of the 3″ paraplete.

Dimensions of figured specimen: Length of cyst 56μm, width 52μm, length of antapical process 26.6μm, length of processes 20.4μm, width of paracingulum ca. 7μm.

Remarks: *Spiniferites asperulus* Matsuoka is easily distinguishable from other species of *Spiniferites* in possessing a thin granular periphragm and a characteristic antapical process. The previously known range of this species is Late Miocene to Early Pleistocene in the coastal area of the Sea of Japan (Matsuoka 1983). This is the first record from Recent sediments.

The thecal equivalence of this cyst is probably a species of *Gonyaulax* on the basis of its paratabulation.

Equivalent thecate form: unknown; but probably a cyst of the genus *Gonyaulax*.

Spiniferites bentori (Rossignol) Wall and Dale 1971
Pl. 5, figs. 1–6; Pl. 6, figs. 1–2; Text-fig. 3.

1964 *Hystrichosphaera Bentori* Rossignol, p. 84–85, pl. 1, figs. 3,7,8; pl. 3, figs. 2,3; text-figs. A–F.

1965 *Hystrichosphaera bentori* Rossignol; Wall, p. 298–300, figs. 1–5, 10, 24–29.

1966 *Hystrichosphaera bentori* Rossignol; Morzadec-Kerfourn, p. 137–138, pl. 1, fig. 1.

1966 *Hystrichosphaera bentori* Rossignol; Wall and Dale, fig. 1.

1967 *Hystrichosphaera bentori* Rossignol; Wall, p. 101, pl. 14, fig. 4, text-fig. 2.

1967 *Hystrichosphaera nodosa* Wall, p. 101–102, pl. 14, figs. 7–9, text-fig. 2.

1967 *Hystrichosphaera bentori* Rossignol; Wall and Dale, pl. 1, fig. B.

1968 *Hystrichosphaera bentori* Rossignol; Harland, p. 542–543, figs. 3,4,6,7,14–18.

1968 *Leptodinium churchillii* Harland, p. 548–550, figs. 12,13,22–24.

1968a Resting spore of *Gonyaulax digitalis* (Pouchet); Wall and Dale, p. 269, pl. 1, figs. 4–5.

1969 *Hystrichosphaera bentori* Rossignol; Rossignol, fig. 24, (3), pl. IV, figs. 10, 12.

1970 ?*Spiniferites bentori* (Rossignol) Wall and Dale, p. 52, pl. 1, figs. 26,28.

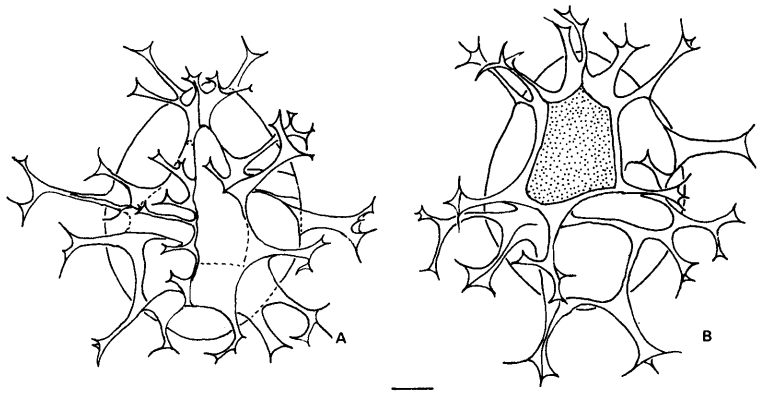
1971 ?Cyst of *Gonyaulax digitalis* (Pouchet); Wall, pl. 1, pl. 2, fig. 3.

1974 ?*Gonyaulax digitalis* (Pouchet)-*Spiniferites nodosus* (Wall); Harland, p. 231, pl. I, figs. 7,8.

1974 *Spiniferites bentori* (Rossignol); Ried, p. 598–600, pl. 2, figs. 14–16, text-fig. 3.

1977 *Spiniferites bentori* (Rossignol); Harland, p. 98–99, pl. 2, figs. 1–5.

1984 *Spiniferites bentori* (Rossignol); Bradford and Wall, p. 34–35, pl. 3, figs. 1–3, 7,10,11.



Text-figure 3. *Spiniferites bentori* (Rossignol) Wall and Dale, A ; ventral surface, B ; dorsal surface, scale bar is 10μm. Slide NG 13–2 : O(12.8/131.0).

Description : Proximate cyst is intermediate in size and elongate to ovoidal in shape. Epicyst has an apical boss. Cyst wall consists of two layers, the thick periphragm and the relatively thin endophragm adpressed between processes. Periphragm is coarsely granular and occasionally shows a reticulate structure near basal part of procesesses. Processes are solid and sometimes flexuous, gonal only and tapering with trifurcate distal tips. Some processes have membranous stalks near proximal base continuing from well developed parasuture. Paracingulum is relatively narrow, about one-tenth of the cyst length in width, and is laevorotary in about three times of its own width. Parasulcus is clearly defined and comprises more than four paraplatelets including As,Ps,Rs,Ls and other accessory paraplatelets. Paratabulation is well represented by distinctive parasuture, 4′, 6″, 6c, 6‴, 1p, 1⁗, As, Ps and several other paraplatelets. The 6″ paraplate is always triangular in shape, and the 1⁗ paraplate is always much reduced and is contained in the parasulcus. The 2‴ paraplate is smaller than other postcingular paraplates and similar to the 1p paraplate in shape and size. Archeopyle is a reduced precingular type formed by loss of the 3″ paraplate.

Dimensions : Length of cyst 52–60.8μm, width 44.8–51.6μm, length of processes 16–19μm, width of paracingulum ca. 8μm.

Remarks : The present specimens are easily differentiated from other species of *Spiniferites* in having larger cyst body, coarsely granular and relatively thick periphragm, and a distinctive apical boss. This species is characterized by having only gonal processes, but Wall and Dale (1971) pointed out that it has more numerous intergonal spines, finer spines and more

reduced septa. The present specimens are closely similar to those of Rossignol (1964) in having only gonal processes.

Ecological distribution in previous record:

Tropical-subtropical; estuarine (Wall et al. 1977).

Temperate; inner to outer neritic (Harland 1983).

Equivalent thecate form: *Gonyaulax digitalis* (Poucht) by Wall and Dale (1968), but the cyst morphology described by them is somewhat different in process form of the present specimens.

Spiniferites sp. cf. *bentori* (Rossignol) Wall and Dale 1970
Pl. 4, figs. 4–6.

Compare:

1970 *Spiniferites bentori* (Rossignol) Wall and Dale, p. 52, pl. 1, figs. 26, 28.

1971 Cyst of *Gonyaulax digitalis* (Pouchet); Wall, pl. 1, pl. 2, fig. 3.

1974 *Gonyaulax digitalis* (Pouchet)–*Spiniferites nodosus* (Wall); Harland, p. 231, pl. I, figs. 7,8.

Dimensions of figured specimen: Length of cyst 45μm, width 39μm, length of processes ca. 7μm.

Descriptive remarks: The present specimen is similar to *Spiniferites bentori* (Rossignol) in having its ovoidal cyst body with a distinctive apical boss, but different from the latter in that slender intergonal processes are well developed. Except for the cyst shape, this species also resembles *Spiniferites hyperacanthus* (Deflandre and Cookson).

Spiniferites bulloideus (Deflandre and Cookson) Sarjeant 1970
= *Spiniferites ramosus* (Ehrenberg) Mantell 1854 in sensu Harland 1983
Pl. 1, figs. 8–12; Pl. 2, figs. 1–9, Text-fig. 4.

1955 *Hystrichosphaera bulloidea* Deflandre and Cookson, p. 264, pl. 5, figs. 3,4.

1965 *Hystrichosphaera bulloidea* Deflandre and Cookson; Wall, p. 300–302, fig. 6.

1967 *Hystrichosphaera bulloidea* Deflandre and Cookson; Wall and Dale, pl. 1 (K).

1968a *Hystrichosphaera bulloidea* Deflandre and Cookson; Wall and Dale, p. 270–271, pl. 1, figs. 14,15.

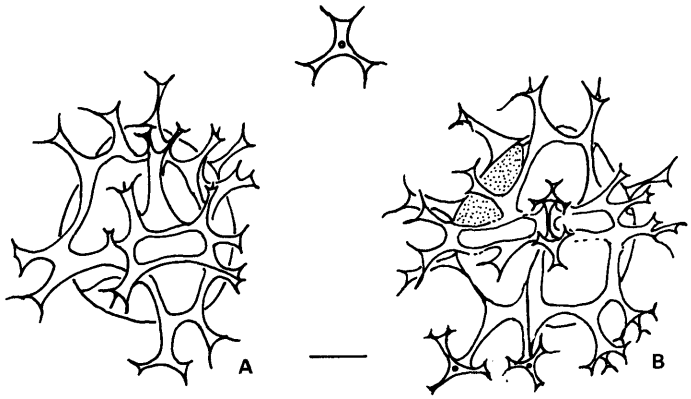
1970 ?*Spiniferites ramosus* (Ehrenberg); Wall and Dale, p. 49–50, pl. 1, figs. 1–15.

1971 ?Cyst of *Gonyaulax* sp. aff. G. *spinifera* (Claparède and Lachemann); Wall, pl. 2, fig. 4.

1970 *Spiniferites bulloideus* (Deflandre and Cookson) Sarjeant, p. 75.

1981 *Spiniferites* cf. *bulloideus* Deflandre and Cookson ; Matsuoka, pl. 2, fig. 7.

1984 *Spiniferites bulloideus* (Deflandre and Cookson) ; Bradford and Wall, p. 37, pl. 3, figs. 15–18.



Text-figure 4. *Spiniferites bulloideus* (Deflandre and Cookson) Sarjeant, A ; oblique ventral surface, B ; oblique dorsal surface, scale bar is 10μm. Slide NG 13–3 : O(16.0/127.1).

Description: Small proximate cyst is ovoidal in shape. Its polar view shows a nearly circular outline. Cyst wall consists of two layers, the thin and transparent periphragm and the endophragm adpressed between processes. Processes derived from the periphragm are solid and sometimes hollow with somewhat membranous stalks near proximal base, and gonal only with trifurcate distal extremities branching bifurcately. Processes developed at the contact part of 2″′, 3″′ and 1″″ paraplates are larger than the other hollow and tapering with well developed membranous parasuture. Paracingulum is moderately wide, one-fourth to one-fifth of the cyst length, and is distinctively laevorotary in two to three times of its own width. Parasulcus is also wide, but does not any features reflecting paraplatelets. Paratabulation is 4′, 6″, 6c, 6″′, 1p and 1″″. The 6″ paraplate is always triangular and the 1″′ is also always strongly reduced. Archeopyle is a reduced precingular type formed by loss of the 3″ paraplate.

Dimensions: Length of cyst 28.4–34.4μm, width 26–30.4μm length of processes 8–13μm, width of paracingulum 7μm.

Remarks: Several species of *Spiniferites* are closely similar to *S. bulloideus* (Deflandre and Cookson), because of their smaller ovoidal cyst body and somewhat unclear features of processes. The present species,

however, is distinguishable from other species in having smooth to very finely granular cyst wall and only gonal processes with trifurcate distal ends.

Harland (1977) revised the complex species previously identified as *S. bulloideus* (Deflandre and Cookson) and *S. ramosus* (Ehrenberg), and he showed that some specimens formerly assigned to *S. bulloideus* (Deflandre and Cookson) are synonyms of *S. ramosus* (Ehrenberg) and concluded that the original specimen described by Deflandre and Cookson (1955) is a junior synonym of *Spiniferites ramosus*, and that *Hystrichosphaera bulloidea* described by Wall and Dale (1968) is probably another new species. The present specimens well coincide with *Hystrichosphaera bulloidea* Deflandre and Cookson descrived by Wall (1965), according to larger gonal processes well developed on the hypocyst and ovoidal cyst shape.

Ecological distribution in previous record:

Arctic to temperate; inner to outer neritic as *S. ramosus* (Ehrenberg) (Harland 1983).

Cosmopolitan; estuarine (Wall et al. 1977).

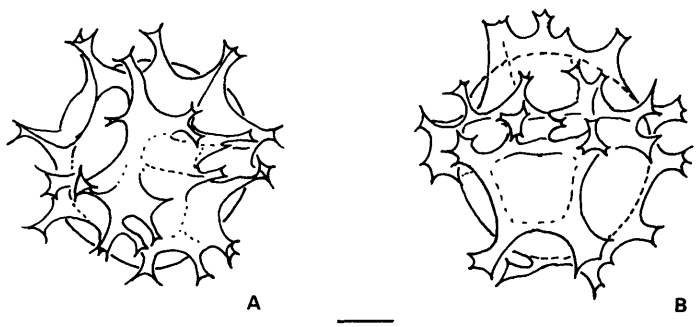
Eqivalent thecate form: *Gonyaulax scrippsae* Kofoid by Wall and Dale (1968).

Spiniferites sp. cf. *delicatus* Reid 1974

Pl. 1. figs. 1–7, Text-figs. 5, 6.

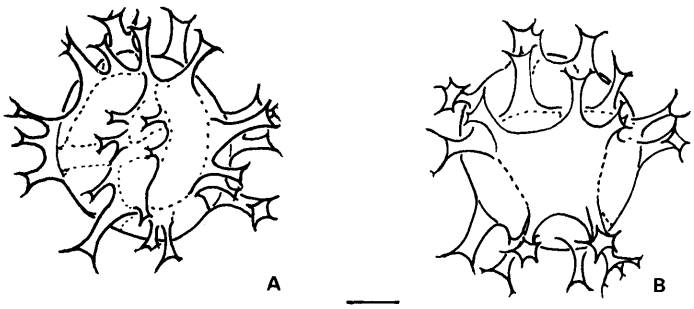
Compare:

1966 ?*Hystrichosphaera* cf. *tertiaria* Eisenack and Gocht; Morzadec-Kerfourn, p. 138, pl. 1, fig. 3.



Text-figure 5. *Spiniferites* sp. cf. *delicatus* Reid, A; oblique ventral surface, B; oblique dorsal surface, scale bar is 10 μm. Slide NG 13–2 : O(17.5/140.7).

1974 *Spiniferites delicatus* Reid, p. 601–602, pl. 2, figs. 20–22.
1977 *Spiniferites delicatus* Reid ; Harland, p. 99, pl. 2, figs. 13–15.
1977 *Spiniferites delicatus* Reid ; Reid and Harland, pl. 1, figs. 13–14.
1982 *Spiniferites delicatus* Reid ; Matsuoka, pl. 2, figs. 5,6.



Text-figure 6. *Spiniferites* sp. cf. *delicatus* Reid, A ; ventral surface, B ; dorsal surface, scale bar is 10μm. Slide SZ 3–3 : O(9.5/132.3).

Description : Proximate cyst is small in size and subspherical in shape without any apical boss. Wall consists of two layers, the smooth and relatively thick endophragm and the finely granular periphragm adpressed between processes. Processes are subconical to tapering, and gonal only. The processes arising at the corner between the 4″′ and 1″″ paraplates are hollow with petaloid distal extremities. Some other processes are also hollow. Parasuture is reduced and unclear, especially on the dorsal area. Paracingulum is relatively narrow, about one-eighth to one-tenth of the cyst length, and displaced at one time of its own width. Parasulcus is also distinct, but does not apparently reflect any sulcal paraplatelet. Paratabulation coincides with that of the other species of *Spiniferites* bearing four apical paraplates. The 1″′ paraplate may be reduced and the 2″′ paraplate is similar to the 1p paraplate in size and shape. Archeopyle is a precingular type formed by loss of the 3″ paraplate.

Dimensions : Length of cyst 36.4–44.4μm, width 33.6–38.8μm, length of processes 8–14μm, width of paracingulum ca. 6μm.

Remarks : The present species is similar to *Spiniferites delicatus* Reid in having some hollow processes with petaloid distal tips and a subspherical cyst body, but differs from the latter in lacking the high sutural flange at the hypocyst and possessing parasutural septa poorly developed. This species also resembles *S. bulloideus* (Deflandre and Cookson) in general cyst shape, but differs in having a relatively narrow paracingulum and

some hollow processes with petaloid tips.

Ecological distribution in previous record:

Temperate; inner neritic to outer neritic as *Spiniferites delicatus* (Harland 1983).

Equivalent thecate form: Probably *Gonyaulax scrippsae* Kofoid by Wall and Dale (1968).

Spiniferites hyperacanthus (Deflandre and Cookson) Sarjeant 1970
Pl. 3, figs. 5–12, Text-fig. 7.

1955 *Hystrichosphaera hyperacantha* Deflandre and Cookson, p. 264, pl. 6, fig. 7.

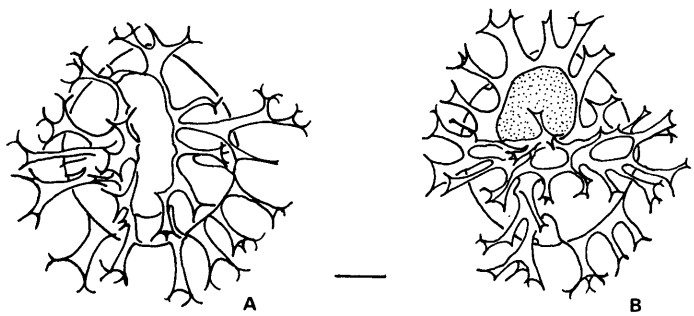
1964 *Hystrichosphaera furcata* var. *multiplicata* Rossignol, p. 86, pl. 1, fig. 14, pl. 3, fig. 16.

1967 *Hystrichosphaera hyperacantha* Deflandre and Cookson, Wall, p. 100, pl. 14, fig. 3.

1974 *Spiniferites hyperacanthus* (Deflandre and Cookson) Reid, p. 603–604, pl. 4, fig. 35.

1984 *Spiniferites ramosus* subsp. *multiplicatus* (Rossignol) Lentin and Williams; Bradford and Wall, p. 40, pl. 1, figs. 15–17; pl. 5, figs. 1–3, 5–7.

Description: Proximate cyst is small to intermediate in size and ovoidal to subspherical in shape. Sometimes a broad apical node or boss is present. Cell wall comprises two transparent layers adpressed between processes. Periphragm is smooth to finely granular and the endophragm is thin. Processes are developed at both gonal and intergonal positions, and are slender, tapering and somewhat membranous near the proximal base. Gonal processes have trifurcate distal extremities with bifid branches, while intergonal ones bear bifurcate tips. Paracingulum is relatively narrow,



Text-figure 7. *Spiniferites hyperacanthus* (Deflandre and Cookson) Sarjeant, A; ventral surface, B; dorsal surface, scale bar is 10μm. Slide NG 13–2: O(10.6/146.6).

about one-sixth to one-eighth of the cyst length. Parasulcus is also well defined, but any feature reflecting paraplatelet is absent. Paratabulation is clearly indicated by well developed parasuture and basically coincides with that of the genus. Archeopyle is a reduced precingular type derived from loss of the 3″ paraplate.

Dimensions: Length of cyst 38.2–40.3μm, width 34–38.5μm, length of processes 12–18.5μm, width of paracingulum ca. 6.5μm.

Remarks: According to the original description given by Deflandre and Cookson (1955), *Spiniferites hyperacanthus* (Deflandre and Cookson) has a circular outline. This feature reveals when the specimens are observed from a polar view. This species is different from *S. bulloideus* (Deflandre and Cookson) in possessing many intergonal processes and from *S. mirabilis* (Rossignol) in lacking conspicuous membranous processes on the antapical area.

Geographical distribution in previous record:

Around the British Isls, (Reid 1974), and in the Persian Gulf (Bradford and Wall 1984).

Equivalent thecate form: *Gonyaulax spinifera* complex by Wall and Dale (1968).

Spiniferites mirabilis (Rossignol) Sarjeant 1970
Pl. 3, figs. 1–4.

1963 ?cf. *Hystrichosphaera mirabilis* Rossignol, figs. 14–16, nom, nud.
1964 *Hystrichosphaera mirabilis* Rossignol, p. 86–87, pl. 2, figs. 1–3, pl. 3, figs. 4,5.
1966 *Hystrichosphaera mirabilis* Rossignol; Morzadec-Kerfourn, p. 138, pl. 1, fig. 2.
1966 *Hystrichosphaera mirabilis* Rossignol; Wall and Dale, fig. 2.
1967 *Hystrichosphaera mirabilis* Rossignol; Wall, p. 101, pl. 14, figs. 5,6, text-fig. 2.
1967 *Hystrichosphaera mirabilis* Rossignol; Wall and Dale, pl. 1, fig. F.
1968a Resting spore of *Gonyaulax spinifera* (Claparède and Lachmann): Wall and Dale, p. 207, pl. 1, fig. 10, text-fig. 4.
1969 *Hystrichosphaera mirabilis* Rossignol; Rossignol, fig. 24(2), pl. 4, figs. 2,3,11.
1970 *Spiniferites mirabilis* (Rossignol) Sarjeant, p. 76.
1974 *Spiniferites mirabilis* (Rossignol); Reid, p. 606–607, pl. 4, figs. 2,3,11.
1976 *Spiniferites mirabilis* (Rossignol); Dale, pl. 1, fig. 5.
1977 *Spiniferites mirabilis* (Rossignol); Harland, p. 101, pl. 2, fig. 6.
1977 *Spiniferites mirabilis* (Rossignol); Reid and Harland, pl. 1, fig. 1.
1979 *Spiniferites mirabilis* (Rossignol); Harland, pl. 1, figs. 1–4.
1982 *Spiniferites mirabilis* (Rossignol); Matsuoka, pl. 2, figs. 3–4.

1984 *Spiniferites mirabilis* (Rossignol) ; Bradford and Wall, p. 38, pl. 4, figs. 1–4.

Description: Proximate cyst is intermediate to small in size and subspherical to ovoidal in shape. Cyst wall is relatively thin and consists of two layers, the periphragm with the smooth to finely granular surface and the endophragm adpressed between processes. Processes comprises two types, gonal and intergonal, and they are long conical to tapering with somewhat membranous proximal base. The gonal type has trifurcate distal branches and the intergonal type bears bifurcate extremities. Parasuture around the antapical plate, especially the boundary between the 4″′ and 1″″ paraplates, is well developed and forms a large membranous process often with deeply dentate margin. Paratabulation is represented by parasutural septa and basically coincides with that of the genus. Archeopyle is a precingular type formed by loss of the 3″ paraplate.

Dimensions: Length of cyst 36–41.6μm, width 36–40.4μm, length of processes 10–18.4μm, width of paracingulum ca. 6.5μm.

Remarks: *Spiniferites mirabilis* (Rossignol) resembles *S. membranaceous* (Rossignol) in having well developed antapical process with high membranous parasuture, but differs from the latter in possessing many intergonal processes and antapical process often bearing deeply dentate extremities.

This species is unable to be distinguishable from *S. hyperacanthus* (Deflandre and Cookson) carring well developed intergonal processes in the case of that such orientation observed as polar view and poor preservation.

Ecological distribution in previous record:

Cosmopolitan; neritic (Wall et al. 1977).

Arctic to Temperate; inner neritic to oceanic (Harland, 1983).

Equivalent thecate form: *Gonyaulax spinifera* complex by Wall and Dale (1968).

Spiniferites sp. cf. *rubinus* (Rossignol) Sarjeant 1970

Pl. 2, figs. 10–13.

Compear:

1964 *Hystrichosphaera rubina* Rossignol, p. 87–88, pl. 1, figs. 12–13.

1970 *Spiniferites rubinus* (Rossignol) Sarjeant, p. 76.

1979 *Spiniferites rubinus* (Rossignol) ; Harland, p. 537, pl. 2, figs. 4–11.

1984 *Spiniferites rubinus* (Rossignol) ; Bradford and Wall, p. 42, pl. 5, figs. 13–15.

Description: Small proximate cyst is subspherical in shape without any apical boss. Cyst wall comprises two layers, the smooth and thin endophragm, and the thin and smooth to finely granular periphragm adpressed between processes. Processes consist of only gonal type, and furcation at the distal extremities is very poor. Some of the processes developed at apical and antapical areas are distinctively membranous and form wide flange-like parasuture with loricate distal extremities. Some arising at the corner of the 4″′, 5″′ and 1″″ paraplates are short and hollow with petaloid or elongate tips in plane view. A few processes situating at the paracingulum are short conical to tapering with irregurarily trifurcate branches. Paracingulum is moderately wide, about one-fifth to one-sixth of the cyst length and is laevorotary in one to two times of its own width. Parasulcus is also clearly defined but no paraplatelet may be developed. Paratabulation is typical for the genus except for unclear apical series. Archeopyle is a precingular type formed by loss of the 3″ paraplate.

Dimensions: Length of cyst 35.3–39.5μm, width 34.5–36.4μm, length of processes 6.4–8.5μm, width of paracingulum ca. 5.5μm.

Remarks: *Spiniferites rubinus* (Rossignol) is easily distinguishable from other species of the genus in being characterized by well-developed membranous processes. The present specimens have this character, but some processes are hollow with somewhat pressed petaloid tips or irregurally furcate ends. In having these processes, the present ones are different from *S. bentori* subsp. *truncatus* (Rossignol). These features have been described in the Pleistocene specimens of the Bay of Biscay by Harland (1979) and in Quaternary specimens of Mediterranean by Rossignol (1974).

Geographical distribution in previous record: This species has been recorded from the north Atlantic Pleistocene in the Bay of Biscay (Harland 1979) and Mediterranean (Rossignol 1964), and surface sediment off the coast of Iran (Bradford and Wall 1984).

Equivalent thecate form: unknown; but probably *Gonyaulax* sp.

Spiniferites sp. cf. *ramosus* (Ehrenberg) Mantell 1854
Pl. 4, figs. 1–3; Pl. 6, figs. 3–4.

Compare:

1966 *Hystrichosphaera ramosa* (Ehrenberg) var. *ramosa* Davey and Williams, p. 33–34, pl. 1, figs. 1, 6; pl. 3, fig. 1, text-fig. 8.

Dimensions: Length of cyst 42–47μm, width 36–38μm, length of processes ca. 12μm.

Description: The small to intermediate present specimens are characterized by an ovoidal cyst body with relatively thin wall. The periphragm is nearly smooth. The processes are cylindrical to tapering, only gonal and somewhat membranous at the proximal base. The distal tips are trifurcate with bifid extremities. The archeopyle is precingular and enlarged, and probably includes some apical paraplates.

Remarks: These specimens are similar to *Hystrichosphaera ramosa* (Ehrenberg) var. *ramosa* Davey and Williams, but differs from the latter in having more elongate cyst body and the smooth periphragm.

Genus *Lingulodinium* Wall 1967 emend. Wall and Dale 1973

Type species: *Lingulodinium machaerophorum* (Deflandre and Cookson 1955) Wall 1967
= *Hystrichosphaera machaerophorum* Deflandre and Cookson 1955

Lingulodinium machaerophorum (Deflandre and Cookson) Wall 1967

Pl. 8, figs. 1–5.

1951 Resting spore of *Gonyaulax polyedra* Stein ; Nordli, p. 207–208, figs. 1a–1f.

1954 cf. *Gonyaulax polyedra* Stein ; Erdtman, fig. 2B.

1955 *Hystrichosphaerdium machaerophorum* Deflandre and Cookson, p. 274, pl. 9, figs. 4,8.

1959 Cyst of *Gonyaulax,* Mckee et al., pl. 1, fig. 9.

1961 *Hystrichosphaeridium ashdodense* Rossignol, p. 322, pl. 1, fig. 9. nom. nud.

1962 *Hystrichosphaeridium ashdodense* Rossignol ; Rossignol, p. 132, pl. 2, fig. 2, nom. nud.

1964 *Baltisphaeridium machaerophorm* (Deflandre and Cookson) ; Rossignol, p. 90–91, pl. 2, fig. 14, pl. 3, figs. 20,21.

1964 Cyst of *Gonyaulax polyedra* Stein ; Evitt and Davidson, p. 4–5, pl. 1, figs. 6–8, 13.

1966 ?*Hystrichosphaeridium isocalamus* Deflandre and Cookson ; Morzadec-Kerfourn, p. 139,pl. 2, figs. 1,2.

1966 ?*Hystrichosphaeridium redonensis* Morzadec-Kerfourn, p. 139, 140, pl. 2, fig. 3.

1966 ?*Hystrichosphaeridium zoharyi* Rossignol ; Morzadec-Kerfourn, p. 140, pl. 2, fig. 4, (not pl. 4, fig. 3).

1966 *Baltisphaeridium machaerophorum* (Deflandre and Cookson) ; Morzadec-Kerfourn, p. 140, pl. 3, figs. 1,2.

1966 *Cleistosphaeridium machaerophorum* (Deflandre and Cookson) Davey et al., p.

170.

1967 Cyst of *Gonyaulax polyedra* Stein ; Evitt, p. 43, pl. 6, figs. 13–19, text-figs. 13–14.

1967 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall, p. 109–110, pl. 15, figs. 16,17, text-fig. 6.

1967 Cyst of *Gonyaulax polyedra* Stein ; Wall et al., fig. 1,

1967 Cyst of *Gonyaulax polyedra* Stein ; Wall and Dale, pl. 1, fig. N.

1968 *Lingulodinium* cf. *machaerophorum* (Deflandre and Cookson) Wall ; Harland, p. 548, figs. 8, 8a, 27, 28.

1968a Resting spore of *Gonyaulax polyedra* Stein ; Wall and Dale, p. 271–272, pl. 1, fig. 18, pl. 3, figs. 4–6.

1969 *Baltisphaeridium machaerophorum* (Deflandre and Cookson) ; Rossignol, figs. 24 (16), pl. IV, fig. 1.

1969 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall ; Downie and Singh, figs. 7,8,10,11.

1971 *Baltisphaeridium* sp. Takahashi, p. 20–21, pl. 3, figs. 2,3,5.

1971 Cyst of *Gonyaulax polyedra* Stein ; Wall, pl. 2, figs. 7,8.

1971 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall ; Jux, p. 168, 171–172, pl. 28, figs. 23–29.

1973 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall ; Wall, Dale and Harada, p. 24, pl. 2, figs. 5,6, pl. 3, figs. 11,12.

1974 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall ; Wall and Dale, fig. 1p.

1974 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall ; Reid, p. 591–592, pl. 1, figs. 6,7.

1977 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall ; Harland, p. 94–96, pl. 2, figs. 22–24, pl. 4, figs. 11,17, text-fig. 2.

1977 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall ; Reid and Harland, pl. 1, fig. 2.

1981 Cyst form of *Gonyaulax polyedra* Stein ; Kobayashi, Matsuoka and Iizuka, p. 53–55, pl. 1, figs. A,C,D.

1984 *Lingulodinium machaerophorum* (Deflandre and Cookson) ; Bradford and Wall, p. 31, pl. 1, figs. 7–9, 12–16.

Dimensions: Cyst diameter 44–46μm, length of processes 14.4–16.4μm, diameter of processes at proximal base ca. 4.8μm.

Remarks: *Lingulodinium machaerophorum* (Deflandre and Cookson) is also morphologically variable species in the following two points ; process shape and archeopyle structure. Processes vary from short conical, taper-

ing and cylindrical to weakly lagenate, and those distal extremities are also various; from evexate and bulbose to somewhat capitate in a single specimen. Most of present specimens have tapering to cylindrical stalks with evexate to bulbose distal ends. The archeopyle of this species is formed by usually release of three to four precingular paraplates, probably 2″ to 5″, but occasionally including apical and anterior intercalary series. Therefore, poorly preserved specimens recovered from surface sediments show a half spherical form as observed in *Polysphaerdium zoharyi* (Wall).

Ecological distribution in previous record:

Cosmopolitan; estuarine (Wall et al. 1977).

Temperate to tropical; inner to outer neritic and oceanic (Harland 1983).

Equivalent thecate form: *Gonyaulax polyedra* Stein by Wall and Dale (1968) and Kobayashi et al. (1981).

Genus *Operculodinium* Wall 1967

Type species; *Operculodinium centrocarpum* (Deflandre and Cookson 1955) Wall 1967
= *Hystrichosphaeridium centrocarpum* (Deflandre and Cookson) Wall 1967

Operculodinium centrocarpum (Deflandre and Cookson) Wall 1967

Pl. 7, figs. 1–6.

1945 Cyst of *Protoceratium reticulatum* (Claparède and Lachmann); Braarud, p. 15–17, pl. IV, figs. d, e, text–fig. 6.

1953 *Hystrichosphaeridium* sp. a; Cookson, p. 115, pl. II, figs. 26,27.

1954 Cyst of *Protoceratium reticulatum* (Claparède and Lachmann); Erdtman, fig. 1B.

1955 *Hystrichosphaeridium centrocarpum* Deflandre and Cookson, p. 272–273, pl. 8, figs. 3,4.

1964 Cyst of *Protoceratium reticulatum* (Claparède and Lachmann); Evitt and Davidson, p. 5, pl. 1, fig. 12.

1961 *Baltisphaeridium centrocarpum* (Deflandre and Cookson) Gerlach, p. 192–193, pl. 28, fig. 9.

1966 *Cordosphaeridium tiara* (Klumpp, 1953) subsp. *centrocarpum* (Deflandre and Cookson, 1955) Morgenroth, p. 26, pl. 54, fig. 12; pl. 6, fig. 1.

1966 *Baltisphaeridium centrocarpum* (Deflandre and Cookson); Wall and Dale, fig. 4.

1967 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall, pl. III, pl. 16, figs. 1,2,5.

1967 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall; Wall and Dale, p.

352, pl. 1, fig. M.

1967 Cyst of *Gonyaulax grindleyi* Reinecke, p. 158–160, pl. 1, figs. A–C.

1968a *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Wall and Dale, p. 272, pl. 1, fig. 20.

1968b *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Wall and Dale, pl. 1, no. 12.

1968 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Harland, p. 546–548, figs. 11,11a,25,26.

1969 *Hemicystodinium zoharyi* (Rossignol) ; Harland and Downie, pl. 7, fig. 10.

1969 *Hemicystodinium zoharyi* (Rossignol) ; Downie and Singh, figs. 1,2.

1971 Cyst of *Protoceratium reticulatum* (Claparède and Lachmann) ; Wall, pl. 2, fig. 6.

1973 *Protoceratium reticulatum* (Claparède and Lachmann)-*Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Harland, p. 236–239, pl. II, figs. 4, 7–16, pl. III, fig. 1–6, pl. IV, figs. 1,2.

1974 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Reid, p. 594–595, pl. 2, figs. 10,11.

1974 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Davey and Rogers, pl. 1, fig. 6.

1976a *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Matsuoka, p. 364–365, pl. II, fig. 10.

1976b *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Matsuoka, p. 112–113, pl. 27, figs. 3–8.

1976 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Jux, pl. 1, fig. 4, pl. 4, figs. 1–3, pl. 5, figs. 1–4.

1976 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Dale, pl. 1, fig. 3.

1977 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Harland, p. 96–97, pl. 1, fig. 19, pl. 4, figs. 9,10.

1977 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Reid and Harland, pl. 1, fig. 8.

1980 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Harland and Reid in Harland et al., p. 213, fig. 2P.

1982 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Harland, pl. 1, fig. 1–4.

1982 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Matsuoka, pl. 2, figs. 7,8.

1984 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall ; Bradford and Wall, p. 32–33, pl. 1, figs. 10, 11.

Dimensions : Cyst diameter 34–35.2μm, length of processes 8–10μm.

Remarks: The morphological variation of this species is recognized in following two characters. One of them is observed in length of processes. The slender and cylindrical processes vary from one-tenth to one-fourth of the cyst diameter. The cyst with the shorter processes is known as a nodular form (Harland 1974). Another variable character is revealed in the surface structure of periphragm. This character varies from apparently coarsely granular to finely reticulate owing to the fibrous periphragm.

Operculodinium centrocarpum (Deflandre and Cookson) is similar to *O. israelianum* (Rossignol), but differs from the latter in bearing slender and relatively long cylindrical processes and relatively finely reticulate periphragm. Actually the intermediate forms, however, is present.

Ecological distribution in previous record:

Cosmopolitan; neritic (Wall et al. 1977).

Temperate to tropical; inner to outer neritic and oceanic (Harland, 1983).

Equivalent thecate form Protoceratium reticulatum (Claparède and Lachmann) Diesing
= *Gonyaulax grindleyi* Reinecke by Wall and Dale (1968).

Operculodinium israelianum (Rossignol) Wall 1967
Pl. 7, figs. 11, 12.

1961 *Hystrichosphaeridium israelianum* Rossignol, p. 322, non. nud.
1962 *Hystrichosphaeridium israelianum* Rossignol, p. 132, pl. 2, fig. 3.
1964 *Baltisphaeridium israelianum* (Rossignol) Rossignol, p. 91, pl. 2, fig. 12; pl. 3, figs. 13,14.
1966 *Cleistosphaeridium israelianum* (Rossignol) Davey, Downie, Sarjeant and Williams, p. 170.
1967 *Operculodinium israelianum* (Rossignol) Wall, p. 111, pl. 16, figs. 3,4.
1968b *Operculodinium israelianum* (Rossignol) Wall; Wall and Dale, pl. 1, nos. 10,11.
1976 *Operculodinium israelianum* (Rossignol) Wall; Matsuoka, p. 113, pl. 27, figs. 1,2.
1984 *Operculodinium israelianum* (Rossignol) Wall; Bradford and Wall, p. 33–34, pl. 1, fig. 17; pl. 2, figs. 1,2,5.

Description: Chorate cyst is usually intermediate in size and subspherical to ovoidal in shape. Cyst wall comprises two layers adpressed between processes. Endophragm is thin and smooth, and periphragm is relatively thick and shows apparently granular to fibro-pitted structure. Periphragm alone makes up the processes of which distribution is apparently evenly

nontabular but basically may be intratabular. Processes are numerous and usually short conical with acuminate distal extremities. Proximal base of processes carries some striations. Archeopyle is probably a reduced precingular type formed by displacement of the paraplate 3″. Operculum is free.

Dimensions: Cyst diameter 33.6–48μm, length of processes 4–6μm.

Remarks: *Operculodinium israelianum* (Rossignol) resembles *O. crassum* Harland in having relatively short conical processes and apparently granular surface of the processes, but is distinguishable from the latter in possessing thinner periphragm.

Wall and Dale (1968) mentioned that *O. israelianum* (Rossignol) is an intermediate form between *O. centrocarpum* (Deflandre and Cookson) and *O. psilatum* Wall in morphorogical character. However, *O. israelianum* (Rossignol) has been not known in any surface sediment of the subboreal to boreal regions. This evidence suggests that *O. israelianum* (Rossignol) is the ecologically independent species.

Ecological distribution in previous record:

Tropical to subtropical; estuarine (Wall et al., 1977).

(Temperate) to tropical, inner to outer neritic (Harland, 1983).

Equivalent thecate form: Probably *Protoceratium reticulatum* (Claparède and Lachmann) Diesing by Wall and Dale (1968).

Operculodinium crassum Harland 1979

Pl. 6, figs. 6–8: Pl. 7, figs. 7–10.

1979 *Operculodinium crassum* Harland, p. 536, pl. 2, figs. 12–14.

1983 *Operculodinium crassum* Harland; Matsuoka, p. 126, pl. 7, fig. 9, pl. 8, figs. 1, 3–4, 6.

Description: Chorate cyst is intermediate to small in size and subspherical to ovoidal in shape. Cyst wall consists of two layers adpressed between processes. Endophragm is thin and smooth. Periphragm is spongy between processes and therefore, it apparently shows finely reticulate. Processes formed from the periphragm are flexuous, long conical with capitate extremities, and sometimes furcate on a way. Because of this wall condition, such structure often reveals. The distribution of processes is basically intratabular but apparently nontabular in poor preservation. Paracingulum is sometimes indicated by paralell row of processes developed

under the archeopyle. Archeopyle is a precingular type probably formed by loss of the 3″ paraplate. Operculum is free.

Dimensions: Cyst diameter 40.8–47.2μm, length of processes 12.8–16μm, thickness of cyst wall ca. 2μm.

Remarks: This cyst is similar to *Operculodinium israelianum* (Rossignol), but differs in having longer processes and more spongy periphragm. Actually it is very difficult to distinguish these two species, because the intermediate forms are sometimes present.

Equivalent thecate form: unknown: but probably a species of the Gonyaulacoid Lineage.

Genus *Protogonyaulax* Taylor 1979

Type species: *Protogonyaulax tamarensis* (Lebour) Taylor 1979
= *Gonyaulax tamarensis* Lebour 1925

Protogonyaulax catenella (Whedon and Kofoid) Taylor 1979

Pl. 6, fig. 5.

1980 Cyst of *Protogonyaulax catenella* (Whedon and Kofoid) Taylor 1979; Fukuyo, p. 51.

1981 Hypnozygote of *Protogonyaulax catenella* (Whedon and Kofoid) Taylor; Yoshimatsu, p. 136, pl. II, figs. 9–12.

Description: Proximate cyst is elongate and has a round polar end. Cyst wall basically consists of two layers, the thin periphragm and thick endophragm. Both layers are smooth and transparent. Cyst completely lacks any ornamentation on the surface. Archeopyle is probably a chasmic type, and formed at the apex.

Dimensions: Length of cyst 44–46.8μm, width 29.5–31.2μm.

Remarks: Before extracted chemical treatment, this cyst is surrounded by transparent and adhesive materials with such silicate small particles as diatoms, silicoflagellates and silt.

Protogonyaulax tamarensis (Lebour) also produces the cyst undifferentiable from the present species, but according to Fukuyo (1982a), the former is mainly distributed in the cool temperate region. The cyst of *Gyrodinium instriatum* is also similar to this cyst, but differs in having an ovoidal body and a tremic archeopyle.

Ecological distribution in previous record:

Warm temperate (?); Fukuyo (1982).

Family Pyrophacaceae Lindemann 1928 (Tuberculodinioid cyst)

Genus *Tuberculodinium* Wall 1967 emend. Wall and Dale 1971

Type species: *Tuberculodinium vancampoae* (Rossignol 1962) Wall 1967
= *Pterospermopsis* ? *vancampoae* Rossignol 1962

Tuberculodinium vancampoae (Rossignol) Wall 1967
Pl. 8, fig. 6, 7.

1962 *Pterospermopsis* ? *vancampoae* Rossignol, p. 134, pl. 2, fig. 1.
1964 *Pterospermopsis* ? *vancampoae* Rossignol; Rossignol, p. 90, pl. 2, figs. 17,18, pl. 3, fig. 15.
1967 *Tuberculodinium vancampoae* (Rossignol) Wall, p. 114, pl. 16, figs. 15,16.
1971 Cyst of *Pyrophacus vancampoae* (Rossignol) Wall and Dale, p. 234–235, figs. 10–25.
1976 *Tuberculodinium vancampoae* (Rossignol) Wall; Matsuoka, p. 114, pl. 29, figs. 6,7.
1978 *Tuberculodinium vancampoae* (Rossignol) Wall; Harland, pl. 3, fig. 11.
1982 *Tuberculodinium vancampoae* (Rossignol) Wall; Matsuoka, pl. 1, figs. 10,11.
1984 *Tuberculodinium vancampoae* (Rossignol) Wall; Bradford and Wall, p. 44, pl. 6, figs. 5–10.
1984 Cyst of *Pyrophacus steinii* (Schiller) Wall and Dale, Matsuoka, p. 103.

Description: Intermediate to large chorate cyst is compressed anteroposteriorly, and is circular in polar view and ellepsoidal in lateral view. Cyst wall consists of two layers, the smooth, transparent and the relatively thin endophragm and the periphragm, adpressed between processes. Endophragm makes up the central body and periphragm alone made up the processes and outer mambrane. Processes are basically intratabular, about thirty to forty in number, and comprise two parts; large spherical proximal part and small spherical distal part, and apparently are lagenate to bullose. Another small spherical processes are sometimes distributed in both polar regions. Distal extremity of these large processes is flared and occasionally fused in adjacent ones. These elements form a outermost membrane in good preserved specimens except for both polar regions.

Paratabulation is represented by intratabular processes and archeopyle

as 6–7′, 0a(?), 8–10″, 0c, 9–13″′, 0p(?), 6–8″″. In apical and antapical areas, another extra small processes are sometimes present, but these may not reflect any large paraplate. Paracingulum does not possess any ornament and indicated by moderate space between rows of precingular and postcingular processes. Parasulcus may not be reflected by any feature. Archeopyle is a characteristic hypocystal type formed by loss of two to five antapical intercalary paraplates. The princeple archeopyle parasutures representing hypocystal paraplate boundaries are long rectangular and different from the antapical plates of the thecate form in shape. Opercula are basically detached.

Dimensions of figured specimen: Cyst diameter 72μm, length of processes 10.8μm, width of processes 6.8μm.

Remarks: *Tuberculodinium vancampoae* (Rossignol) is a quitely unique cyst in shape and different from all other modern cysts in its processes and hypocystal archeopyle.

Based on an incubation experiment, Wall and Dale (1971) clarified that *Tuberculodinium vancampoae* (Rossignol) is a cyst form of *Pyrophacus vancampoae* (Rossignol). But around South and West Japan the thecate forms of the genus *Pyrophacus* are identified only as *P. horologium* (Stein) and *P. steinii* (Schiller) in sensu of Wall and Dale (1971), and *P. vancampoae* (Rossignol) has never been known. Nevertheless the cyst form, *Tuberculodinium vancampoae* (Rossignol) is often found and common in innerbay sediments of those areas. Furthermore, based on incubation of living cysts, Matsuoka (1984) concluded that *Tuberculodinium vancampoae* (Rossignol) is not only the cyst form of *Pyrophacus vancampoae* (Rossignol) but also that of *P. steinii* (Schiller).

Ecological distribution in previous record:

Tropical-subtropical; estuarine (Wall et al. 1977).

Tropical to temperate; inner to outer neritic (Harland 1983).

Equivalent thecate form: *Pyrophacus steinii* (Schiller) by Wall and Dale (1971) and *Pyrophacus steinii vancampoae* (Rossignol) by Matsuoka (1984).

Order Peridiniales Taylor 1980 (Peridinioid cyst)

Family Peridiniaceae Ehrenberg 1832

Genus *Brigantedinium* Reid 1977

Type species; *Brigantedinium simplex* (Wall 1965) Reid 1977

= *Chytroeisphaeridia simplica* Wall 1965

Brigantedinium cariacoensis (Wall) Reid ex Harland and Reid 1980
Pl. 14, figs. 13, 14.

1967 *Chytroeisphaeridia cariacoensis* Wall, p. 113–114, pl. 16, figs. 13,14.
1967 *Peridinium avellana* (Meunier) Lebour ; Wall and Dale, pl. I, fig. 5.
1968 *Peridinium avellana* (Meunier) ; Wall and Dale, p. 277, pl. 3, fig. 29, pl. 4, figs. 1,2.
1968a Resting spore of *Peridinium* ? *denticulatum* Gran and Barrarud ; Wall and Dale, p. 277.
1968a Resting spore of *Peridinium punctulatum* Paulsen ; Wall and Dale, p. 276–277, pl. 2, fig. 27.
1976 Cyst of *Peridinium* cf. *P. avellana* (Meunier) ; Dale, pl. I, fig. 14.
1977 Cyst of *Protoperidinium avellana* (Meunier) ; Reid and Harland, pl. 1, fig. 20.
1977 *Brigantedinium cariacoense* (Wall) Reid, p. 434, pl. 1, fig. 2.
1977 *Brigantedinium cariacoensis* (Wall) Reid ; Harland, p. 104, pl. 3, figs. 10,11,13.
1982 *Protoperidinium (Archaeperidinium* sect. *Fuscusasphaeridium) avellana* (Meunier) Balech ; Harland, p. 373–374, text-fig. 6, 7B, pl. 38, figs. 4–9.
1982 *Protoperidinium (Archaeperidinium* sect. *Fuscusasphaeridium) denticulatum* (Gran and Braarud) Balech ; p. 376, text-figs. 7A, 10.
1982 *Protoperidinium (Protoperidinium* sect. *Asymmetroperidinium) punctulatum* (Paulsen) Balech 1974 ; Harland, p. 381–382, text-figs. 15–17, pl. 42, figs. 3–6.
1984 *Protoperidinium avellana* (Meunier) Balech ; Matsuoka, p. 38–39, pl. 2, figs. 5–7.

Description: Small chorate cyst is spherical in shape and dark brown in color. Cyst wall consists of one layer, the smooth autophragm only. Any ornamentation is not developed and does not indicate the paratabulation except for the archeopyle. Paracingulum is sometimes fairly reflected by shallow indentation of the autophragm. Intercalary archeopyle is hexagonal in shape with one arched side transversely extended, and formed by loss of the 1a or 2a paraplate.

Dimensions of figured specimen: Cyst diameter 30.4μm.

Remarks: This spherical and brown cyst is closely similar to *Brigantedinium simplex* in shape and color, but differs from the latter in possessing a hexagonal intercalary archeopyle. Especially, one arched side of the archeopyle is a diagnostic feature in this *Archaeperidinium* group. However, these cysts in poor preservation and / or before excystment can be indistinguishable from each other.

According to incubation experiments carried out by Wall and Dale (1968) and Matsuoka (1984), the thecate forms of these cysts are *Protoperidinium avellana* (Meunier), *Protop.* ? *denticulatum* (Gran and Braarud) or *Protop. punctulatum* (Paulsen).

Ecological distribution in previous record:

Cosmopolitan; estuarine to neritic as 'grouped *Peridinium* species' (Wall et al. 1977).

Temperate; inner neritic (Harland, 1983).

Equivalent thecate form: Probably *Protoperidinium (Archaeperidinium* sect. *Fuscusasphaeridium) avellana* (Meunier) Balech by Wall and Dale (1968) and Matsuoka (1984).

Brigantedinium majusculum Reid 1977
Pl. 15, figs. 1–4.

1977 *Brigantedinium majusculum* Reid, p. 434–435, pl. 1, fig. 5.
1983 *Brigantedinium majusculum* Reid; Dale, fig. 20.

Description: Intermediate cyst is spherical in shape, light brown in color, and consists of the autophragm, thin and smooth. Any feature reflecting paratabulation is not observed except for the archeopyle. Archeopyle is relatively large and hexagonal in shape, and probably is formed by loss of the anterior intercalary 2a paraplate.

Dimensions: Cyst diameter 50–68μm.

Remarks: This cyst is similar to *Brigantedinium simplex* (Wall) in shape, but differs from the latter in having a larger cyst body and larger hexagonal intercalary archeopyle. In practice, these three brown and spherical cysts belonging to the genus *Brigantedinium* is not distinguishable on each other in such case of poor preservation as splite, derformation and bad orientation at the observation.

Geographical distribution in previous record:

Around the British Isles (Reid 1977).

Equivalent thecate form: *Protoperidinium* sp. suggested by Dale (1983).

Brigantedinium simplex (Wall) Reid ex Harland and Reid 1980
Pl. 15, fig. 5.

1965 *Chytroeiphaeridia simplica* Wall, p. 308, figs. 7,20.

1968 *Peridinium conicoides* Paulsen ; Wall and Dale, p. 277, pl. 2, figs. 29,30, pl. 3, figs. 27,28.
1976 Cyst of *Peridinium conicoides* Paulsen ; Dale, pl. I, fig. 13.
1976 *Peridinium conicoides* Paulsen ; Matsuoka, p. 358–359, pl. II, figs. 5–9.
1977 *Brigantedinium simplex* (Wall) Reid, p. 435–436, pl. 1, figs. 3,4.
1977 *Brigantedinium simplex* (Wall) Reid ; Harland, p. 104–105, pl. 3, figs. 7–9, 12.
1977 Cyst of *Protoperidinium conicoides* (Paulsen) Balech ; Reid and Harland, pl. 1, fig. 16.
1980 *Brigantedinium simplex* (Wall) Reid ex Harland and Reid, p. 222–223.
1982 *Protoperidinium (Protoperidinium* sect. *Brigantedinium) conicoides* (Paulsen) Balech ; Harland, pp. 382, 383, text-fig. 18, pl. 38, figs. 1–3.

Description : Small and dark brown cyst is circular in polar view and broadly bean-shaped in lateral view. Epicyst is half-spherical, and hypocyst has two wide and round antapical bosses. Cyst wall consists of the smooth autophragm only. Except for the archeopyle, paratabulation is not reflected by any feature. Paracingulum is sometimes indicated by shallow indentation of the autophragm transversely extended on dorsal side. Parasulcal area is suggested by broad indentation, in which two small pores are developed. The pore in posterior site may be the longitudinal flagellar one and anterior site is probably correspond with the transverse flagellar one at the motile stage. Intercalary archeopyle appears a large trapezoidal shape and derived from loss of the 2a paraplate. Operculum is sometimes detached and traped within the cyst body.

Dimensions : Cyst diameter 36.8–50μm.

Remarks : In the only case of well preservation, this cyst differs from *Brigantedinium cariacoensis* (Wall) in having broadly bean-shaped cyst and trapezoidal archeopyle.

The present specimens are somewhat larger than those of Hachinohe Coast in cyst diameter reported by Matsuoka (1976).

The cysts included in the thecate cells have been often found in the plankton assemblage off the Woods Hole region (Wall and Dale 1968) and Hachinohe, northeast Japan (Matsuoka, 1976).

Ecological distribution in provious record :

Cosmopolitan : estuarine to neritic as 'grouped *Peridinium* species' (Wall et al. 1977).

Temperate ; inner neritic (Harland, 1983).

Equivalent thecate form : *Protoperidinium (Protoperidinium* sect. *Brigantedinium) conicoides* (Paulsen) Balech by Wall and Dale (1968).

Genus *Selenopemphix* Benedek 1972 emend. Bujak 1980

Type species : *Selenopemphix nephroides* Benedek 1972

Remarks: Bujak (in Bujak et al., 1980) emended the diagnosis of this genus and replaced some spinate specis such as *S. urmuta* and *S. coronata,* and pointed out that modern cyst genus *Multispinula* is probably synonymous with the fossil genus *Selenopemphix* in having a cyst body antero-posteriorly compressed and the intercalary archeopyle corresponding to the 2a paraplate which are offseted from the dorsal midline. After that, Harland (1982) established a new section *Selenopemphix* in the modern genus *Protoperidinium* in reviewing Recent and Quaternary *Protoperidinium* cysts.

Selenopemphix quanta (Bradford) comb. nov.

Pl. 11, figs. 1–9.

1965 *Perdinium* sp. (Cyst-form 6) Wall, p. 308, figs. 17, 23.
1968 Resting spore of *Peridinium conicum* (Gran) Ostenfeld and Schmidt ; Wall and Dale, p. 273–274, pl. 2, figs. 4,5.
1968 Resting spore of *Peridinium nudum* Meunier ; Wall and Dale, p. 227–228, pl. 4, fig. 5.
1975 *Multispinula quanta* Bradford, p. 3067–3070, figs. 5–7.
1976 Cyst of *Peridinium conicum* (Gran) ; Dale, pl. I, fig. 17.
1977 *Multispinula quanta* Bradford ; Reid, p. 448–449, pl. 3, figs. 30–33.
1977 *Multispinulosa quanta* Bradford ; Harland, p. 106, pl. 3, fig. 14, pl. 4, figs. 18,19.
1977 *Multispinula quanta* Bradford ; Reid and Harland, pl. 1, fig. 19.
1980 *Multispinula quanta* Bradford ex Harland and Reid, p. 223.
1980 *Protoperidinium conicum* (Gran) Balech ; Fukuyo, No. 59, figs. G,H.
1982 *Protoperidinium (Protoperidinium* sect. *Selenopemphix) conicum* (Gran) Balech ; Harland, p. 384–385, text-fig. 19, pl. 39, figs. 1–3, pl. 42, figs. 1,10.
1984 *Protoperidinium (Protoperidinium* sect. *Selenopemphix) conicum* (Gran) Balech ; Bradford and Wall, p. 48, pl. 21, fig. 12.

Description: Cyst is usually flattened antero-posteriorly and shows a broad bean shape in polar view. Strongly convex epicyst has a small but distinctive apical horn with some spinous processes. Hypocyst possesses two small antapical bosses. Paracingulum is indicated by two raws of processes and the parasulcus is represented by a shallow indentation. Processes are spinous and slightly flexuous and basically makes a parasutural

distribution. Six rows of processes are apparently developed in lateral view. The most upper row marks a boundary between apical and anterior intercalary paraplate series. The next upper row probably indicates a boundary between anterior intercalary and precingular paraplate series. The two rows in the equatorial part make the paracingulum. Two rows or cluster of processes developed in the hypocyst may indicate two antapical bosses. Archeopyle is roundly and broadly hexagonal in shape and is formed by loss of the 2a paraplate, and it is clearly distributed asymmetrically from the dorsal midline.

Dimensions: Length of cyst 22–25.6μm, width 38–42.8μm length of processes ca. 15μm, width of paracingulum ca. 4.5μm.

Remarks: Usually most specimens recovered from the samples are more or less deformed and damaged, and lateral view of this cyst rarely encountered. Therefore, we hardly observe six rows of processes and the strongly convex epicyst.

Kobayashi and Matsuoka (1984) recognized two morphotypes of the cyst in *Protoperidinium conicum* (Gran) from surface sediments of Omura Bay. The present cysts consist of only type A of them. Another cyst, type B, characterized heptagonal outline in equatorial view is not found in any sample of Nagasaki Bay and Senzaki Bay.

Ecological distribution in previous record:

Cosmopolitan; estuarine to neritic (Wall et al. 1977).

Tropical; outer neritic, and temperate; inner to outer neritic (Harland, 1983).

Equivalent thecate form: *Protoperidinium (Protoperidinium* sect. *Selenopemphix) conicum* (Gran) Balech by Wall and Dale (1968) and Kobayashi and Matsuoka (1984).

Selenopemphix alticinctum (Bradford) comb. nov.
Pl. 15, figs. 6–10.

1968 Resting spore of *Peridinium subinerme* Paulsen; Wall and Dale, p. 276, pl. 2, figs. 22–24.

1975 *Omanodinium alticinctum* Bradford, p. 3070–3072, figs. 23–28.

1979 Cyst of *Protoperidinium subinerme* (Paulsen) Loeblich, III; Harland, pl. 1, fig. 16.

1980 *Omanodinium alticinctum* Bradford ex Harland and Reid, p. 223.

1982 *Protoperidinium (Protoperidinium* sect. *Selenopemphix) subinerme* (Paulsen) Loeblich, III; Harland, p. 398, text-fig. 23, pl. 39, fig. 6.

1984 *Protoperidinium (Protoperidinium* sect. *Selenopemphix) subinerme* (Paulsen) Loeblich, III ; Bradford and Wall, p. 49, pl. 2, figs. 13,17.

Description: Chorate cyst is intermediate in size, light brown in color and is somewhat compressed antero-posteriorly. Outline of cyst is nearly circular to roundly cordate in polar view. Cyst wall consists of the smooth to slightly wrinkled autophragm. Epicyst is broadly conical with a small apical boss and hypocyst is a trapezoidal shape in dorso-ventral view without distinctive antapical horns.

Paratabulation is not reflected by any feature except for the archeopyle. Paracingulum is clearly indicated by extension of the autophragm transversely surrounding the cyst body. Lists of the paracingulum extension is roughly denticulate. Parasulcal area is also distinctively represented by clear indentation of the autophragm. Intercalary archeopyle is hexagonal and derived from loss of the 2a paraplate, and are probably offseted from the dorsal midline.

Dimensions of figured specimen: Width of cyst 50μm.

Remarks: This cyst is characterized by a body somewhat compressed antero-posteriorly and a well developed paracingulum. The present specimens have a slightly wrinkled surface of the autophragm.

Bujak (in Bujak et al. 1980) suggested that this species might be assignable to the fossil genus *Solenopemphix* based on the cyst shape. Bujak (1984) pointed out that the present specis may be conspecific with a fossil species, *S. nephroides* Benedek.

Ecological distribution in previous record:

Temperate; inner neritic (Harland, 1983).

Equivalent thecate form: *Protoperidinium subinerme* (Paulsen) Balech by Wall and Dale (1968).

Genus *Multispinula* Bradford 1975

Remarks: The type species of this genus formerly designated are transfered to the fossil genus *Selenopemphix*. Therefore, another species of this genus should be selected as the generotype, but there is no species which is fit for this genus at the present.

Multispinula? *minuta* Reid and Harland 1980

Pl. 17, figs. 13, 14.

1977 Dinoflagellate cyst E Reid and Harland, pl. 2, fig. 11.

1980 ?*Multispinula minuta* Harland and Reid in Harland et al. p. 216,218, fig. 2 M–O.

Description: Small chorate cyst is subsperical in shape and pale brown in color. Cyst wall comprises the smooth autophragm only, and covered with numerous and nontabular processes. These processes are short, slender flexuous and tapering with aculeate distal extremity. Paratabulation does not indicated by any ornamentation and archeopyle. Paracingulum and parasulcus are not represented by any feature. Archeopyle is a probably chasmic type, but exactly unknown.

Dimensions: Cyst diameter 31.6–33.2μm, length of processes 3–4μm.

Remarks: *Multispinula*? *minuta* resembles Dinoflagellate cyst type B described in this paper, but differs from the latter and other spherical and brown cysts in having aculeate processes.

The spherical and brown cysts with numerous slender processes are known as acritarch forms. Some of them are cysts of the small *Peridinium* and nacked dinoflagellates according to incubation experiments carried out by Dale (1977), Fukuyo (1982) and Matsuoka (in press). The motile form of this cyst has been not known, but possibly is assignable to nacked dinoflagellates.

Geographical distribution in previous record:

Beaufort Sea by Harland and Reid in Harland et al. (1980).

Equivalent thecate form: Unknown; but possibily correspond to the gymnodinialean species.

Genus *Trinovantedinium* Reid 1977 emend. Bujak 1984

Type species: *Trinovantedinium capitatum* Reid 1977

Trinovantedinium capitatum Reid

Pl. 9, figs. 1–6; Pl. 10, figs. 1–6.

1908 Bestachelte cysts Paulsen, pl. 11, fig. 8.

1968 Resting spore of *Peridinium pentagonum* Gran; Wall and Dale, p. 274–275, pl. 2, figs. 11–12.

1968 Resting spore of *Peridinium* sp. cf. *P. pentagonum* Gran; Wall and Dale, p. 274–275, p. 2, figs. 11,12.

1975 ?Cyst of *Peridinium* sp. I, Davey and Rogers, pl. 1, fig. 12.

1976 Cyst of *Peridinium pentagonum* Gran; Dale, pl. I, fig. 15.

1976 *Peridinium* sp. aff. *P. pentagonum* Gran; Matsuoka, p. 361, pl. III, fig. 8.

1977 *Trinovantedinium capitatum* Reid, p. 437–438, pl. 1, figs. 6–8.

1977 *Lejeunia applanata* Bradford, p. 47–49, fig. 2 ; 1–8.

1977 *Trinovantedinium capitatum* Reid ; Harland, p. 108–109, pl. 3, figs. 15,16.

1977 Cyst of *Protoperidinium pentagonum* (Gran) Balech ; Reid and Harland, pl. 1, fig. 17.

1982b *Protoperidinium pentagonum* (Gran) Balech ; Matsuoka, No. 108, figs. C,D.

1982 *Protoperidinium (Protoperidinium* sect. *Trinovantedinium) pentagonum* (Gran) Balech ; Harland, p. 386, text-fig. 22, pl. 39, figs. 7–11, pl. 42, fig. 8.

1984 *Protoperidinium (Protoperidinium* sect. *Trinovantedinium) pentagonum* (Gran) Balech ; Bradford and Wall, p. 48–49, pl. 2, figs. 4, 7, 14.

Description : Cyst shows a pentagonal and elongate peridinioid-shape with clearly defined paracingulum and parasulcus. Epicyst is triangular in dorso-ventral view with a short but distinctive apical boss. Trapezoidal hypocyst provides with two symmetrical antapical horns. Processes are numerous and short, acuminate but occasionally capitate or bifid. The distribution of processes is basically intratabular as seen in Pl. 9, figs. 1,2 but sutural processes are observed in the paracingular zone. Paracingulum is indicated by two sutural rows of these short processes and is hardly displaced at the ventral area. Parasulcus is reflected by indentation of the autophragm. Two pores, probably both of transverse and longitudinal flagellar pores at the motile stage, are occasionally observed in the sulcul area. Archeopyle is large and intercalary with four long sided and two very short sided archeopyle parasutures, and is formed by displacement of the 2a paraplate.

Dimensions : Length of cyst 74.4–100.8μm, width 68–87.6μm, length of processes 3.2–5.2μm, width of paracingulum 4.8–6.8μm.

Remarks : Variation within this species appears to be wide in cyst shape. The outline of the epicyst varies from convex to straight, and sometimes has a small shoulder. While, the hypocyst shows a converstraight to concave-trapezoid in shape.

Wall and Dale (1968) reported two cyst types, *Peridinium pentagonum* (Gran) and *P.* sp. of. P. *pentagonum* (Gran), but these two may show the individual variation and may be included in the single species.

Ecological distribution in previous record:

Cosmopolitan ; estuarine to neritic (Wall et al. 1977).

Temperate ; inner to outer neritic (Harland, 1983).

Equivalent thecate form: *Protoperidinium (Protoperidinium* sect. *Trinovantedinium) pentagonum* (Gran) Balech by Wall and Dale (1968).

Genus *Quinquecuspis* Harland 1977

Type species ; *Quinquecuspis concretum* (Reid 1977) Harland 1977
= ?*Trinovantedinium concretum* Reid 1977

Remarks: Bujak (1984) suggested that this genus may be synonymous with *Lejeunicysta,* but this is characterized by more indentation of both paracingulum and parasulcus, and by well developed antapical horns.

Quinquecuspis concretum (Reid) Harland 1977

Pl. 12, figs. 3–8, Pl. 13, figs. 1–4.

1964 ?*Peridinium leonis* Pavillard ; Evitt and Davidson, p. 5–7, pl. 1, fig. 9, text-fig. 1.
1968 Resting spore of *Peridinium leonis* Pavillard ; Wall and Dale, p. 276, pl. 2, 18–21.
1971 Cyst of *Peridinium leonis* Pavillard ; Wall, pl. 2, fig. 13.
1976 *Peridinium leonis* Pavillard ; Matsuoka, p. 359–360, pl. III, fig. 9.
1977 ?*Trinovantedinium concretum* Reid, p. 438–439, pl. 1, figs. 9–11.
1977 Cyst of *Protoperidinium* cf. *P. leonis* (Pavillard) Balech ; Reid and Harland, pl. 1, fig. 15.
1977 *Quinquecuspis concretum* (Reid) Harland, p. 107, pl. 3, figs. 1–6, 17–20.
1982 *Protoperidinium (Protoperidinium* sect. *Quinquecuspis) leonis* (Pavillard) Balech ; Harland, p. 385, text-fig. 20, pl. 41, figs. 1–14, pl. 42, figs. 7, 9.

Description: Cyst consists of the autophragm, sometimes with rough longitudinal striation and pale brown in color, and shows a pentagonal shape in dorso-ventral view. Epicyst is broadly conical with a small apical boss and hypocyst is triangular to trapezoidal in equatorial view with two distinctive and symmetrical antapical horns. The extremities of these horns are thicken and acuminate. The line between both antapical horns are strongely concave. Paracingulum and parasulcus are occasionally indicated by indentation of the autophragm. Intercalary archeopyle is apparently large trapezoidal but basically hexagonal in shape and is formed by loss of the 2a paraplate.

Dimensions: Length of cyst 54.4–77.2μm, width 51.2–74μm.

Remarks: This cyst shows a wide variation in general shape. The outline varies from somewhat convex through straight to concave shape. Two well developed antapical horns and apparently triangular, but the trapezoidal archeopyle characterize this cyst.

Ecological distribution in previous record:

Tropical to temperate; inner to outer neritic (Harland, 1983).

Equivalent thecate form: *Protoperidinium (Protoperidinium* sect. *Quinquecuspis) leonis* (Pavillard) Balech by Wall and Dale (1968).

Genus *Votadinium* Reid 1977

Type species: *Votadinium calvum* Reid 1977

Votadinium calvum Reid 1977

Pl. 12, figs. 1, 2.

1966 *Peridinium* sp. (Cyst-form 4) Wall, p. 307, text-figs. 14, 15, 22.
1966 *Peridinium oblongum* (Aurivillius) Paulsen; Wall and Dale, figs. 5, 6.
1968 Cordate resting spore of *Peridinium oblongum* (Aurivillius) Paulsen; Wall and Dale, pl. 272–273, pl. 1, figs. 25–28.
1975 Cyst of *Peridinium oblongum* (Aurivillius); Davey and Rogers, pl. 1, fig. 11.
1976 *Peridinium oblongum* (Aurivillius); Matsuoka, p. 560; pl. III, figs. 2,3, pl. IV, figs. 4,5.
1977 *Votadinium calvum* Reid, p. 444–445, pl. 2, figs. 21–23.
1977 ?*Votadinium calvum* Reid; Harland, p. 109, pl. 3, fig. 21.
1982 *Protoperidinium (Protoperidinium* sect. *Votadinium) oblongum* (Aurivillius) Balech; Harland, p. 380–381, text-fig. 14, pl. 40, figs. 10–12.

Description: Large to intermediate cyst is roundly peridinioid in shape and brown in color. Cyst wall comprises the smooth autophragm only. Epicyst is half-spherical in shape and carries a round apical boss. Hypocyst is roundly trapezoidal with two broad and symmetrical antapical bosses which are slightly thickened at the ends. Paracingulum is rarely reflected by shallow indentation. Parasulcus is broadly indented and sometime possesses two small pores which probably represent two flagellar pores at the motil stage. Archeopyle is basically intercalary and often includes not only anterior intercalary, 2a, but also some apical paraplates. But apical boss remained usually on the ventral side.

Dimensions: Length of cyst 68–76μm width of cyst 76–88μm.

Remarks: This cyst is apparently similar to round specimens of *Quinquecuspis concretum* (Reid) in having a peridinioid cyst body. But the former differs from the latter in possessing smooth cyst wall, relatively large intercalary archeopyle and two more round antapical bosses.

Based on incubation experiments, Wall and Dale (1968) reported three different types in the cyst of *Protoperidinium oblongum* (Aurivillius).

Among them, the present specimens are correspond with their third type, which is characterized by very broadly rounded apex and a cordate outline in dorsal view.

In Nagasaki Bay, their first type is rarely found in surface sediments.

Ecological distribution in previous record:

Temperate; inner neritic (Harland, 1983).

Equivalent thecate form: *Protoperidinium oblongum* (Aurivillus) Balech by Wall and Dale (1968).

Votadinium spinosum Reid 1977
Pl. 14, figs. 1–6.

1965 *Peridinium* sp. (Cyst-form 5) Wall, p. 307, fig. 16.

1968 Resting spore of *Peridinium claudicans* Paulsen; Wall and Dale, p. 273, pl. 2, figs. 1,2.

1971 Cyst of *Peridinium claudicans* Paulsen; Wall, pl. 2, fig. 12.

1977 *Votadinium spinosum* Reid, p. 445–446, pl. 2, figs. 24–26.

1982 *Protoperidinium (Protoperidinium* sect. *Votadinium) claudinans* (Paulsen) Balech Harland, p. 380, text-fig. 13.

Description: Intermediate cyst is nearly circular to cordate in dorsal view and light brown in color. Cyst wall consists of the relatively thin autophragm only. Epicyst shows a half circular shape in frontal view without any apical boss. Hypocyst is roundly trapezoidal and also lacks any conspicuous antapical horn. Cyst body is compressed dorso-ventraly and densely covered with nontabular, numerous, short and erect to curved processes with a circular distal extremities. Paratabulation is not indicated by any feature except for the archeopyle. Paracingulum is not reflected by any ornamentation, but parasulcus is represented by shallow indentation of the autophragm. Archeopyle is a large intercalary type probably including a few apical paraplates sometimes. Operculum is basically free.

Dimensions: Length of cyst 56μm, length of processes 5.2–6μm.

Remarks: This cyst is a characteristic species in having nearly circular to cordate cyst body covered with many spinous processes. The present specimens lack any distinctive antapical horn and so the cyst body is nearly circular in dorso-ventral view, but the specimens recovered by Wall and Dale (1968) bear two broadly rounded antapical lobes. This difference seems to be an intraspecific variation.

Ecological distribution in previous record:

Temperate; inner neritic (Harland, 1983).

Equivalent thecate form: *Protoperidinium (Protoperidinium* sect. *Votadinium) claudicans* (Paulsen) Balech by Wall and Dale (1968).

Genus *Stelladinium* Bradford 1975

Type species: *Stelladinium reidii* Bradford 1975

Stelladinium abei n. sp.

Pl. 14, figs. 7–10.

Diagnosis: Cyst with pentagonal ambitus, small to intermediate in size and brown in color. Epicyst conical with one apical horn. Hypocyst rectangular with two antapical horns. Paracingulum represented by projection of autophragm.

"Cystae proximae quae habent ambitum pentagonalem dorsoventraliter sunt parvae vel intermediae in magnitudine et brunneae in colore. Epitractum est conicale cum uno cornu apicali. Hypotractum quod habet duo cornua in antapice est rectangulare. Paracingulum repraesentatur proiectione autophragmatis. Archeopyla est intercalaris. Tabulatio abest."

Holotype: Slide no. SZ 1a–3 (81.5/34.2), Pl. 14, figs. 7–10, Sample no. SZ 1a, Recent sediment in Senzaki Bay, West Japan.

Dimensions of figured specimen: Length of cyst 40μm, width 44μm.

Description: Cyst is peridinioid in dorso-ventral view, and carries one conspicuous apical and two symmetrical and conical antapical horns. Cyst body is compressed dorso-ventrally except for the paracingular region. Cyst wall comprises two thin layers, much adpressed autophragm with microgranular to smooth surface. Paratabulation is not indicated by any feature. Paracingulum lacks any horn-like projection and represented by projected shelf of the autophragm, transversely surrounding the cyst body. Parasulcal area is suggested by moderate indentation of the autophragm. Archeopyle is apparently trapezoidal exactly with four long and two short sides, and formed by loss of the 2a paraplate. Operculum is probably free.

Remarks: This new cyst is similar to *Stelladinium stellatum* Reid and *S. reidii* Bradford in having a pentagonal ambitus and conspicuous one apical and two antapical horns. This cyst, however, differs from the latter two in lacking distinctive horns positioned at the cingular zone and a trapezoidal hypocyst.

Equivalent thecate form: The thecal affinity of this cyst has been unknown, but probably correspond with a species of the genus *Protoperidinium*.

Genus *Protoperidinium* Berg emend. Balech 1974

Type species: *Protoperidinium pellucidum* Berg 1881

Protoperidinium latissinum (Kofoid) Balech 1974

Pl. 13, figs. 7, 8.

1968 Resting spore of *Peridinium latissinum* Kofoid; Wall and Dale, p. 274, pl. 2, fig. 7.

1982 *Protoperidinium (Protoperidinium* sect. *Protoperidinium) latissinum* (Kofoid) Balech; Harland, p. 378, 380.

Description: Large to intermediate proximate cyst is romboidal in shape and light brown in color. Cyst wall consists of the smooth autophragm only. Epicyst is isoscelles triangular with a conical apical horn. Hypocyst is also nearly isoscelles triangular except for the antapical area. Paracingulum is reflected by indentation of the autophragm. Two distinctive antapical horns are broadly conical in shape and symmetrical. Archeopyle is basically hexagonal with two very short sides and therefore, shows a trapezoidal shape apparently. Operculum is detached.

Dimensions of figured specimen: Length of cyst 102μm, width 80μm.

Remarks: This cyst resembles *Quinquecuspis concretum* [= cyst of *Protoperidinium leonis* (Pavillard)] in having a smooth and brown autophragm and two conspicuous antapical horns. The former, however, differs from the latter in possessing a nearly triangular hypocyst and two broadly conical antapical horns. In variation, this cyst ranges from strongly concave (for example in Wall and Dale, 1968, pl. 2, fig. 7) to nearly straight (present specimen) in shape.

This cyst has not been named in paleontological sensu.

Ecological distribution: Warm temperate.

Equivalent thecate form: *Protoperidinium latissinum* (Kofoid) Balech.

Harland (1982) regarded this species belonging to the Para-Hexa group, and based on this evidense, he erected a new section *Protoperidinium* stat. nov. As the result, only this species in the Para-Hexa group is known to produce a resting cyst. But Taylor (1976) already pointed out that the first

apical plate of *Protop. latissinum* (Kofoid) varies in "ortho", "meta" and "para" forms owing to the shifting of sutures by only a few microns. These variations have been also observed in unialgal culture of living cysts by Matsuoka and Kobayashi (unpublished data). And the cyst morphology between this and similar species such as *Protop. leonis* (Pavillard) is not so different. Therefore, based upon these evidences, *Protop. latissinum* should be basically assignable to the Ortho-Hexa group.

Order Gymnodiniales Lemmermann 1910 (Gymnodinioid cyst)

Family Polykrikaceae Kofoid and Swezy 1921

Genus *Polykrikos* Bütschli 1873

Type species: *Polykrikos schwartzii* Bütschli 1873

Polykrikos schwartzii Bütschli 1873

Pl. 16, figs. 4–10.

1887 Umrindete cysts Hensen, p. 80, pl. 4, figs. 32a, b, pl. 6, figs. 67–68.
1968 ?Resting spore of naked dinoflagellate Wall and Dale, p. 281, pl. 4, fig. 28.
1977 Cyst of *Polykrikos* sp. 1 Reid and Harland, pl. 2, figs. 1–3.
1977 *Polykrikos* cysts Harland, p. 109–110, pl. 4, figs. 1–6.
1978 Resting cyst of *Polykrikos schwartzii* Bütschli; Reid, p. 227, pl. 1, figs. 1–9.
1981 Cyst of *Polykrikos schwartzii* Bütschli; Harland, 78–79, pl. 1, figs. 1–9, pl. 2, figs. 1–9, pl. 3, figs. 1–4, pl. 4, figs. 1–6, text-figs. 2, 6–8.
1982 Cyst of *Polykrikos schwartzii* Bütschli; Matsuoka, pl. 2, fig. 14.
1982 Cyst of *Polykrikos kofoidii* Chatton; Fukuyo, p. 208–209, pl. 4, figs. 1–3.

Description: Elongate proximate cyst is brown in color. Cyst wall comprises two or three layers adpressed between ornamentations. Periphragm is strongly fibrous, and its surface apparently shows a fibro-pitted structure between ornamentations. Periphragm also makes a muri structure and this structure indicates a network system. Meches making up of the network varies from large to small in size, and at the sulcul area, they become smaller and irregular in shape. Basically, seven transverse series composed of the network exist. Archeopyle is a tremic type formed at the polar end, probably apical area. Operculum is fundamentally detached.

Dimensions: Length of cyst 30–58.4μm, width 20–40μm, height of ornamentations 4–9.2μm.

Remarks: According to Harland (1981), this cyst has an apical archeo-

pyle, but the marginal line of the opening does not indicate any regularity which reflects the boundary between apical and precingular or anterior intercalary paraplates. Therefore, the opening of this cyst is not the apical archeopyle but another type. Matsuoka (in press) names a tremic archeopyle to this opening type.

Fukuyo (1982) reported that this cyst is assignable to *Polykrikos kofoidii* Chatton based on the incubation experiment. On the other hand, during the incubation, Morey-Geins and Ruse (1980) showed another different cyst type of *P. kofoidii,* which is covered with large, hollow and spinous processes.

The morphological character of both motile forms shown by Morey-Geins and Ruse, and Fukuyo is common to each other. It is the future problem which type is the cyst of *Polykrikos schwartzii.*

Ecological distribution in previous record:

Temperate; inner neritic (Harland, 1983).

Polykrikos sp. cf. *kofoidii* Chatton 1914

Pl. 16, figs. 1–3.

1980 Cyst of *Polykrikos kofoidi* Chatton; Morey-Gains and Ruse, p. 230–231, fig. 4.

1982 Cyst type PS-1 Fukuyo, p. 209, pl. IV, figs. 7–8.

non 1982 Cyst of *Polykrikos kofoidii* Chatton: Fukuyo, p. 208–209, pl. IV, figs. 1–3.

Description: Intermediate proximate cyst is elongate in shape and light brown in color. Cyst wall comprises of two layers, the endophragm and the periphragm adpressed between processes or shelf-like ornamentations. Endophragm is smooth and relatively thick, and periphragm is strongly fibrous, clearly wrinkled near proximal base of processes or shelf-like ornamentations, and forms processes and / or shelf-like ornamentations transversely developed. Processes are strongly fibrous and tubiform to buccinate with irreguraly patulate distal extremities. Shelf-like ornamentations are also fibrous and are formed by transverse connection of two or more adjacent processes. Five rows of processes or shelf-like ornamentations are transversely developed.

The middle row of them may reflect the paracingulum. Except for these ornamentations, no feature represents any paratabulation and parasulcus. Archeopyle is a tremic type formed at the polar end, probably apical area. Operculum is basically free.

Dimension of figured specimen: Length of cyst 52μm, width 40μm, height of processes or shelf-like ornamentation ca. 10μm.

Remarks: This cyst is similar to the cyst of *Polykrikos schwartzii,* but differs from the latter in having processes or shelf-like ornamentations, and is also different from the cyst of *P. kofoidii* Chatton shown by Morey-Gains and Ruse (1980) in having not short cylindrical processes but shelf-like ornamentations. But according to the tremic archeopyle and the nature of cyst wall, this cyst may be closely related with a cyst of the genus *Polykrikos*.

Genus *Pheopolykrikos* Chatton 1933

Type species : *Pheopolykrikos beauchampii* Chatton 1933
= *Polykrikos beauchampii* (Chatton) Loeblich 1980

Pheopolykrikos hartmannii (Zimmermann) Matsuoka and Fukuyo 1985

Pl. 17, figs. 1–4.

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

Description: Small to intermediate cyst is spherical in shape and light to pale brown in color. Cyst wall consists of the thin and granular periphragm and the smooth endopragm, strongly adpressed between processes. Processes are hollow, short and conical in shape with acuminate distal extremities. At proximal base of processes, several clear striations are well developed. The distribution of processes is completely nontabular. Archeopyle is a chasmic type and is probably formed at median zone of the cyst.

Dimensions: Cyst diameter 50–56μm, length of processes ca. 7μm.

Remarks: The spherical dinoflagellate cysts provided with many processes have been known in such species as *Operculodinium centrocarpum* (Deflandre and Cookson), *Lingulodinium machaerophrum* (Deflandre and Cookson) and *Multispinula* ? *minuta* Harland and Reid. Especially the present cyst is closely similar to *M.* ? *minuta* in being brown in color and having slender acuminate processes. But the former differs from the latter in having short conical processes with several striations at proximal base

and a characteristic split archeopyle.

Most specimens recovered from surface sediments are much deformed and do not show a complete spherical shape, because of its thin and weak cyst wall. The cyst filled with protoplasts including a few red pigmented bodies is usually surrouded by fine sediment particles held between processes.

Geographical distribution in previous record:

Southern part of Harimanada, Seto Inland Sea by Fukuyo (1982) and Omura Bay by Matsuoka (1982).

Genus *Gyrodinium* Kofoid and Swezy 1921

Type species: *Gyrodinium spirale* (Berg) Kofoid and Swezy 1921

Gyrodinium instriatum Freudental and Lee 1963

Pl. 16, figs. 11, 12.

1982 Cyst of *Gyrodinium instriatum* Frudental and Lee; Fukuyo, p. 206–207, pl. 1, figs. 1–6.

1985 *Gyrodinium instriatum* Frudental and Lee; Matsuoka, pl. 3, fig. 5, Fig. 1c.

Description: Elleptical to ovoidal cyst is small to intermediate. Cyst wall consists of the relatively thick and transparent autophragm, and is not covered with any ornamentation. Archeopyle is a tremic type with circular margin completely detached, and is formed at the polar end.

Dimensions of figured specimen: Length of cyst 32.8μm, width 30μm.

Remarks: The cyst filled with protoplasts is surrounded by transparent adhesive materials provided with fine silicate particles and fragments of diatoms and silicoflagellates. But after chemical treatment, these materials was dissolved and diappeared.

Before excystment the cyst of *Gyrodinium instriatum* closely resemble the cyst of *Protogonyaulax catenella* (Whedon and Kofoid) and *Protog. tamarensis* (Lebour) in having ellipsoidal cyst body and a transparent adhesive material. But the former differs from the latter two in possessing a circular archeopyle and a somewhat ovoidal cyst body after germination.

Geographical distribution in previous record:

Southern part of Harimanada, Seto Inland Sea by Fukuyo (1982).

Lineage indet.

Dinoflagellate cyst type A
Pl. 15, fig. 11.

1982 Cyst of *Diplopsalis* sp. ? Matsuoka, pl. 2, fig. 11.

Description: Small proximate cyst is probably spherical in shape and brown in color. Cyst wall consists of the smooth autophragm only. Processes are probably nontabular, long conical, hollow, flexuous and curved with acuminate distal extremities. Any feature and ornamentation do not represent the paracingulum, parasulcus and paratabulation. Archeopyle is unclear but probably a chasmic type with some zigzag archeopyle sutures.

Dimensions of figured specimen: Cyst diameter 38μm, length of processes ca. 6μm.

Remarks: This cyst resembles the cyst of *Protoperidinium minutum* (Kofoid) described by Fukuyo et al. (1977), but differs from the latter in having a chasmic archeopyle. This cyst is also similar to Dinoflagellate cyst type D described here in possessing a brownish cyst body covered with processes, but different from the latter in bearing long conical with acuminate distal extremities.

Equivalent thecate form: Based on the archeopyle type and the nature of cyst body, this cyst may belong to the Diplopsalinae (Matsuoka, unpublished data).

Dinoflagellate cyst type B
Pl. 14, figs. 11, 12.

Description: Small proximate cyst is spherical in shape and light brown in color. Cyst wall consists of the finely granular autophragm only. No ornamentation such as processes is present, and nothing reflects the paracingulum. Parasulcus is represented by indentation of the autophragm. Archeopyle is broadly hexagonal in shape and probably formed by loss of the 2a paraplate. Operculum is free.

Dimensions of figured specimen: Cyst diameter 35μm.

Remarks: The archeopyle of this species does not directly contact with the equatorial region which is probably regared as the paracingulum. Based on this and its hexagonal shape, this cyst has an intercalary archeo-

pyle. Therefore, this cyst may be assignable to the motile genus *Protoperidinium*.

Equivalent thecate form: Unknown, but probably a species belonging to the Hexa-type group of the genus *Protoperidinium*.

Dinoflagellate cyst type C
Pl. 17, figs. 7–12.

Description: Small chorate cyst is spherical to ovoidal in shape and light brown in color. Cyst wall consists of the autophragm with two thin layers much adpressed between processes. This phragm is smooth to finely granular and forming processes. Processes are slender and very short conical with acuminate distal extremities, and sporadic in distribution. Process arrangement is probably intratabular, but appears random in poorly preserved specimens. Paracingulum is rarely indicated by row of processes beneth the archeopyle in dorsal side. Archeopyle is probably trapezoidal in shape. Operculum is free.

Dimentions: Cyst diameter 28.8–36.4μm, length of processes ca. 3μm.

Remarks: Owing to its trapezoidal archeopyle and spherical cyst body with simple processes, this cyst species resembles *Operculodinium centrocarpum* (Deflandre and Cookson) and *O. israelianum* (Rossignol), but differs from the latter two in bearing a light brown and small cyst body, and a thin and smooth autophragm.

Equivalent thecate form: According to the nature of cyst wall and the archeopyle shape, this cyst may be assignable to the genus *Protoperidinium*.

Dinoflagellate cyst type D
Pl. 17, figs. 5, 6.

Description: Proximate cyst is small in size and probably subspherical in shape. Cyst wall is pale to light brown in color and consists of the smooth autophragm only. Processes covere with the cyst body and are apparently nontabular, hollow, long subconical with truncated distal extremities. Any feature and ornamentation do not define the paracingulum and parasulcus. Paratabulation is not represented, too. Archeopyle may be a long chasmic type, probably running along the meridional zone.

Dimensions: Cyst diameter 35–39.5μm, length of processes 9.5–14μm.

Remarks: This cyst also apparently resembles *Operculodinium centro-*

carpum (Deflandre and Cookson), but differs from the latter in having brownish cyst body with long subconical processes. The original shape of this cyst is supposed to be spherical to subspherical, but most recovered specimens have been damaged and deformed.

Equivalent thecate form: According to the nature of cyst wall and the archeopyle type, this cyst may be assignable to the Peridiniaceae, but no further information is currently avairable.

Dinoflagellate cyst type E
Pl. 16, figs. 13–14.

1982 Cyst of *Peridinium* sp. Matsuoka, pl. 1, fig. 9.

Description: Small proximo-chorate cyst is spherical in shape, light brown in color and is covered with numerous, nontabular and simple processes. Cyst wall may consist of two thin layers strongly adpressed between processes. Processes are long and needle-like with acuminate distal tips. Any ornamentation does not reflect the paracingulum and parasulcus. Archeopyle is a chasmic type with slightly zigzag archeopyle sutures.

Dimentions of figured specimen: Cyst diameter 36μm.

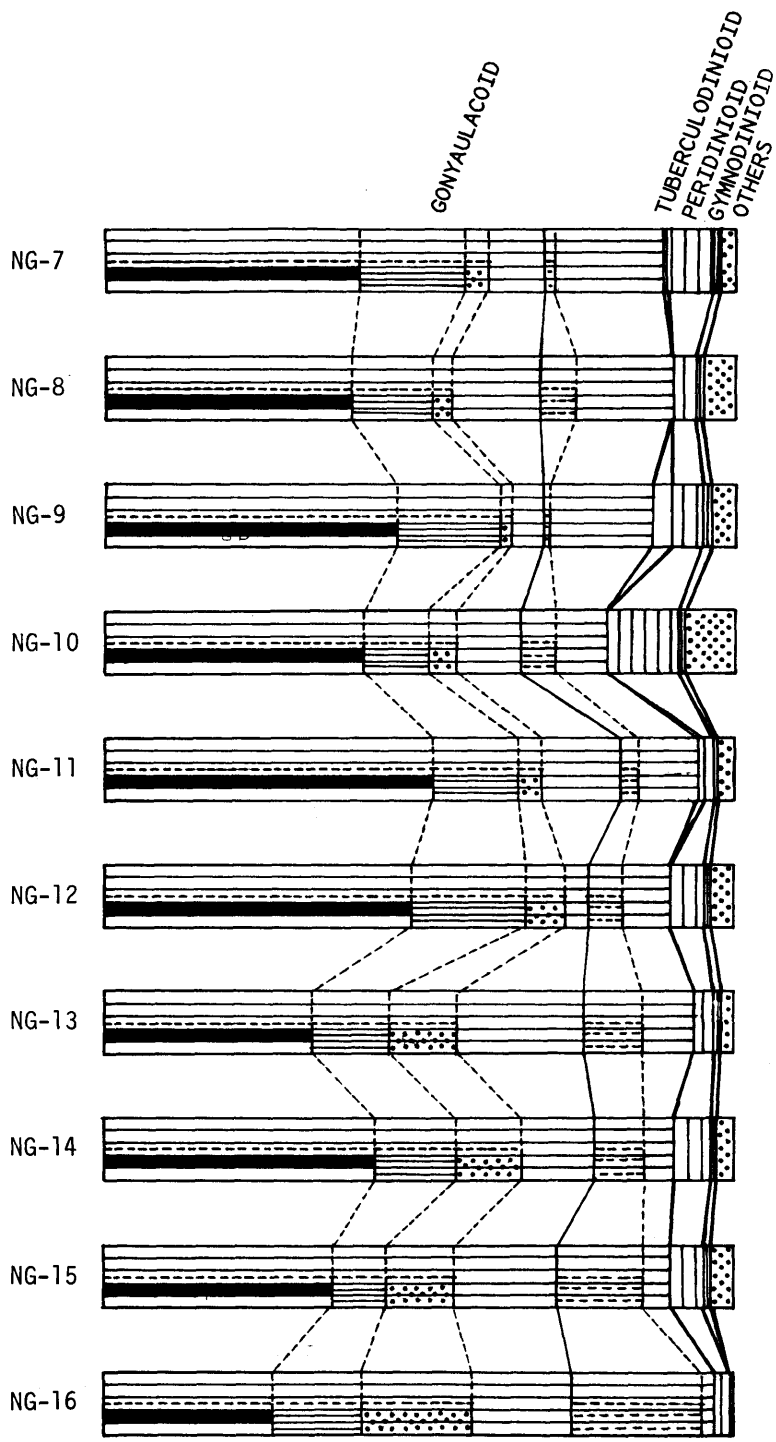
Remarks: The present species closely resembles *Multispinula? minuta* in its spherical and brownish cyst body, but differs from the latter in having not fibrous but longer and more solid processes.

Equivalent thecate form: Small ortho-type species of the genus *Peridinium* by Matsuoka (unpublished data).

VI) Note on the dinoflagellate cyst assemblages of Nagasaki Bay and Senzaki Bay

1) Nagasaki Bay:

In all samples, cysts belonging to the Gonyaulacales are dominat, and mainly include the genera *Spiniferites, Operculodinium, Lingulodinium* and *Impagidinium*. The most frequent genus *Spiniferites* comprises following species; *Spin. bentori* (Rossignol), *Spin. bulloideus* (Deflandre and Cookson), *Spin.* sp. cf. *delicatus, Spin. hyperacanthus* (Deflandre and Cookson), *Spin. mirabilis* (Rossignol), *Spin.* sp. cf. *ramosus* (Ehrenberg), *Spin.* sp. cf. *rubinus* (Rossignol) and others. Among them, *Spin. bulloideus* (Deflandre and Cookson), *Spin. hypercanthus* (Deflandre and Cookson)-*Spin. mirabilis*



Text-figure 8. Percentage frequency of dinoflagellate cysts recovered from samples of Nagasaki Bay. Legend is same in Text-fig. 9.

(Rossignol), *Spin.* sp. cf. *delicatus* always occupy more than fifty percent of the total population.

Lingulodinium machaerophorum (Deflandre and Cookson) generally increase from off-shore (NG 7) to the inner bay (NG 16). On the contrary, *Operculodinium* species decrease toward the inner part of the bay. *Tuberculodinium vancampoae* (Rossignol) is rare and only occures in the outer part of the bay.

Protoperidinium cysts of the Peridinioid mainly comprise *Brigantedinium majusculum, Brig. cariacoensis* (Wall), *Selenopemphix quanta* (Bradford), *Trinovanterdinium capitatum* and *Quinquecuspis concretum* (Reid), and these are minor elements in the whole.

The cysts assignable to the Gymnodinioid are also minor in the population and consists of only one species, *Pheopolykrikos hartmannii* (Zimmermann).

2) Senzaki Bay:

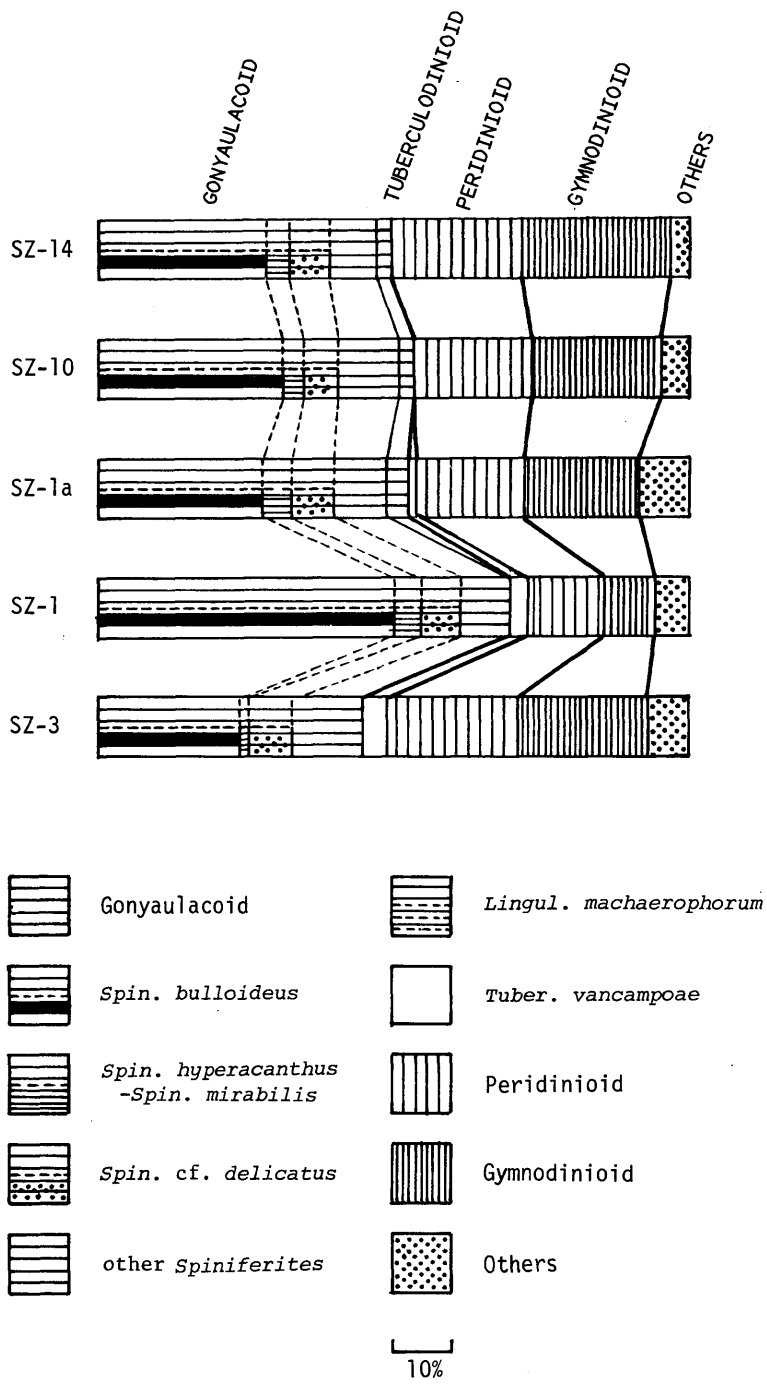
The cyst assemblage of Senzaki Bay is dominated by three major groups, the Goniaulacoid, Peridinioid and Gymnodinioid. The genus *Spiniferites* occupies about fifty percent of the total cyst population and consists of mainly of following four species; *Spin. bulloideus* (Deflandre and Cookson), *Spin.* sp. cf. *delicatus* and *Spin. hyperacanthus* (Deflandre and Cookson)-*Spin. mirabilis* (Rossignol). Other genera of this group are minor, especially *Lingulodinium machaerophorum* being very rare.

Tuberculodinium vancampoae (Rossignol) is more abundant than that of Nagasaki Bay.

Two genera, *Brigantedinium* and *Selenopemphix,* make up about eighty percent of the Peridinioid cysts. A new cyst form belonging to the genus *Stelladinium* is found in the sample SZ 1a, but it is very rare.

The cysts of the Gymnodinioid comprise *Gyrodinium instriatum, Polykrikos* sp. cf. *kofoidii, Polykrikos schwartzii* and *Pheopolykrikos hartmannii* (Zimmermann). Among them, *Pheopolyk. hartmannii* (Zimmermann) is predominant.

The dominant species of the genus *Spiniferites* are common in both cyst assemblages of Nagasaki Bay and Senzaki Bay, but its relative propotion in Senzaki is lower than that in Nagasaki. While, the Gymnodinioid and the cysts of *Protoperidinium* in Senzaki Bay are more dominant than those in Nagasaki Bay.



Text-figure 9. Percentage frequency of dinoflagellate cysts recovered from Senzaki Bay.

3) Comparison with other dinoflagellate cyst assemblages around the Japanese Island

Matsuoka (1982) reported that the dinoflagellate cyst assemblage of Omura Bay, near Nagasaki Bay, mainly consists of *Spiniferites* spp., which also include *Spin. bulloideus* (Deflandre and Cookson), *Spin. mirabilis* (Rossignol), and *Spin. bentori* (Rossignol), *Operculodinium centrocarpum* (Deflandre and Cookson), *Tuberculodinium vancampoae* (Rossignol), *Pheopolykrikos hartmannii* (Zimmermann) and *Polykrikos schwartzii,* and that abundance of these cysts indicates a warm temperate and inner bay environment.

The cyst assemblage of Senzaki Bay is more similar to that of Omura Bay, because both assemblages are characterized by abundance of such Gymnodinioid cysts as *Polyk. schwartzii* and *Pheopolyk. hartmannii* (Zimmermann)。 On the contrary, the assemblage of Nagasaki Bay is fewer in *Tuberculodinium vancampoae* (Rossignol) and Gymnodinioid cysts, and more abundant in Gonyaulacoid cysts, especially in *Spiniferites* spp. It is probably that the difference among Omura Bay, Senzaki Bay and Nagasaki Bay reflects the topography of bays, because Omura Bay and Senzaki Bay are larger in embayment degree than Nagasaki Bay which is more influenced by an oceanic water.

The cyst assemblage of off-Hachinohe coast is dominated by *Operculodinium centrocarpum* (Deflandre and Cookson) and *Protoperidinium* spp., while *Spiniferites* spp. are few (Matsuoka 1976). The assemblage of Nagasaki Bay is very different from that of off-Hachinohe coast in dominance of *Spiniferites*. On the other hand, the assemblage of Senzaki Bay is slightly similar to that of off-Hachinohe coast in that *Protoperidinium* cysts are somewhat predominant. Although Matsuoka (1976) menthioned that the assemblage of off-Hachinohe coast might be deposited under the influence by the warm Tsugaru current which is a branch of the Tsushima current, the effect of this current may be weak judging from the comparison with the typical warm-temperate cyst assemblages revealed in Nagasaki Bay, Omura Bay and Senzaki Bay. Moreover, an abundance of *Brigantedinium* spp. may moderately influenced by the cold Oyashio current. Therefore, we can understand that the assemblage of off-Hachinohe coast may indicate a mixed condition of both warm and cold water currents.

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* : In Japanese.

Table 2. Absolut and relative frequencies of dinoflagellate cysts from surface

Species \ Sation	NG 7		NG 8		NG 9		NG 10		NG 11		NG 12	
Gonyaulacoid Lineage		%		%		%		%		%		%
Spiniferites bulloideus	92	39.8	79	39.7	125	46.3	107	41.2	165	52.5	146	49.2
S. cf. *delicatus*	7	3.0	6	3.0	5	1.9	12	4.6	12	3.8	18	6.1
S. elongatus	1	0.4										
S. hyperacanthus + *S. mirabilis*	40	17.3	26	13.1	44	16.3	28	10.8	43	13.7	58	19.5
S. asperulus												
S. bentori	5	2.2	8	4.0	5	1.9	4	1.5	11	3.5	6	2.0
S. cf. *bentori* + *S.* cf. *rubinus*					2	0.7						
S. cf. *ramosus*									7	2.2		
S. spp. indet.	16	6.9	23	11.6	7	2.6	24	9.2	26	8.3	9	3.0
Operculodinium centrocarpum	20	8.7	27	13.6	27	10.0	12	4.6	15	4.8	11	3.7
O. israelianum									2	0.6		
O. crassum	8	3.5	4	2.0	7	2.6	9	3.5	13	4.1	5	1.7
Lingulodinium machaerophorum	3	1.3	10	5.0	3	1.1	14	5.4	8	2.5	16	5.4
Impagidinium spp.	1	0.4									1	0.3
Protogonyaulax catenella												
Tuberculodinioid Lineage												
Tuberculodinium vancampoae	1	0.4			7	2.6			2	0.6	1	0.3
Peridinioid Lineage												
Brigantedinium spp.	7	3.0	2	1.0	6	2.2	18	6.9	1	0.3	3	1.0
Selenopemphix quanta							3	1.2				
Seleno. alticinctum	3	1.3			1	0.4	1	0.4			1	0.3
Multispinula? minuta			6	3.0	5	1.9	6	2.3	2	0.6	5	1.7
Quinquecuspis concretum			1	0.5	1	0.4						
Trinovantedinium capitatum	5	2.2	3	1.5	2	0.7	2	0.8	3	1.0	7	2.4
Votadinium carvum			1	0.5	2	0.7	2	0.8			2	0.7
V. spinosum					1	0.4	1	0.4				
Protoperidinium latissinum												
Stelladinium abei												
S. reidii							1	0.4				
Dinoflagellate cyst type B			1	0.5								
Scrippsiella trochoidea												
Dubridinium sp.												
Dinoflagellate cyst type A	6	2.6			5	1.9	11	4.2	1	0.3	2	0.7
Dinoflagellate cyst type C	11	4.8			9	3.3	1	0.4			4	1.3
Gymnodinioid Lineage												
Polykrikos schwartzii												
P. cf. *kofoidii*												
Pheopolykrikos hartmannii	2	0.9	2	1.0	3	1.1	2	0.8	1	0.3	2	0.7
Gyrodinium instriatum												
Lineage indet.												
Dinoflagellate cyst type D	3	1.3			3	1.1	2	0.8	2	0.6		
Dinoflagellate cyst type E												
total count	231		199		270		260		314		297	
total / 1ml	2025		2094		4737		1710		3305		1736	

sediments of Nagasaki Bay (NG) and Senzaki Bay (SZ).

NG 13		NG 14		NG 15		NG 16		SZ 1		SZ 1a		SZ 3		SZ 10		SZ 14	
	%		%		%		%		%		%		%		%		%
67	32.5	125	42.5	75	37.3	64	25.4	102	54.5	69	27.9	54	24.3	69	31.5	64	28.7
23	11.2	31	10.5	23	11.4	43	17.1	13	7.0	20	8.1	18	8.1	13	5.9	16	7.2
				1	0.5	2	0.8										
23	11.2	36	12.2	18	9.0	33	13.1	9	4.8	12	4.9	3	1.4	8	3.7	9	4.0
														1	0.5		
23	11.2	16	5.4	8	4.0	14	5.6	3	1.6	5	2.0	5	2.3	4	1.8	8	3.6
		1	0.3	1	0.5			1	0.5	1	0.4						
		6	2.0	6	3.0	4	1.6										
21	10.2	18	6.1	20	10.0	19	7.5	16	8.6	14	5.7	21	9.5	12	5.5	4	1.8
11	5.3	11	3.7	6	3.0	3	1.2	2	1.1	9	3.6	7	3.2	3	1.4	3	1.3
2	1.0	1	0.3														
2	1.0	1	0.3					2	1.1					2	0.9	1	0.4
19	9.2	21	7.1	28	13.9	48	19.0	1	0.5							2	0.9
		2	0.7					1	0.5					1	0.5		
1	0.5																
										3	1.2						
2	1.0			2	1.0	16	6.3			19	7.7	26	11.7	26	11.9	31	13.9
				1	0.5			5	2.7	18	7.3	22	9.9	8	3.7	11	4.9
												1	0.5				
3	1.5	3	1.0	1	0.5			10	5.3	14	5.7	14	6.3	7	3.2	3	1.3
		5	1.7					1	0.5					3	1.4	2	0.9
1	0.5	4	1.4			4	1.6	1	0.5	3	1.2			2	0.9	3	1.3
2	1.0	5	1.7	3	1.5	1	0.4	3	1.6	2	0.8	1	0.5	4	1.8	2	0.9
																1	0.4
				1	0.5												
										2	0.8						
1	0.5																
1	0.5																
										3	1.2						
																1	0.4
1	0.5	3	1.0	3	1.5					3	1.2	1	0.5	3	1.4	4	1.8
				2	1.0	1	0.4										
								1	0.5	5	2.0	1	0.5	2	0.9	1	0.4
												1	0.5	2	0.9	2	0.9
2	1.0	2	0.7	2	1.0			14	7.5	43	17.4	47	21.2	49	22.4	52	23.3
								1	0.5								
2	1.0	3	1.0	1	0.5					2	0.8						
								1	0.5								
207		294		202		252		187		247		222		219		223	
2574		3094		2115		1326		1039		914		1388		1825		1858	

Explanation of Plates

All figures by interference contrast, and magnification X 740, otherwise unless mentioned.

Explanation of Plate 1

Figs. 1-7 *Spiniferites* sp. cf. *delicatus* Reid

Figs. 1-5 ; slide SZ 3-3(89.5 / 42.2), 1 ; ventral surface, 2 ; optical cross section, 3-5 ; dorsal surface of different focus levels, showing the process with petaloid distal tips and weakly developed parasutural septa.

Figs. 6-7 ; slide NG 12-1(91.0 / 41.1), 6 ; optical cross section, 7 ; dorsal surface, showing somewhat membranous processes.

Figs. 8-12 *Spiniferites bulloideus* (Deflandre and Cookson) Sarjeant

Fig. 8 ; slide NG 11-1(87.3 / 39.0), optical cross section.

Fig. 9 ; slide SZ 1a-3(88.0 / 47.0), dorsal surface, showing the precingular archeopyle.

Fig. 10-11 ; slide NG 13-2(96.0 / 26.4), 10 ; optical cross section, 11 ; lateral view.

Fig. 12 ; slide NG 13-1(85.3 / 43.2), ventral surface of dorsal view.

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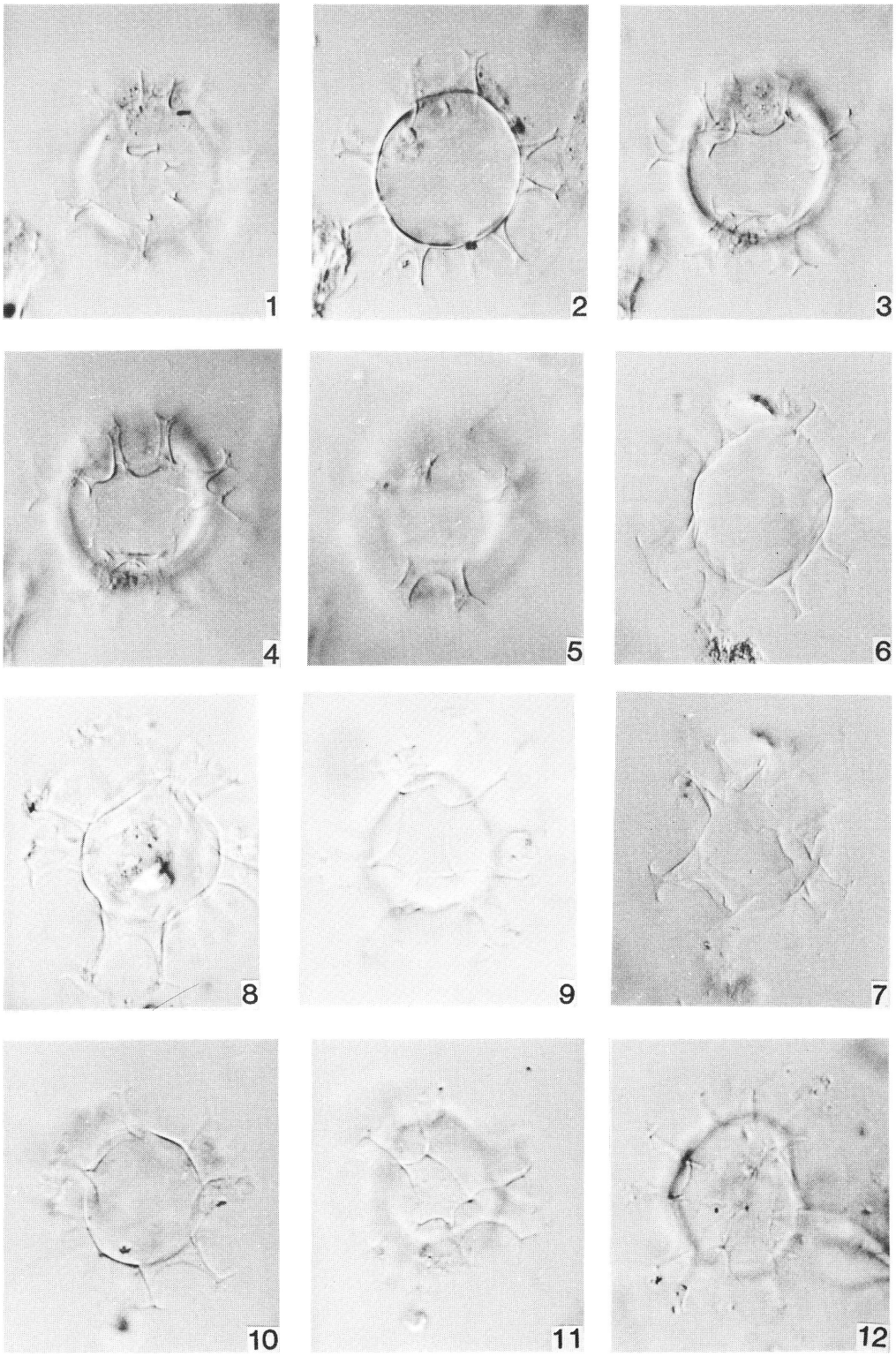
PLATE 1



Explanation of Plate 2

Figs. 1-9 *Spiniferites bulloideus* (Deflandre and Cookson) Sarjeant

Figs. 1-3 ; slide SZ 1a-3(88.0 / 47.0), 1 ; ventral surface, 2 ; optical cross section, 3 ; dorsal surface.

Figs. 4-6 ; slide SZ 3-2(91.7 / 27.4), 4 ; ventral surface, 5 ; dorsal surface, 6 ; optical cross section.

Fig. 7 ; slide NG 13-2(98.5 / 33.2).

Figs. 8-9 ; slide SZ 1-1(90.3 / 47.4), 8 ; dorsal surface, 9 ; ventral surface of dorsal view.

Figs. 10-13 *Spiniferites* sp. cf. *rubinus* (Rossignol) Sarjeant

slide NG 12-1(95.8 / 37.6), 10 ; oblique ventral surface, 11 ; optical cross section, 12 ; oblique dorsal surface, 13 ; extremity of process.

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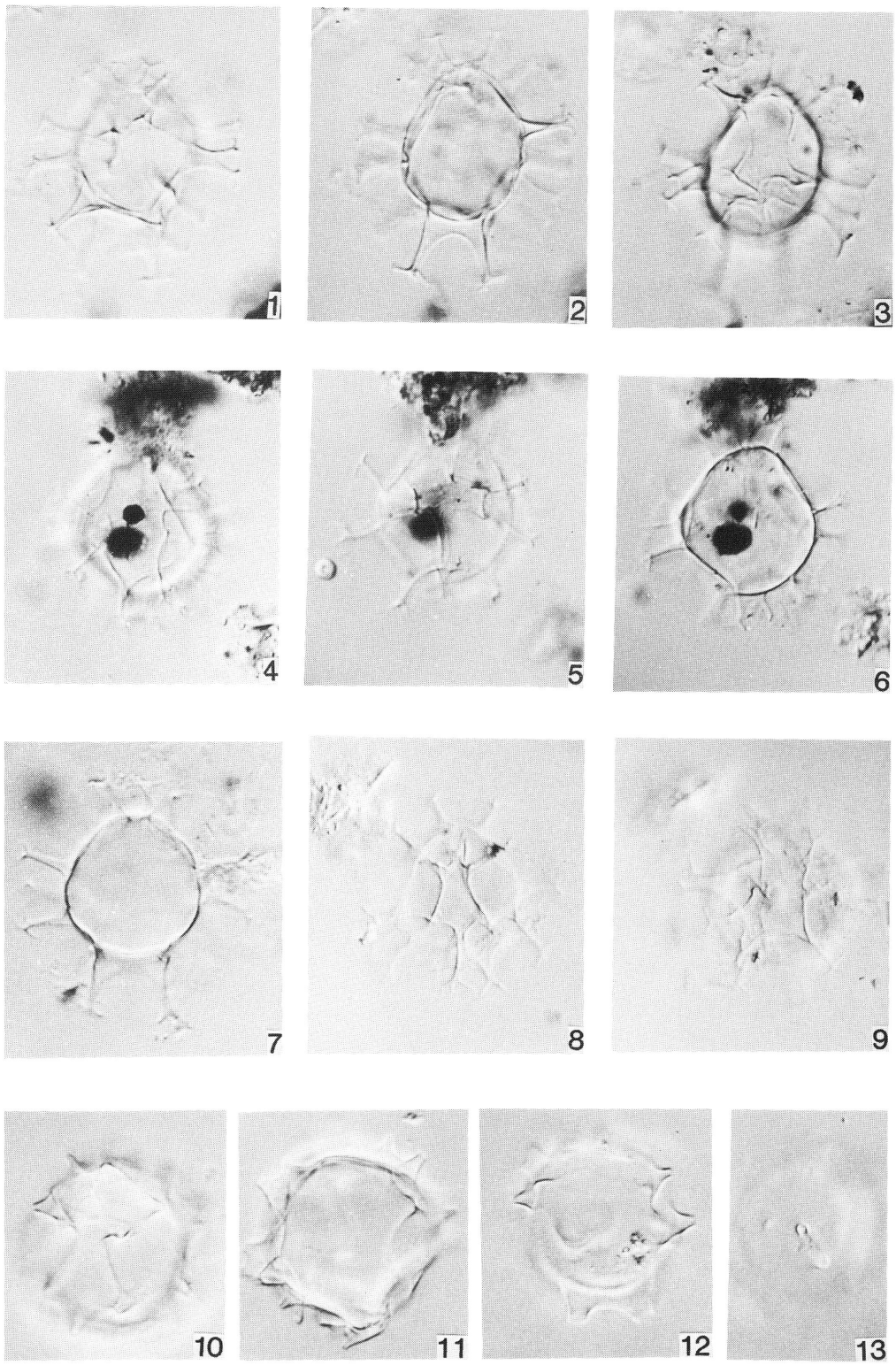
PLATE 2



Explanation of Plate 3

Figs. 1-4 *Spiniferites mirabilis* (Rossignol) Sarjeant

Figs. 1-3 ; slide SZ 1a-3(88.3 / 36.8), 1 ; ventral surface, 2 ; optical cross section, showing the membranous antapical process, 3 ; dorsal surface, showing the precingular archeopyle.

Fig. 4 ; slide NG 15-1(97.3 / 48.5) ; ventral surface, showing the membranous antapical process.

Figs. 5-12 *Spiniferites hyperacanthus* (Deflandre and Cookson) Sarjeant

Figs. 5-6 ; slide NG 15-2(91.7 / 29.6), 5 ; antapical surface of apical view, 6 ; optical cross section of poler view.

Fig. 7 ; slide NG 13-2(91.2 / 42.5), lateral view, showing well developed intergonal processes.

Figs. 8-9 ; slide NG 15-2(89.6 / 33.5), 8 ; oblique dorsal surface, 9 ; ventral surface of dorsal view, showing the triangular 6" paraplate.

Figs. 10-12 ; slide NG 13-1(90.0 / 44.5), 10 ; ventral surface, 11 ; optical cross section, 12 ; dorsal surface of the epicyst.

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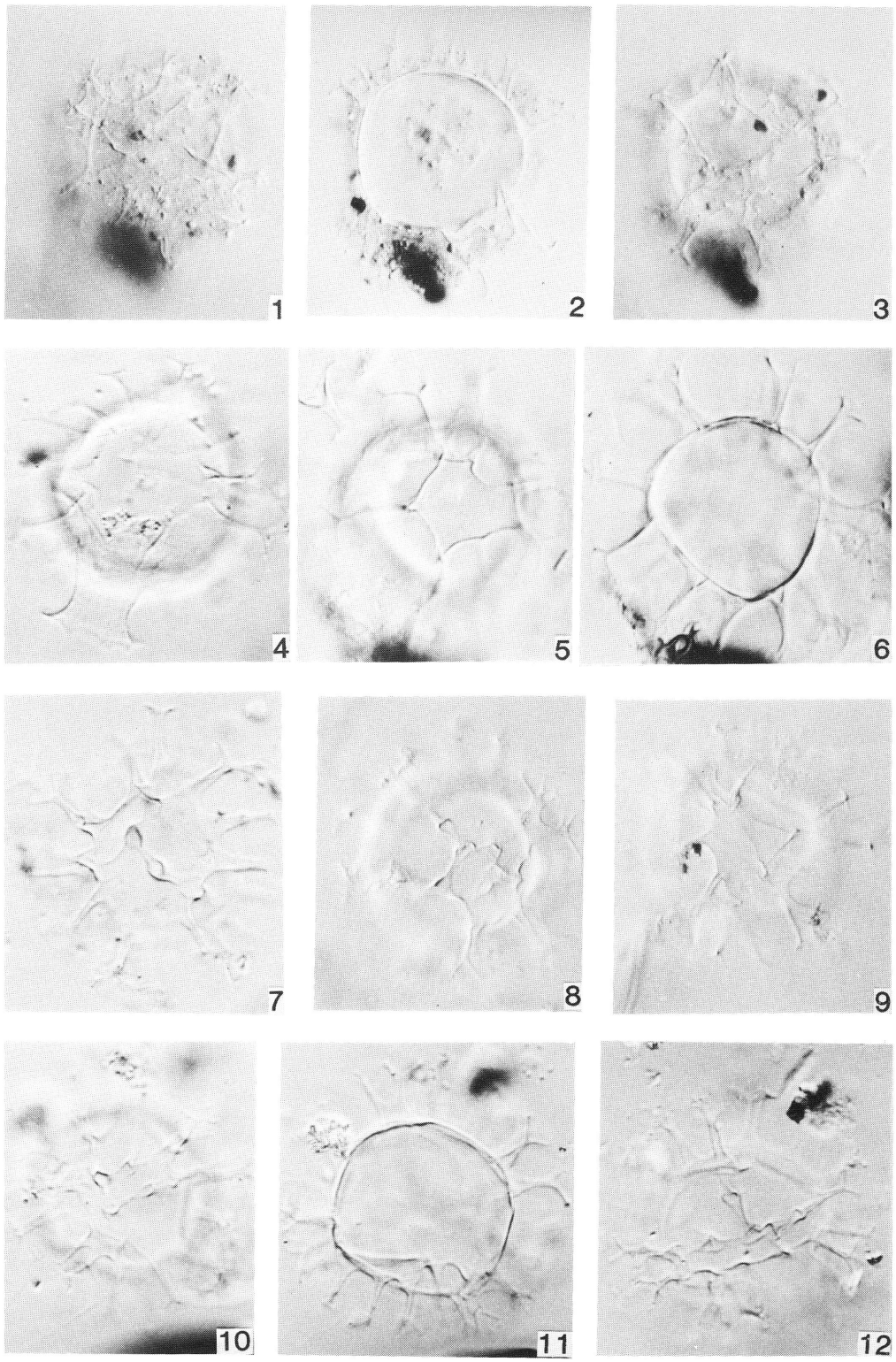
PLATE 3



Explanation of Plate 4

Figs. 1-3 *Spiniferites* sp. cf. *ramosus* (Ehrenberg) Loeblich and Loeblich
slide SZ 3-3(91.2 / 29.5), 1 ; ventral surface of dorsal view, 2 ; optical cross section, 3 ; dorsal surface.

Figs. 4-6 *Spiniferites* sp. cf. *bentori* (Rossignol) Sarjeant
slide SZ 3-2(87.7 / 47.5), 4 ; oblique dorsal surface, 5,6 ; optical cross section, showing the well developed apical boss.

Figs. 7-8 *Spiniferites asperulus* Matsuoka
slide NG 12-1(94.2 / 34.5), 7 ; lateral view, showing the granular surface of periphragm, 8 ; optical cross section, showing the well developed membranous antapical process.

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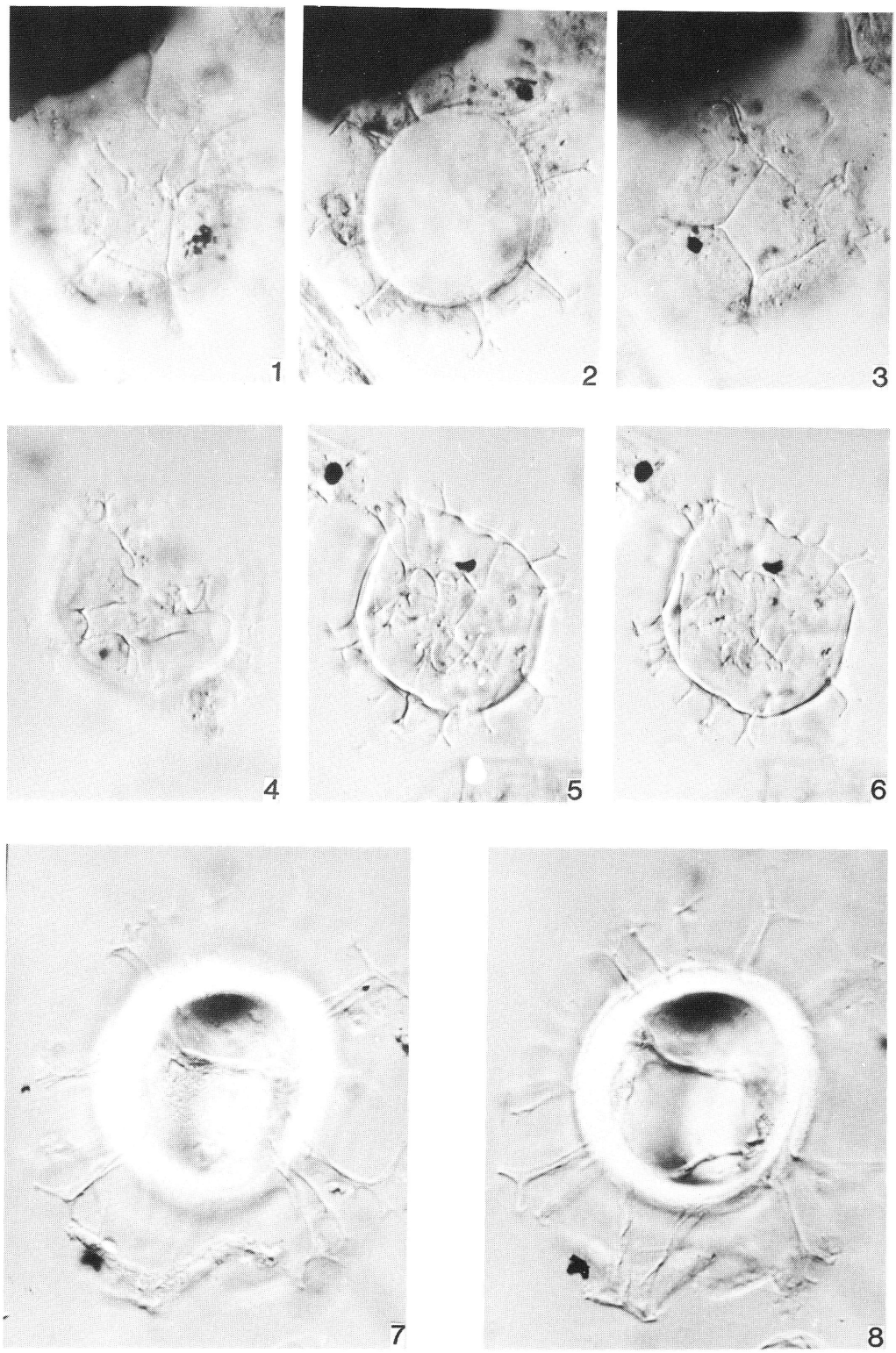
PLATE 4



Explanation of Plate 5

Figs. 1-6 *Spiniferites bentori* (Rossignol) Wall and Dale

Figs. 1-2 ; slide NG 12-1(90.0 / 48.5), 1 ; ventral surface of dorsal view, showing the granular surface of periphragm and the triangular 6" paraplate.

Fig. 3 ; slide NG 13-2(90.2 / 35.3), oblique ventral view, showing the 6" and posterior sulcal plates.

Figs. 4-6 ; slide SZ 1a-3(87.8 / 33.0), 4 ; optical cross section, showing the detached operculum within the cyst cavity, 5 ; nearly optical cross section, showing the 2' and 3' paraplates, 6 ; ventral surface of dorsal view.

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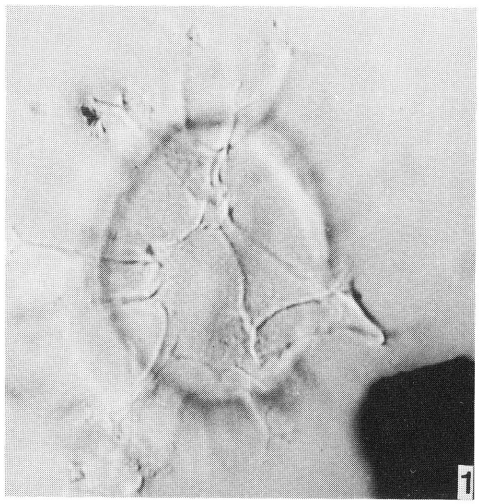
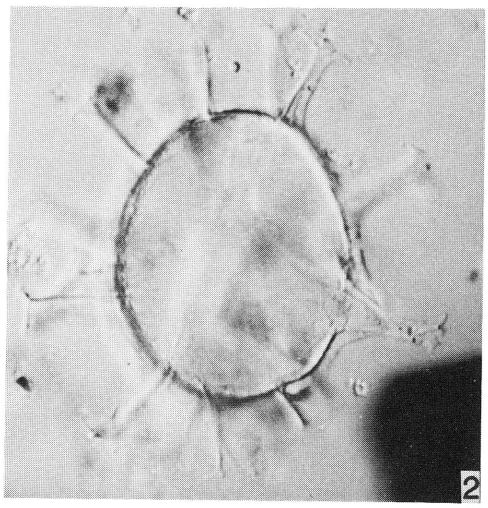
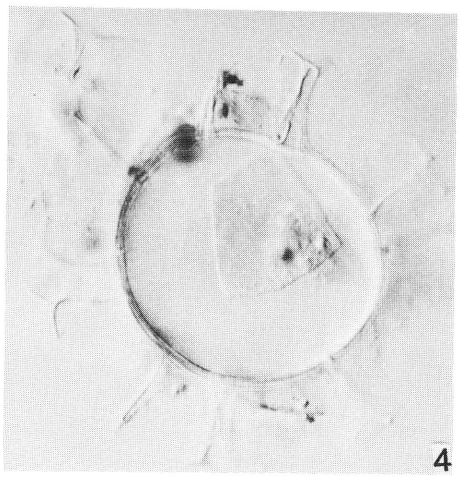
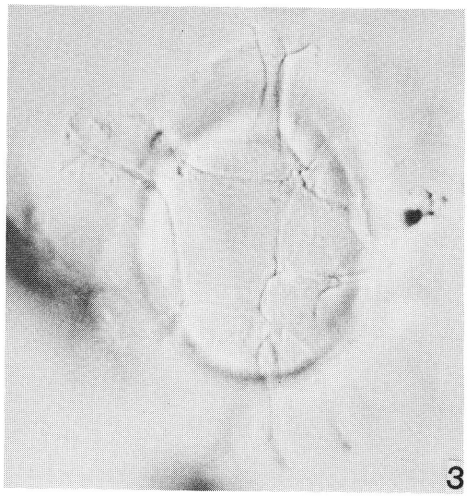
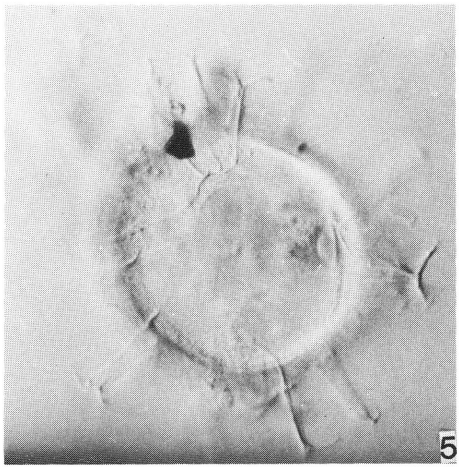
PLATE 5

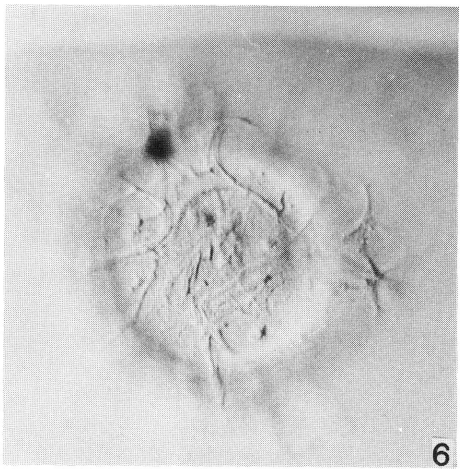












Explanation of Plate 6

Figs. 1-2 *Spiniferites bentori* (Rossignol) Wall and Dale
slide NG 14-1(91.9 / 43.6), 1 ; ventral surface, 2 ; dorsal surface.

Figs. 3-4 *Spiniferites* sp. cf. *ramosus* (Ehrenberg) Loeblich and Loeblich
slide SZ 1a-3(95.0 / 29.3), 3 ; optical cross section, showing the precingular archeopyle, 4 ; lateral view.

Fig. 5 *Protogonyaulax catenella* (Whedon and Kofoid) Taylor
slide NG 13-1(96.0 / 43.5), equatorial view.

Figs. 6-8 *Operculodinium crassum* Harland
slide SZ 1a-3(94.3 / 33.4), 6 ; cyst surface, 7 ; optical cross section, showing the thick wall, 8 ; lateral view, showing the precingular archeopyle.

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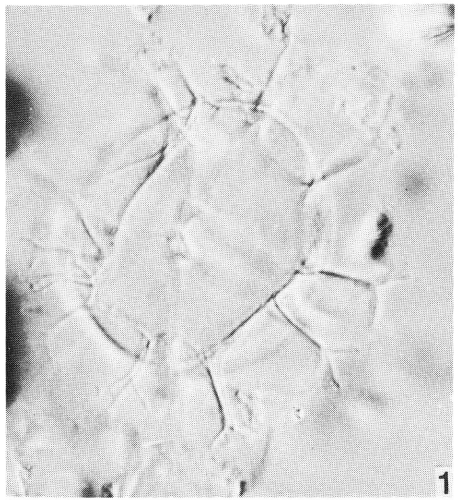
PLATE 6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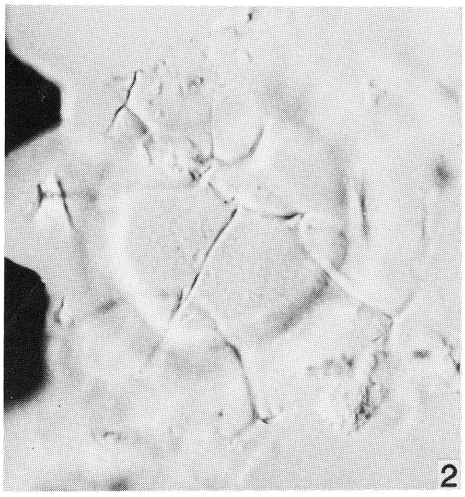
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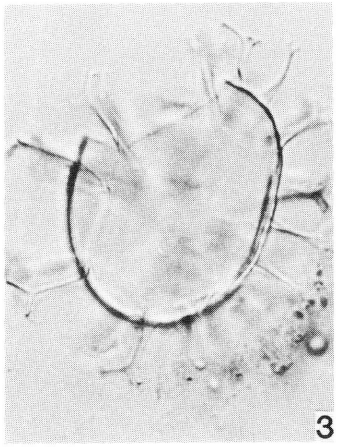
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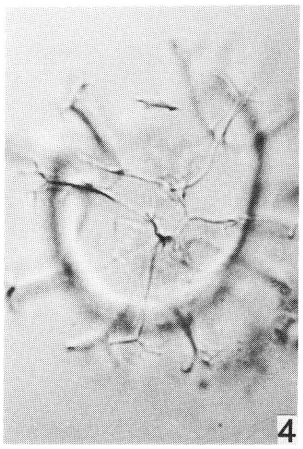
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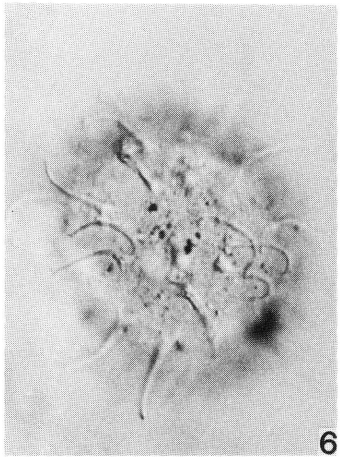
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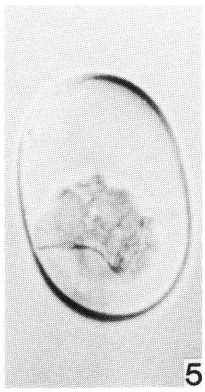
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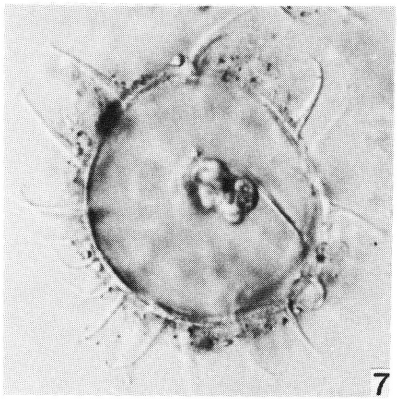
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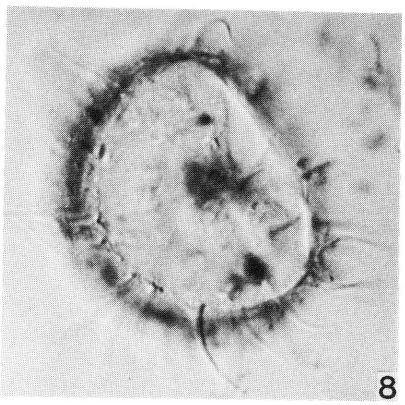
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Explanation of Plate 7

Figs. 1-6 *Operculodinium centrocarpum* (Deflandre and Cookson) Wall

Figs. 1-2 ; slide SZ 3-3(97.0 / 29.6), 1 ; optical cross section, 2 ; lateral view.

Fig. 3 ; slide NG 8-1(84.7 / 41.8), nearly dorsal view, showing the precingular archeopyle.

Figs. 4-5 ; slide NG 13-1(88.0 / 41.0), 4 ; optical cross section, 5 ; dorsal view, showing the archeopyle.

Fig. 6 ; slide SZ 3-2(101.0 / 39.3), optical cross section.

Figs. 7-10 *Operculodinium crassum* Harland

Figs. 7-9 ; slide NG 13-3(92.2 / 46.1), 7 ; oblique lateral view, 8 ; surface of cyst wall, 9 ; optical cross section.

Fig. 10 ; slide NG 13-2(100.5 / 32.0), optical cross section.

Figs. 11-12 *Operculodinium israelianum* (Rossignol) Wall

slide NG 8-1(100.4 / 32.5), 11 ; optical cross section, 12 ; dorsal surface, showing the deformed precingular archeopyle.

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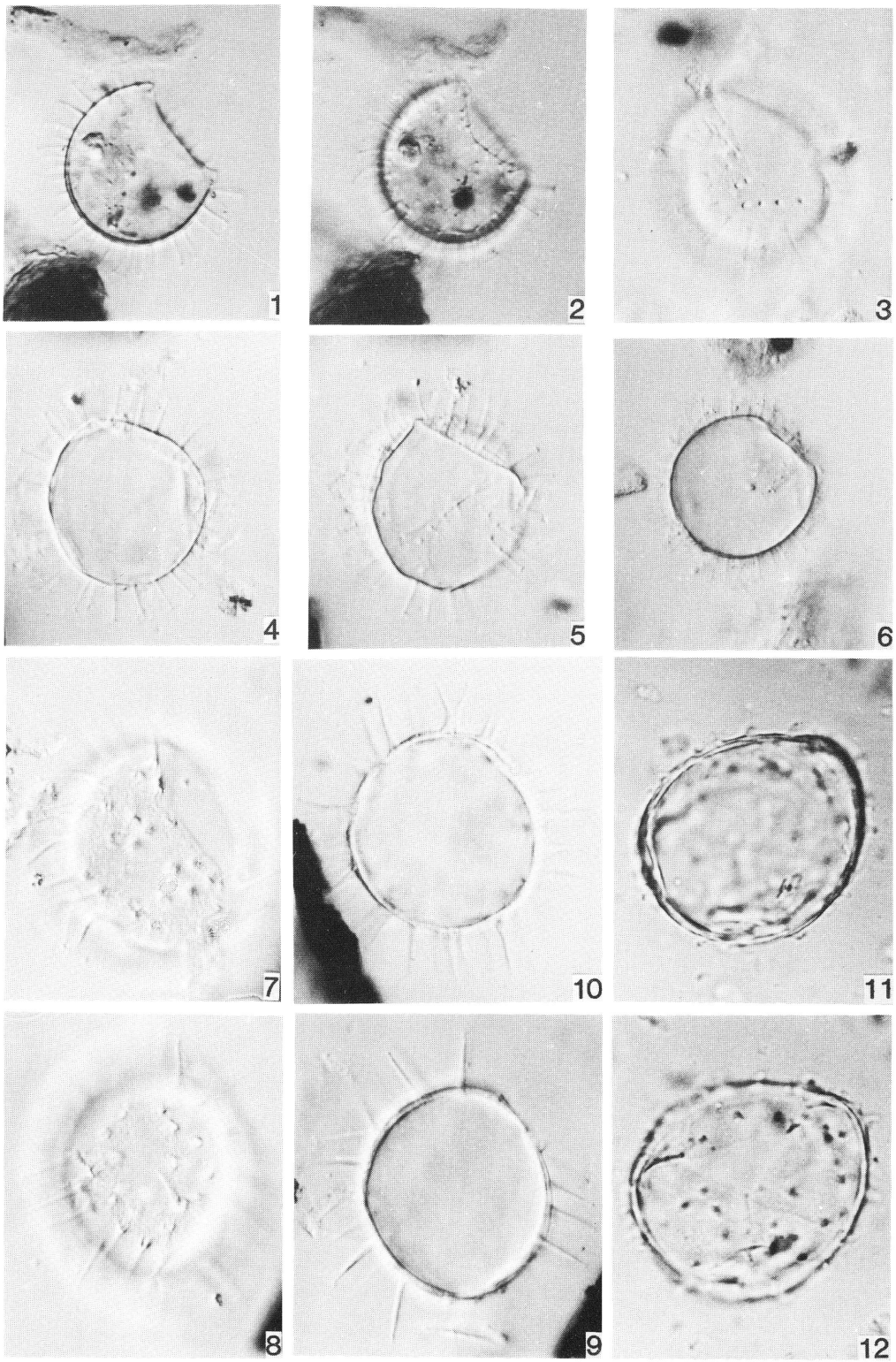
PLATE 7



Explanation of Plate 8

Figs. 1-5 *Lingulodinium machaerophorum* (Deflandre and Cookson) Wall

Figs. 1-2 ; slide NG 15-2(86.2 / 42.0), 1 ; ventral surface, showing the attached operculum, 2 ; optical cross section.

Fig. 3 ; slide SZ 1a-3(89.0 / 41.8), apical view, showing the large combination archeopyle.

Figs. 4-5 ; slide SZ 1-3(85.3 / 46.8), 4 ; lateral view, showing the combination archeople, 5 ; oblique antapical surface.

Figs. 6-7 *Tuberculodinium vancampoae* (Rossignol) Wall

slide 15-3(84.4 / 21.3), 6 ; apical surface, 7 ; oblique antapical view, showing the hypocystal archeopyle.

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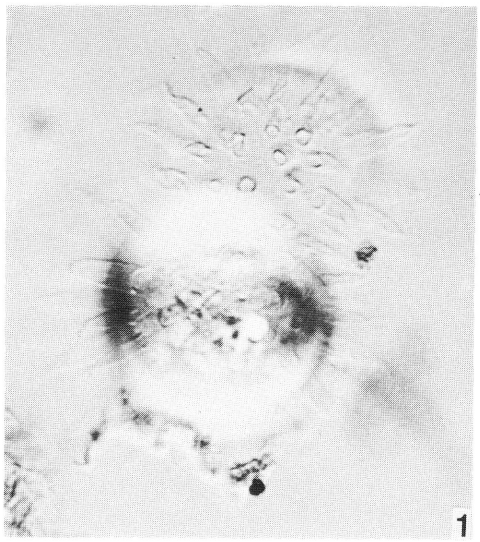
PLATE 8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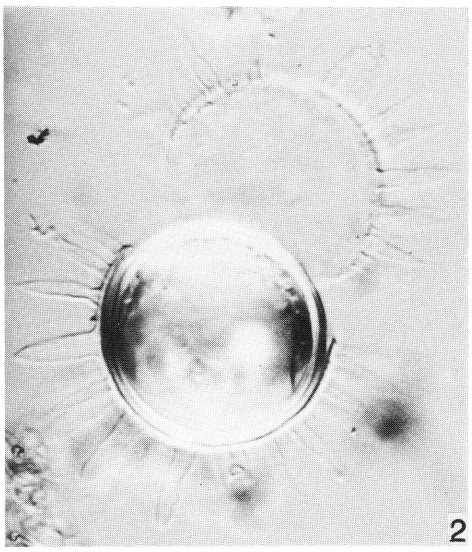
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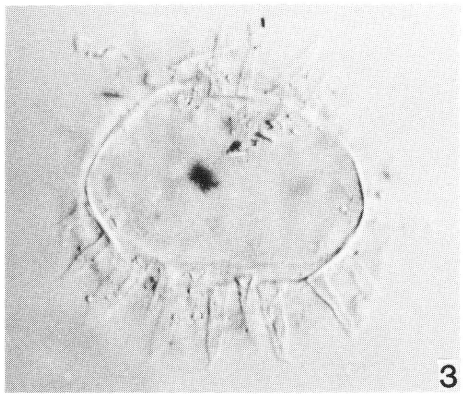
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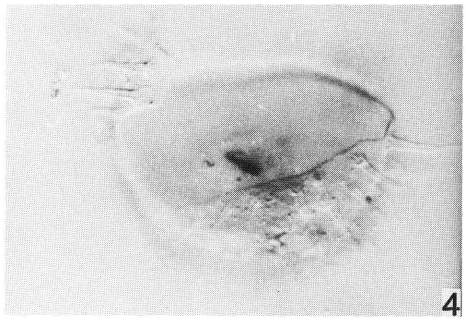
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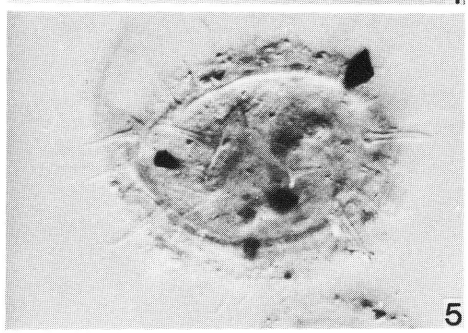
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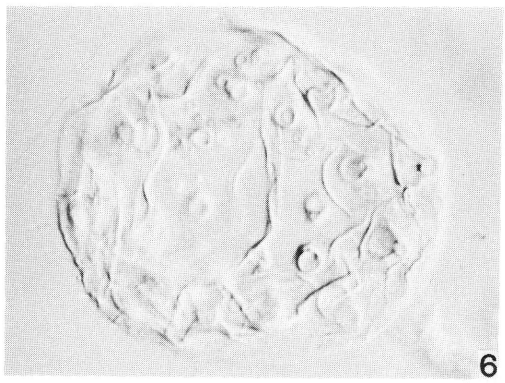
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7

Explanation of Plate 9

Figs. 1-6 *Trinovantedinium capitatum* Reid
[Cyst of *Protoperidinium pentagonum* (Gran) Balech]
Figs. 1-3 ; slide NG 15-1(100.7 / 41.8), 1 ; ventral surface, showing two flagellar pores, 2 ; optical cross section, showing the 1' paraplate on which many short processes are intratabularly distributed, 3 ; dorsal surface, showing the large intercalary archeopyle.
Fig. 4 ; slide NG 13-1(96.4 / 35.3), dorsal surface.
Figs. 5-6 ; slide NG 13-3(94.6 / 36.0), 5 ; dorsal surface of the epicyst, showing the intercalary archeopyle, 6 ; ventral surface.

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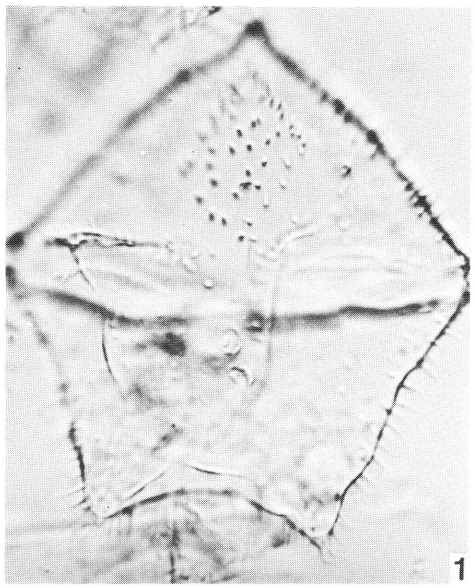
PLATE 9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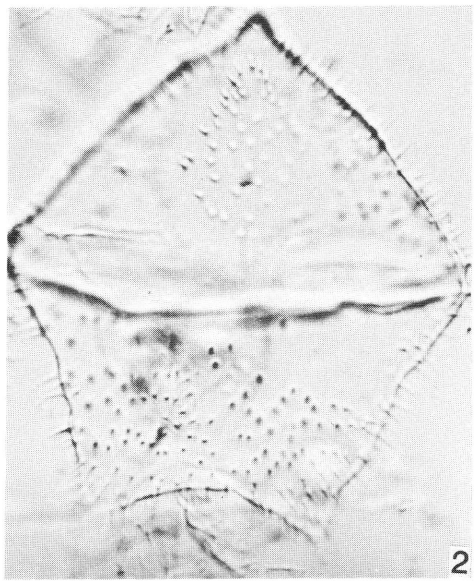
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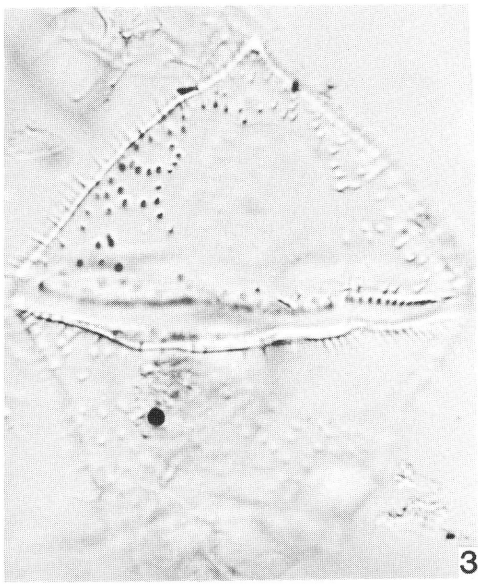
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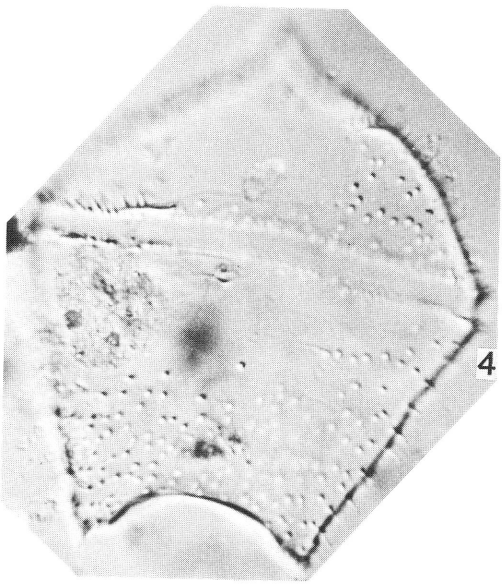
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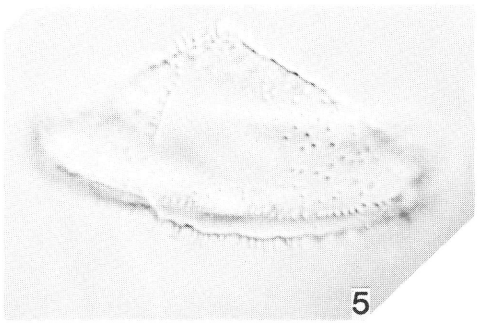
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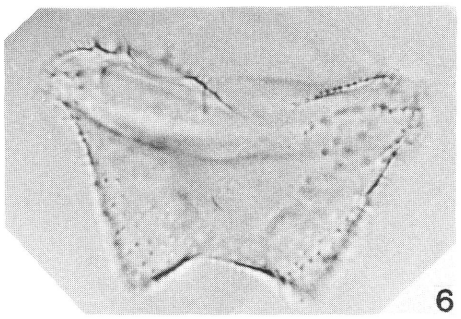
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Explanation of Plate 10

Figs. 1-6 *Trinovantedinium capitatum* Reid
[Cyst of *Protoperidinium pentagonum* (Gran) Balech]
Figs. 1-3 ; slide NG 16-1(86.5 / 44.5), 1 ; ventral surface, 2 ; optical cross section, 3 ; dorsal surface.
Figs. 4-5 ; slide NG 13-3(96.0 / 28.4), 4 ; dorsal surface, showing the intercalary archeopyle, 5 ; ventral surface.
Fig. 6 ; slide SZ 1-2(99.4 / 34.2), optical cross section, showing the roundly pentagonal ambit.

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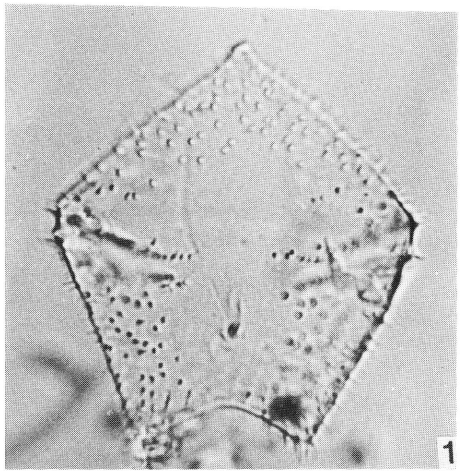
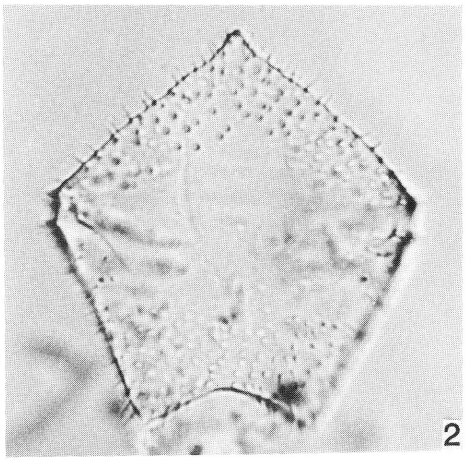
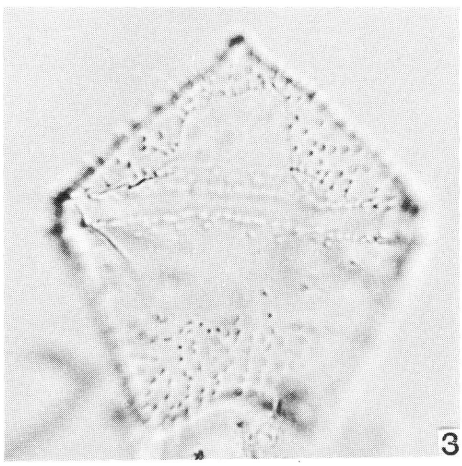
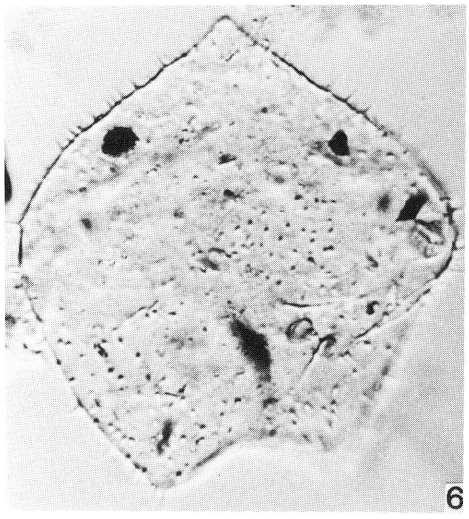
PLATE 10









Explanation of Plate 11

Figs. 1-9 *Selenopemphix quanta* (Bradford) comb. nov.
[Cyst of *Protoperidinium conicum* (Gran) Balech]
Figs. 1-3 ; slide SZ 1-2(94.6 / 41.5), 1 ; apical surface, showing the process cluster which indicates the apical boss, 2 ; optical cross section of apical-antapical view, 3 ; antapical surface.
Figs. 4-5 ; slide NG 10-1(89.8 / 39.0), oblique lateral view.
Fig. 6 ; slide SZ 1-1(97.2 / 30.5), oblique lateral view, showing two short antapical processes.
Figs. 7-8 ; slide SZ 1a-3(81.6 / 25.8), 7 ; oblique ventral surface, showing the parasulcus, 8 ; oblique dorsal surface, showing the intercalary archeopyle.
Fig. 9 ; slide SZ 1a-1(89.7 / 25.4), antapical surface.

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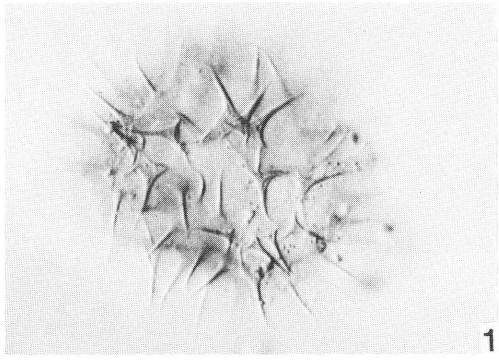
PLATE 11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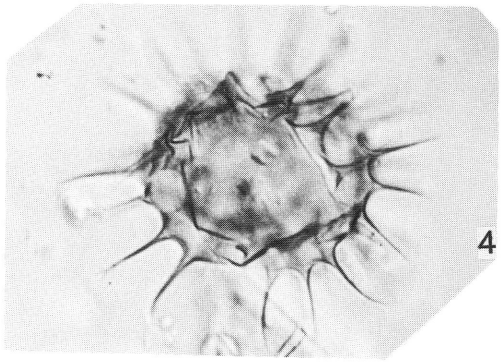
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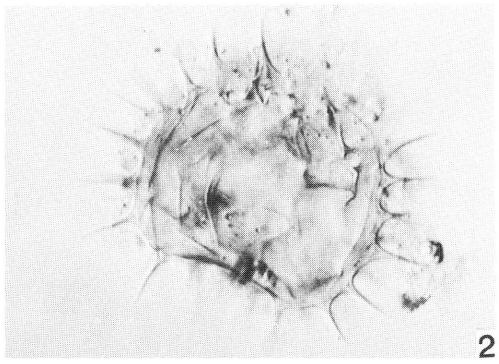
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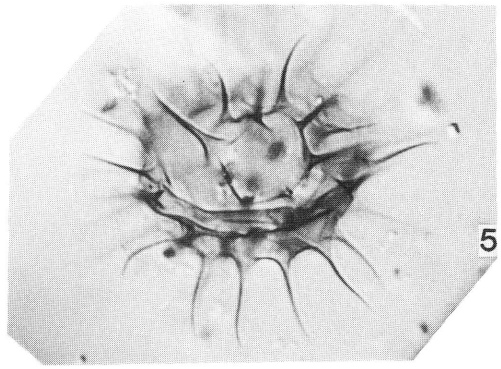
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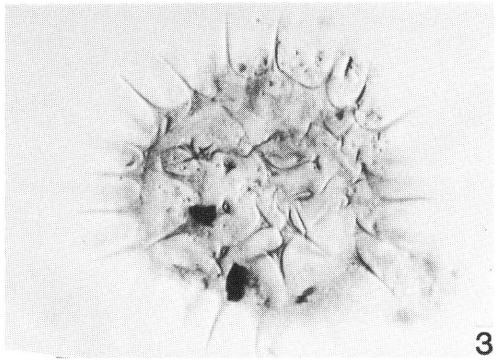
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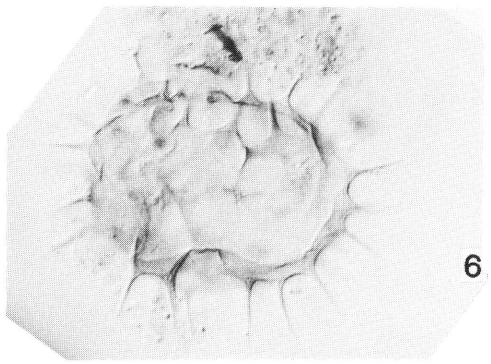
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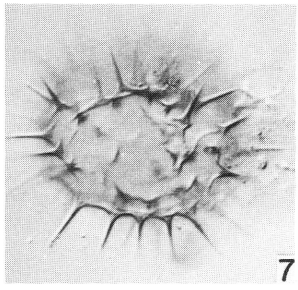
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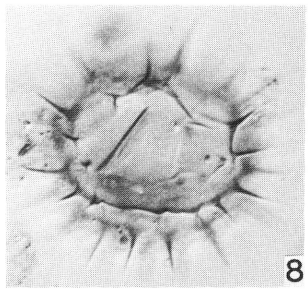
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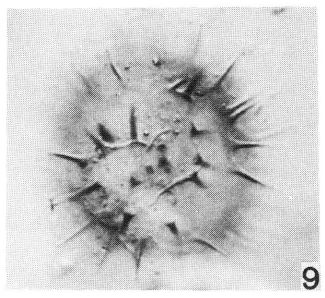
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Explanation of Plate 12

Figs. 1-2 *Votadinium carvum* Reid

[Cyst of *Protoperidinium oblongum* (Aurivillius) Balech]

slide SZ 1-2(88.4 / 42.7), 1 ; ventral surface, showing the shallow parasulcus and low apical boss, 2 ; dorsal surface, showing the large archeopyle.

Figs. 3-8 *Quinquecuspis concretum* (Reid) Harland

[Cyst of *Protoperidinium leonis* (Pavillard) Balech]

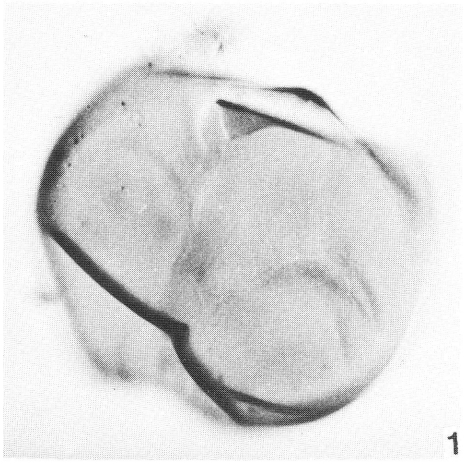
Fig. 3 ; slide SZ 1-2(85.9 / 35.6), oblique dorsal surface, showing some striations on the surface.

Figs. 4-6 ; slide NG 13-2(92.5 / 37.8), 4 ; optical cross section of epicyst, 5 ; lateral view of the right antapical horn, 6 ; lateral view of the left antapical horn, showing the thickning of the tip.

Figs. 7-8 ; slide SZ 3-1(85.7 / 29.5), 7 ; optical cross section, showing the roundly pentagonal ambit, 8 ; ventral surface.

K. MATSUOKA

PLATE 12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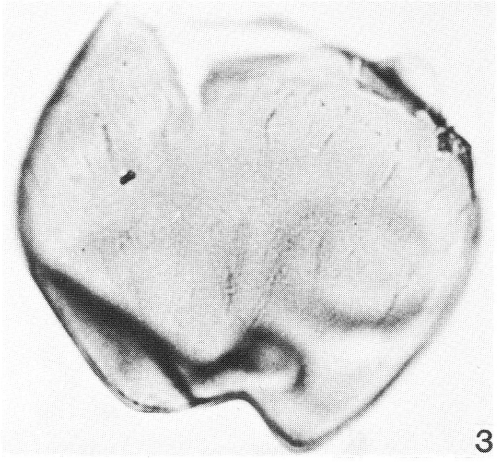
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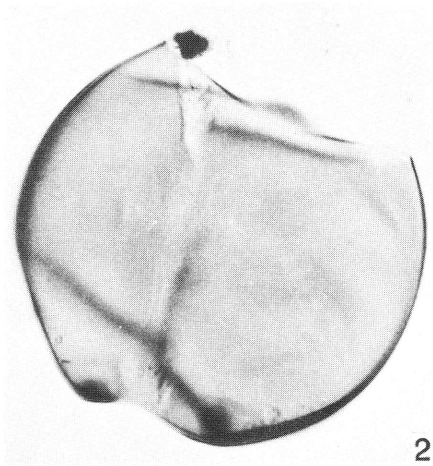
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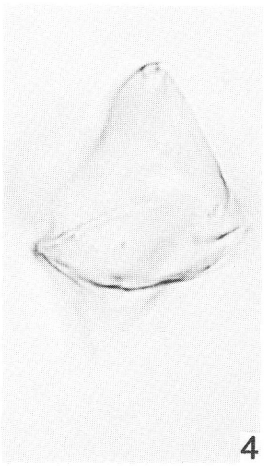
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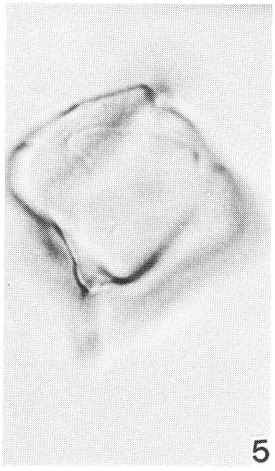
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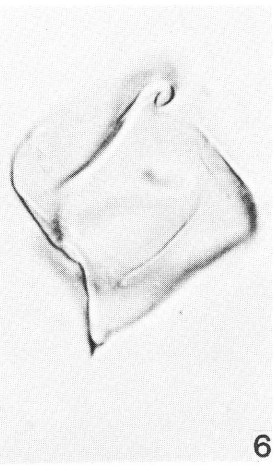
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Explanation of Plate 13

Figs. 1-4 *Quinquecuspis concretum* (Reid) Harland
[Cyst of *Protoperidinium leonis* (Pavillard) Balech]
Figs. 1-2 ; slide SZ 14-1(87.3 / 49.2), 1 ; dorsal surface of the epicyst, 2 ; ventral surface of the hypocyst, showing two conspicuous antapical horns.
Figs. 3-4 ; slide SZ 14-2(95.7 / 40.5), 3 ; ventral surface, showing the parasulcus, 4 ; dorsal surface, showing the intercalary archeopyle.

Figs. 5-6 Cyst of *Protoperidinium* sp. ; slide SZ 3-2(95.0 / 45.4), 5 ; oblique dorsal surface of the epicyst, showing the large intercalary archeopyle, 6 ; oblique ventral surface of the hypocyst, showing the well developed parasulcus.

Figs. 7-8 Cyst of *Protoperidinium latissinum* (Kofoid) Balech
slide NG 15-3(88.1 / 33.2), 7 ; dorsal surface, showing the intercalary archeopyle, 8 ; optical cross section, showing two distinctive antapical horns.

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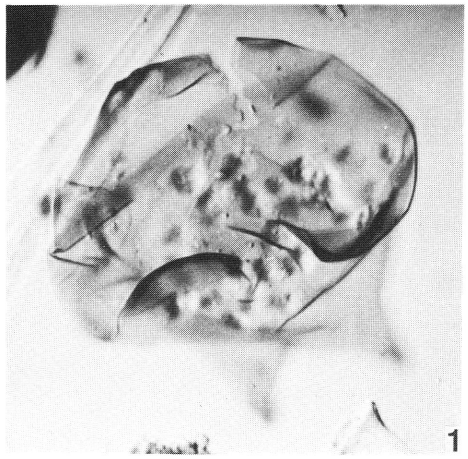
PLATE 13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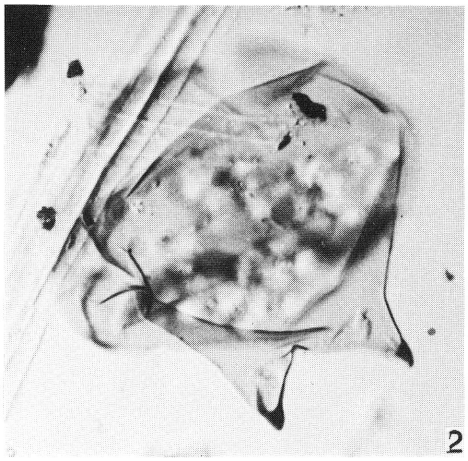
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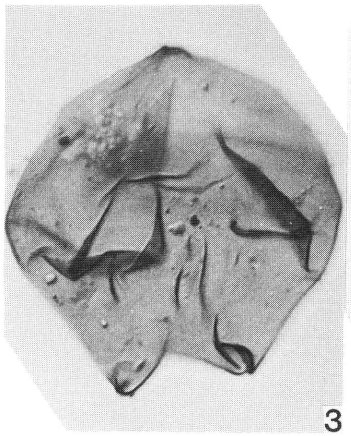
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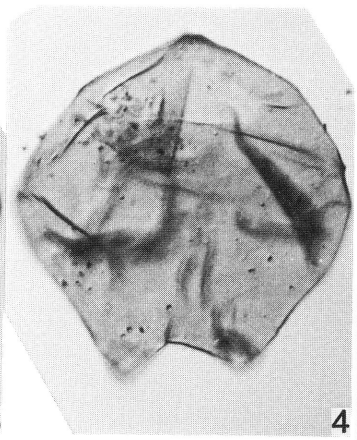
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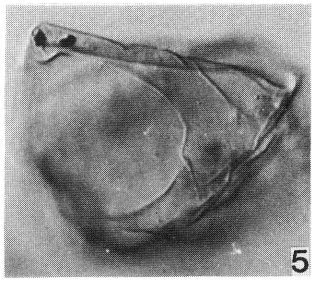
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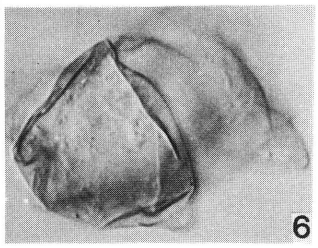
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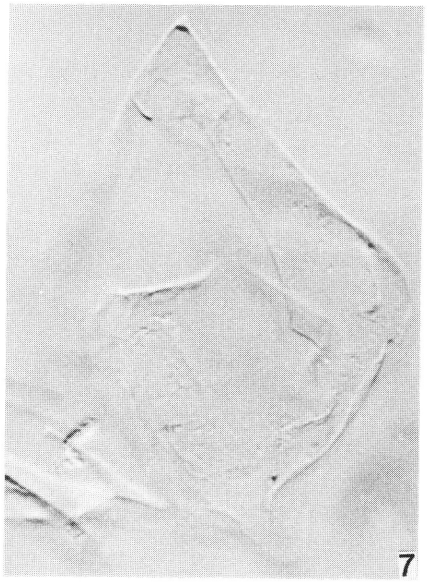
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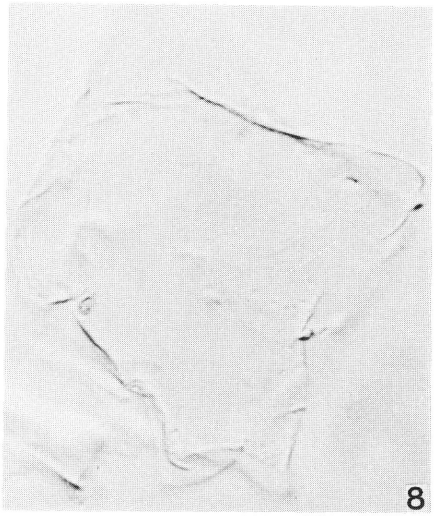
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Explanation of Plate 14

Figs. 1-6 *Votadinium spinosum* Reid

[Cyst of *Protoperidinium claudicans* (Paulsen) Balech]

Figs. 1-3 ; slide SZ 14-2(94.3 / 45.8), 1 ; ventral surface, showing the shallow parasulcus, 2 ; optical cross section, 3 ; dorsal surface.

Figs. 4-5 ; slide SZ 1a-3(89.5 / 32.8), 4 ; optical cross section, 5 ; dorsal surface.

Fig. 6 ; slide SZ 1-1(100.7 / 45.5), oblique lateral view.

Figs. 7-10 *Stelladinium abei* sp. nov.

[Cyst of *Protoperidinium* sp.]

slide SZ 1a-3(81.5 / 34.2), 7 ; ventral surface of the epicyst, showing the apical horn, 8-9 ; optical cross section, showing the well developed paracingulum, 10 ; dorsal surface of the hypocyst, showing two conspicuous antapical horns ; holotype.

Figs. 11-12 Dinoflagellate cyst type B

slide NG 13-2(89.0 / 29.5), 11 ; apical surface, showing the intercalary archeopyle (?), 12 ; antapical surface.

Figs. 13-14 *Brigantedinium cariacoensis* (Wall) Reid

[Cyst of *Protoperidinium avellana* (Meunier) Balech, *Protop. denticulatum* (Gran and Braarud) Balech or *Protop. punctulatum* (Paulsen) Balech]

slide SZ 3-3(98.6 / 26.5), 13 ; optical cross section, 14 ; lateral view, showing a part of the hexagonal intercalary archeopyle.

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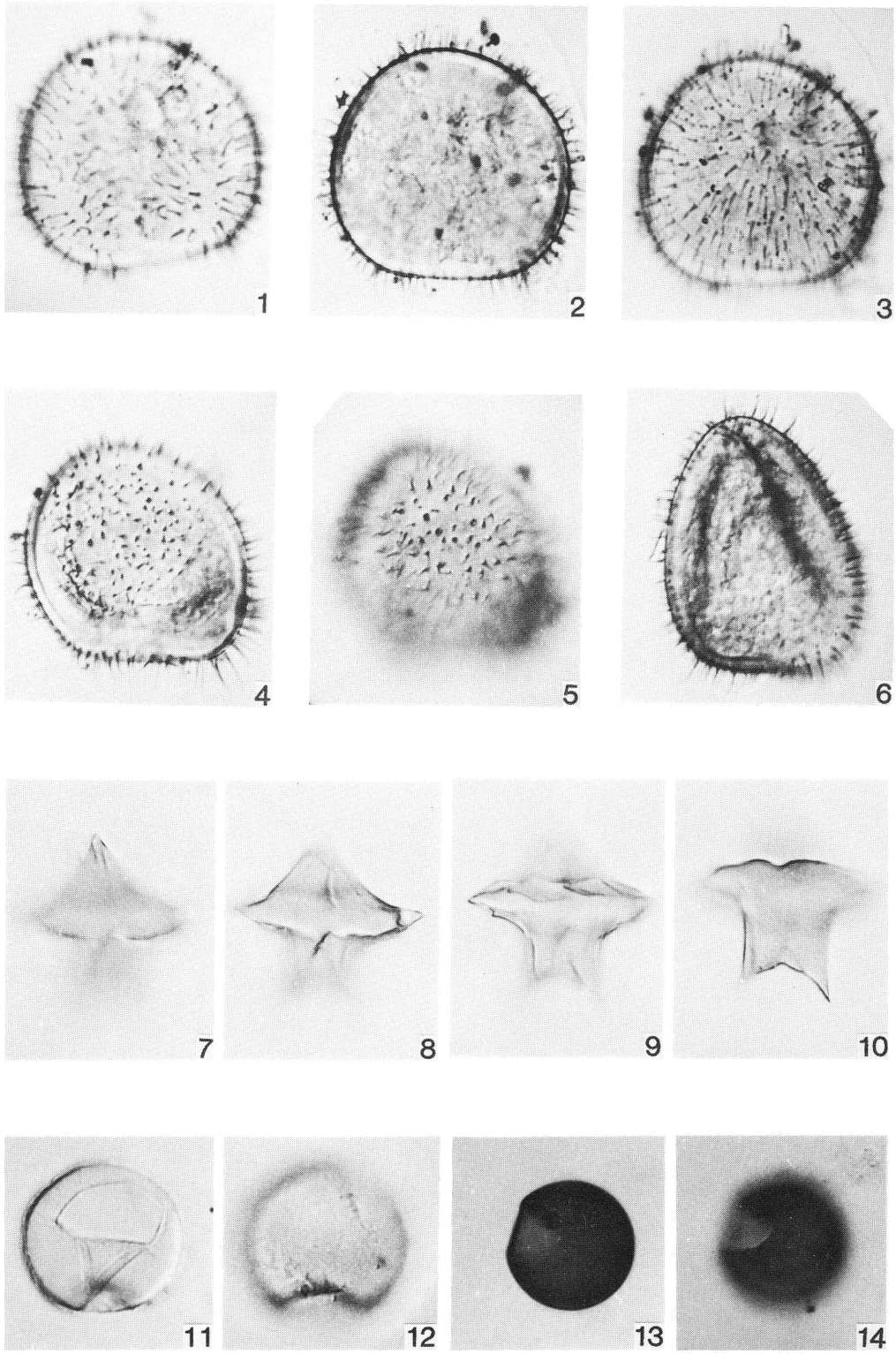
PLATE 14



Explanation of Plate 15

Figs. 1-4 *Brigantedinium majusculum* Reid
[Cyst of *Protoperdinium* sp.]
Figs. 1-2 ; slide NG 13-1(84.5 / 26.2), 1 ; optical cross section, 2 ; oblique dorsal surface, showing the hexagonal archeopyle.
Figs. 3-4 ; slide NG 10-1(90.5 / 44.0), 3 ; oblique dorsal surface showing the archeopyle, 4 ; optical cross section.

Fig. 5 *Brigantedinium simplex* (Wall) Reid ex Harland and Reid
[Cyst of *Protoperidinium conicoides* (Paulsen) Balech]
slide SZ 1a-3(90.3 / 45.1), apical surface(?).

Figs. 6-10 *Selenopemphix alticinctum* (Bradford) comb. nov.
[Cyst of *Protoperidinium subinerme* (Paulsen) Balech]
Figs. 6-8 ; slide SZ 3-1(87.0 / 45.8), 6 ; apical surface, showing the apical horn, 7 ; apical surface, showing the large intercalary archeopyle, 8 ; antapical surface, showing two small antapical horns.
Figs. 9-10 ; slide SZ 14-1(97.4 / 48.2), 9 ; apical surface, 10 ; antapical surface, showing the parasulcus.

Fig. 11 Dinoflagellate cyst type A
slide SZ 1a-3(90.3 / 45.1), showing acuminate processes.

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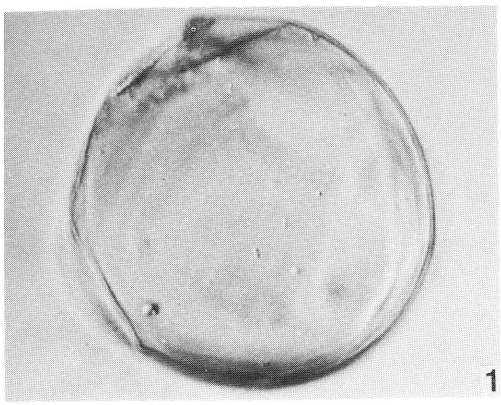
PLATE 15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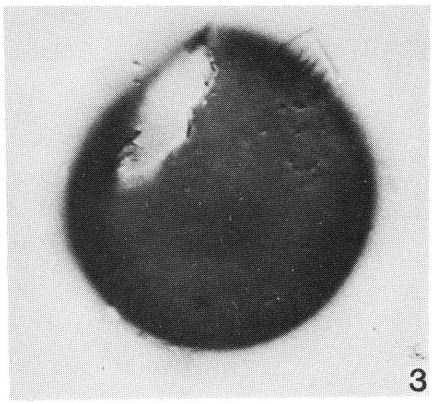
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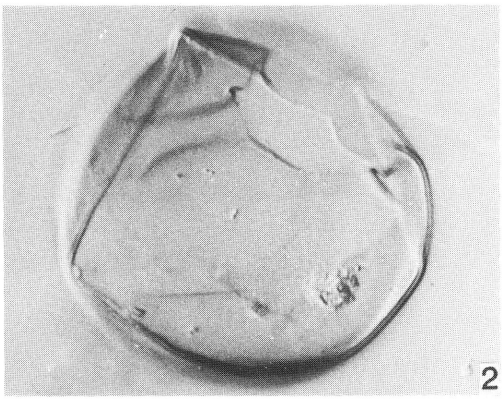
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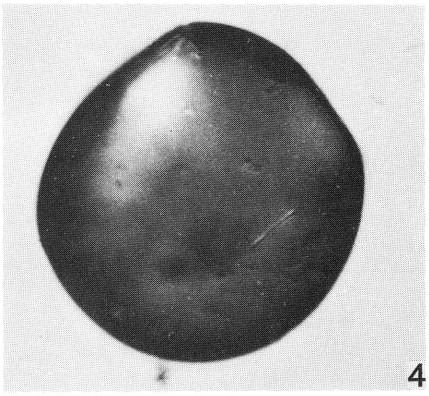
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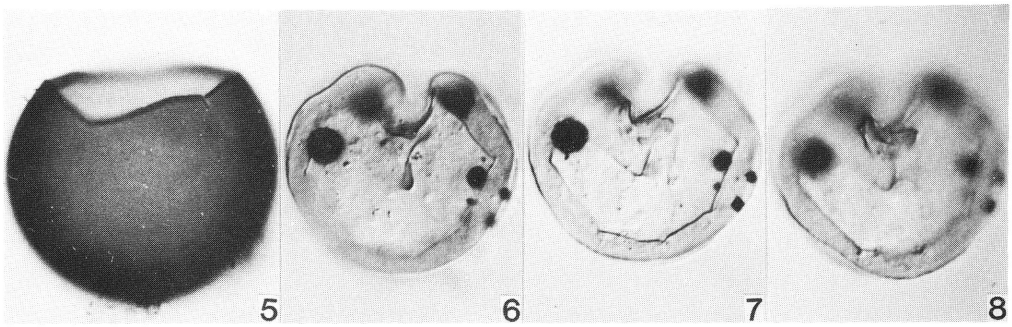
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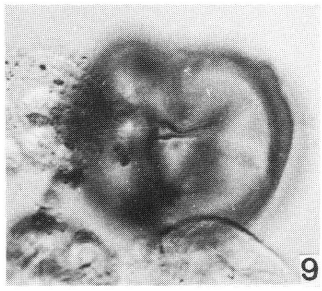
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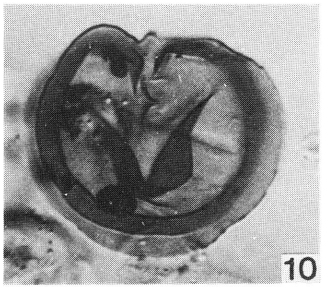
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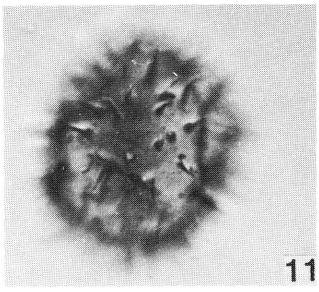
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Explanation of Plate 16

Figs. 1-3 *Polykrikos* sp. cf. *kofoidii* Chatton
slide SZ 1a-1(92.5 / 27.6), 1 ; lateral view, showing the shelf-like ornamentation and the fibrous periphragm, 2 ; optical cross section, 3 ; lateral view at another side.

Figs. 4-10 *Polykrikos schwartzii* Bütschli
Figs. 4-6 ; slide SZ 3-2(94.2 / 48.5) X 390, 4 ; lateral view, showing the coarsely reticulate surface, 5 ; optical cross section.
Figs. 7-8 ; slide NG 13-3(91.4 / 35.0), 7 ; lateral view, showing the tremic archeopyle, 8 ; optical cross section.
Figs. 9-10 ; slide NG 13-2(100.5 / 31.4), lateral view, showing the coarsely reticulate ornamentations.

Figs. 11-12 *Gyrodinium instriatum* Freudental and Lee
slide SZ 1a-3(83.9 / 29.7), 11 ; optical cross section, showing the ovoid armbit, 12 ; surface of the cyst, showing the tremic archeopyle.

Figs. 13-14 Dinoflagellate cyst type E
slide SZ 1a-2(83.7 / 38.2), 13 optical cross section, 14 ; surface of the cyst and processes.

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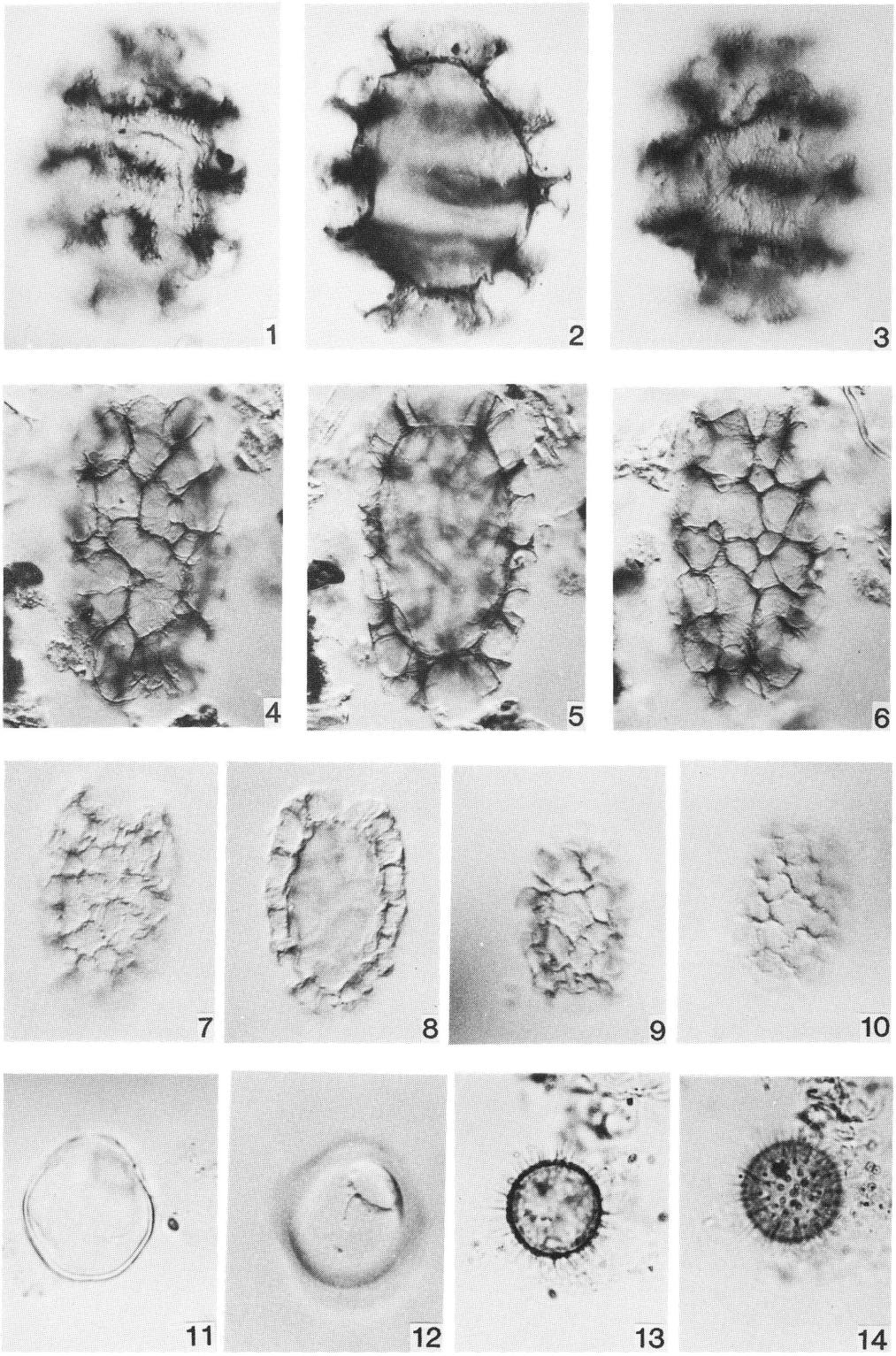
PLATE 16



Explanation of Plate 17

Figs. 1-4 *Pheopolykrikos hartmannii* (Zimmermann) Matsuoka and Fukuyo

Fig. 1 ; slide SZ 1a-3(92.6 / 31.0), optical cross section, showing the chasmic archeopyle.

Fig. 2 ; slide SZ 1a-3(92.6 / 30.7), optical cross section, showing the chasmic archeopyle.

Fig. 3 ; slide SZ 14-2(94.2 / 41.1), surface of the cyst, showing the characteristic processes.

Fig. 4 ; slide SZ 14-2(97.0 / 37.5), optical cross section, showing the chasmic archeopyle.

Figs. 5-6 Dinoflagellate cyst type D

slide NG 15-3(87.3 / 26.7), showing the long subconical processes and the chasmic archeopyle.

Figs. 7-12 Dinoflagellate cyst type C

Figs. 7-9 ; slide NG 15-1(96.4 / 34.0), 7 ; antapical surface (?), 8 ; optical cross section, 9 ; apical surface (?), showing the deformed archeopyle.

Fig. 10 ; slide NG 10-2(86.0 / 39.0), showing the archeopyle.

Figs. 11-12 ; slide NG 13-2(88.4 / 26.0), 11 ; surface of the cyst, 12 ; optical cross section.

Figs. 13-14 *Multispinula*? *minuta* Reid and Harland

slide SZ 3-3(87.2 / 35.5), 13 ; optical cross section, showing the hair-like processes, 14 ; surface of the cyst.

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PLATE 17