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Dinoflagellate Cyst Assemblages in the Surface Sediments from the Northwestern East China Sea

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Thirty-six dinoflagellate cysts, representing 15 genera were identified in the surface sediments obtained from the northwestern East China Sea. Three cyst morphotypes found in this survey have not previously been described in the East China Sea and adjacent waters: *Selenopemphix* sp. 2, *Selenopemphix* sp. 3 and *Trinovantedinium* sp. 1. In the northwestern East China Sea, *Operculodinium centrocarpum*, *Spiniferites bulloideus* and ellipsoidal cysts of *Alexandrium* were commonly observed. Moreover, it was recognized that the ellipsoidal cysts of *Alexandrium*, whose motile cells of *A. tamarense* and/or *A. catenella* are responsible to paralytic shellfish poisoning, distributed not only restricted to the coastal areas but also to the offshore stations far from the Changjiang River mouth.

Key words: Dinoflagellate cysts, The East China Sea, Cyst assemblages, Description

Introduction

The study of dinoflagellate cyst assemblage is useful to interpret the environmental condition of the water column. For example, some cysts are used as indicator for oceanographic features: *Spiniferites mirabilis* as a warm temperate water indicator, whereas *Operculodinium centrocarpum* as a cold water, and *Tuberculodinium vancampoae* as tropical to subtropical inner neritic regions (Versteegh, 1994). Moreover, Kim and Matsuoka (1998) and Matsuoka (1999) investigated eutrophication processes reflected in dinoflagellate cyst assemblages in coastal areas as Omura Bay and Nagasaki Bay in west Kyushu, Japan.

Many studies have clarified cyst-motile cell relationships for modern dinoflagellate cysts by means of excystment and encystment experiments (e.g. Lewis and Dodge, 1987; Lewis, 1991). In spite of those studies, of more than 2000 species of extant dinoflagellates, approximately 80 species are only known to produce a resting cyst in their normal sexual life cycles (Head, 1996). We investigated a literature survey to confirm cyst-motile cell relationships for the cysts found in the study area, and described them.

In this paper, we will show the composition of dinoflagellate cysts recovered from the surface sediments of the northwestern East China Sea, and attempt to record new cyst morphotypes.

Materials and Methods

A research vessel named Ara-ho belonging to Cheju National University in Korea cruised from Cheju Island (Korea) to Shanghai (China), and collected surface sediment samples at 14 stations in 1997 (Fig. 1). Sediment samples were recovered using a gravity core sampler with 35 mm diameter. The sediment in a core was sliced from top to 3 cm, and preserved immediately in a refrigerator till cyst analysis. The subsample was processed following the method of Cho and Matsuoka (1999). Then, we

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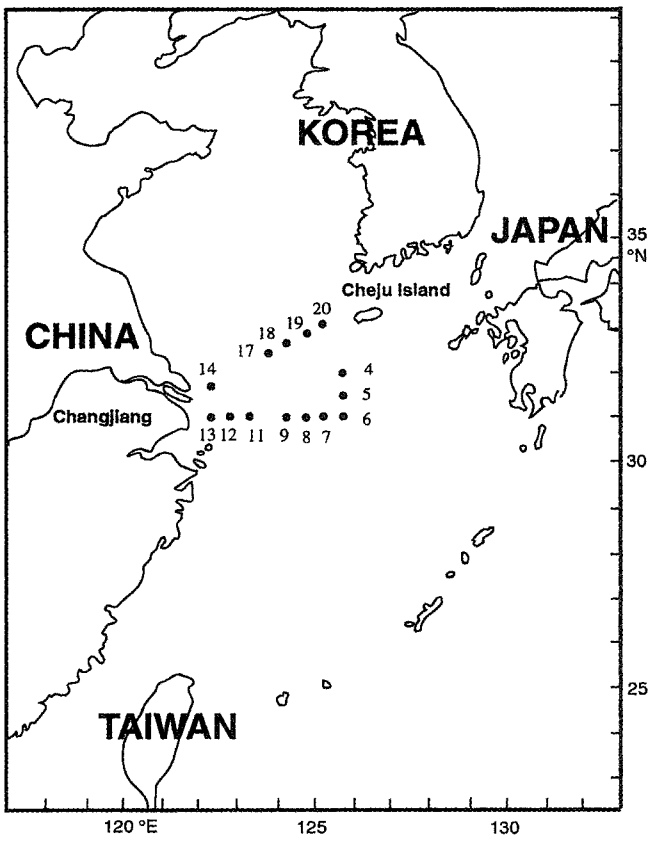


Fig.1. Site map showing surface sediment sampling at the study area.

carried out cyst observation with an inverted microscope (Olympus IX70) equipped with a camera at the magnifications of 100, 200, 400 and 600 times. Sampling dates, locations, water depths and sediment types are shown in Table 1.

Systematic Description

Thirty-six dinoflagellate cysts, representing 15 genera and six groups, were identified from the northwestern East China Sea (Table 2). On the basis of previous studies, cyst-theca relationships in the study are summarized in Table 3.

Gonyaulacoid Group

Genus *Alexandrium*

Most *Alexandrium* cysts are characterized by ellipsoidal, spherical or ovoidal transparent types, sometimes with reddish accumulation bodies and covered with mucilaginous material. In this study, three types of *Alexandrium* cysts (ellipsoidal, spherical and ovoidal) were observed.

Table 1. Water depth, latitude and longitude at each station. Surface sediment sampling was carried out in 1997

Station	Date	Water Depth (m)	Latitude (N)	Longitude (E)	Sediment Type
4	Aug. 26	80	32° 00′	126° 00′	mud
5	Aug. 27	55	31° 30′	126° 00′	mud
6	Aug. 27	55	31° 00′	126° 00′	muddy sand
7	Aug. 27	55	31° 00′	125° 30′	sandy mud
8	Aug. 27	55	31° 00′	125° 00′	sandy mud
9	Aug. 27	35	31° 00′	124° 30′	silty sand
11	Aug. 28	35	31° 00′	123° 30′	silty sand
12	Aug. 28	35	31° 00′	123° 00′	sandy mud
13	Aug. 28	15	31° 00′	122° 30′	mud
14	Sep. 3	15	31° 45′	122° 30′	silt
17	Sep. 3	35	32° 30′	124° 00′	sandy mud
18	Sep. 4	35	32° 45′	124° 30′	muddy sand
19	Sep. 4	55	33° 00′	125° 00′	muddy sand
20	Sep. 4	95	33° 15′	125° 30′	silty sand

Alexandrium sp. 1 (ellipsoidal cyst)

The cyst was ellipsoidal (46~51 μm in length) and transparent, and sometimes had a shrunken cytoplasm. It was often coated by mucilaginous material, expanding approximately 10 μm all around the cyst. The ellipsoidal *Alexandrium* cysts distributed all stations except station 13, which was the nearest site to the mouth of the Changjiang River.

Photo: plate 1, fig. 6.

Distribution: all stations except station 13.

Equivalent thecate form: *Alexandrium catenella, A. tamarense.*

Alexandrium sp. 2 (spherical cyst)

The cyst was transparent and spherical. Mucilaginous substance was not observed in the cyst.

Distribution: stations 8, 19.

Equivalent thecate form: *Alexandrium affine, A. andersonii, A. leei, A. margalefi.*

Genus *Lingulodinium*

Lingulodinium machaerophorum (Deflander & Cookson) Wall

The cyst was round and transparent with long and stout processes (11 μm in length, 3 μm in width) pointing toward tips. Diameter of the cyst was 56 μm.

Table 2. The presence and absence of dinoflagellate cysts at each station

Species/Stations		4	5	6	7	8	9	11	12	13	14	17	18	19	20	Photos
Gonyaulacoid group																
Alexandrium	sp. 1 (ellipsoidal)	*	*	*	*	*	*	*	*		*	*	*	*	*	plate 1, fig. 6
	sp. 2 (spherical)					*								*		—
	sp. 3 (ovoidal)													*		—
Lingulodinium	*machaerophorum*			*					*	*						plate 1, fig. 7
Spiniferites	*bentorii*	*										*	*	*	*	plate 1, fig. 1
	bulloideus	*	*	*	*	*	*	*			*	*	*	*	*	plate 1, fig. 3
	hyperacanthus		*	*												plate 1, fig. 2
	membranaceus											*				—
	mirabilis	*		*		*		*							*	plate 1, figs. 4, 5
	ramosus	*			*	*		*			*		*	*	*	—
	spp.	*	*		*	*	*	*	*	*	*	*	*	*	*	—
Operculodinium	*centrocarpum*	*		*	*	*	*	*				*	*	*	*	plate 1, fig. 8
	israelianum														*	—
Tuberculodinioid group																
Tuberculodinium	*vancampoae*		*			*							*	*		plate 2, fig. 1
Protoperidinioid group																
Brigantedinium	*auranteum*			*	*											plate 2, fig. 2
	cariacoense		*				*	*	*			*				plate 2, fig. 3
	simplex						*									plate 2, fig. 4
	spp.	*		*	*	*	*		*	*		*	*	*		—
Protoperidinium	*latissinum*				*											plate 4, fig. 1
	sp. 1						*									plate 2, fig. 8
	sp. 2										*					plate 2, fig. 7
Selenopemphix	*alticintum*								*							plate 3, fig. 3
	quanta						*									plate 3, fig. 4
	sp. 1						*									plate 3, fig. 7
	sp. 2										*	*				plate 4, figs. 2, 3
	sp. 3		*													plate 3, fig. 2
Steladinium	*reidii*		*	*								*				plate 4, fig. 4
Trinovantedinium	*capitatum*				*	*										plate 3, fig. 6
	sp. 1					*										plate 3, fig. 5
Votadinium	*calvum*							*	*							plate 2, figs. 5, 6
	spinosum									*						plate 3, fig. 1
Diplopsalid group																
Diplopelta	*parva*								*							plate 4, fig. 7
Diplopsalis	*lenticula*						*									*plate 4, fig. 8*
Calciodinellid group																
Scripssiella	*trochoidea*	*	*	*	*	*			*			*		*	*	plate 1, fig. 9
Gymnodinioid group																
Polykrikos	*kofoidii*								*			*				plate 4, fig. 6
	sp. 1 (reticulum)							*								plate 4, fig. 5

Photo: plate 1, fig. 7.

Distribution: stations 6, 12, 13.

Equivalent thecate form: *Lingulodinium polyedra.*

Genus *Spiniferites*

Spiniferites are ovoidal or elongated shaped cysts covered with gonal and/or intergonal processes. The processes are various from long, thin, hollow ones to sutural membrane, with bi- or trifurcate tips. In this study, six morphotypes of *Spiniferites* were obtained, *S. bentorii, S. bulloides, S. hyperacanthus, S. membranaceus, S. mirabilis* and *S. ramosus,* and with other unidentified *Spiniferites. Spiniferites mirabilis* was sometimes found in very large size (66 μm in length) with long stout processes (12 μm in length) (plate 1, fig. 5).

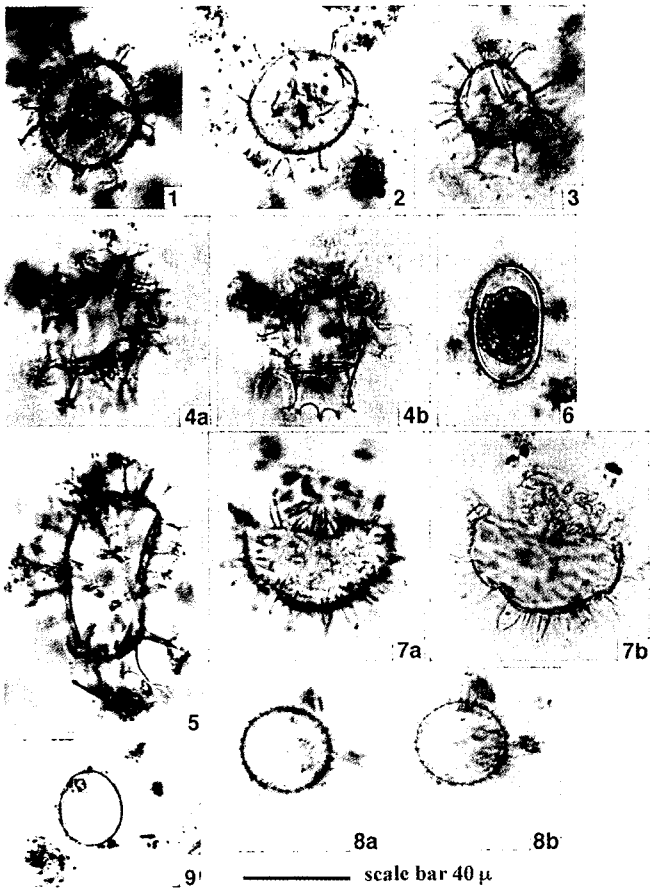
Photo: *Spiniferites bentorii* (plate 1, fig. 1), *S. bulloideus* (plate 1, fig. 3), *S. hyperacanthus* (plate

Table 3. List of dinoflagellate cysts observed in the study area and cyst-theca relationship based on literature survey

Cyst in the Study Area		Nomenclature of Motile Species	Reference Carried out Germination Experiment
		Order Gonyaulacales	
Goniaulacoid group		**Family Gonyaulacaceae**	
Alexandrium	sp. 1 (ellipsoidal)	*Alexandrium tamarense*	Qi et al., 1996; Anderson, 1980
		A. catenella	Sonneman and Hill, 1997
	sp. 2 (spherical)	*A. affine*	Hallegraeff et al., 1991
		A. andersonii	Matsuoka et al., 2000
		A. leei	Fukuyo and Pholpunthin, 1990
		A. margalefi	Hallegraeff et al., 1991
	sp. 3. (ovoid)	*A. minutum*	Bolch et al., 1991
Lingulodinium	*machaerophorum*	*Lingulodinium polyedra*	Wall and Dale, 1968; Nehring, 1997
Spiniferites	*bentori*	*Gonyaulax digitalis*	Wall and Dale, 1968
	bulloideus	*G. scrippsae*	Wall and Dale, 1968
	hyperacanthus	*G. spinifera*	Matsuoka and Fukuyo, 2000
	membranaceus	*G. spinifera*	Bolch and Hallegraeff, 1990; Sonneman and Hill, 1997
	mirabilis	*G. spinifera*	Sonneman and Hill, 1997
	ramosus	*G. spinifera*	Matsuoka and Fukuyo, 2000
	spp.	–	–
Operculodinium	*centrocarpum*	*Protoceratium reticulatum*	Wall and Dale, 1968; Sonneman and Hill, 1997; Nehring, 1997
	israelianum	*Protoceratium reticulatum*	–
Tuberculodinioid group		**Family Pyrophaceae**	
Tuberculodinium	*vancampoae*	*Pyrophacus steinii*	Pholpunthin et al., 1999
		Order Peridiniales	
Protoperidinioid group		**Family Protoperidiniaceae**	
Brigantedinium	*auranteum*	unknown	–
	cariacoense	*Protoperidinium avellanum*	Lewis et al., 1984; Matsuoka, 1984; Sonneman and Hill, 1997
		P. denticulatum	Reid, 1977
		P. punctulatum	Nehring, 1997
	simplex	*P. conicoides*	Lewis et al., 1984; Nehring, 1997; Sonneman and Hill, 1997
	spp.	–	–
Protoperidinium	*latissinum**	*P. latissinum*	Wall and Dale, 1968
	spp.	–	–
Selenopemphix	*alticintum*	*P. subinerme*	Nehring, 1997
	quanta	*P. conicum*	Kobayashi and Matsuoka, 1984; Bolch and Hallegraeff, 1990; Nehring, 1997
	spp.	–	–
Steladinium	*reidii*	*P.* sp. cf. *compressum*	Matsuoka and Fukuyo, 2000
Trinovantedinium	*capitatum*	*P. pentagonum*	Lewis et al., 1984
		Peridinium sp. cf. P. pentago	Wall and Dale, 1968
		Protopdridinium sp.	Inoue, 1990
	sp.	–	–
Votadinium	*calvum*	*P. oblongum*	Bolch and Hallegraeff, 1990; Sonneman and Hill, 1997
	spinosum	*P. claudicans*	Wall and Dale, 1968; Lewis et al., 1984
Diplopsalid group		**Family Diplopsalidaceae**	
Diplopelta	*parva**	*Diplopelta parva*	Bolch and Hallegraeff, 1990
Diplopsalis	*lenticula**	*Diplopsalis lenticula*	Matsuoka, 1988; Nehring, 1997
Calciodinellid group		**Family Calciodinellaceae**	
Scrippsiella	*trochoidea**	*Scrippsiella trochoidea*	Bolch and Hallegraeff, 1990; Sonneman and Hill, 1997
		Order Gymnodiniales	
Gymnodinioid group		**Family Polykrikaceae**	
Polykrikos	*kofoidii**		Morey-Gaines and Ruse, 1980
	sp. 1 (reticulum)	*Polykrikos kofoidii*	Fukuyo, 1981; Matsuoka and Cho, 2000
		P. schwartzii	Dale, 1976

Nomenclature marked at cyst with asterisk (*) means the same name as the motile species.
Almost of the cited references are selected to carry out germination experiments; (–) indicates no germination experiment yet, while underline means informed from the references without germination experiment.

PLATE 1



1, fig. 2), *S. mirabilis* (plate 1, figs. 4, 5).

Distribution: all stations.

Equivalent thecate form: *Gonyaulax scrippsae* (*Spiniferites bulloideus*), *G. digitalis* (*S. bentorii*), *G. spinifera* (*S. hyperacanthus, S. membranaceus, S. mirabilis, S. ramosus*).

Remark: So far, several dinoflagellate cysts were incubated to produce motile thecae which were identical to a dinoflagellate described as *Gonyaulax spinifera*. These cysts included *Nematospheropsis balcombiana, Spiniferites mirabilis* and *Tectatodinium pellitum* in Wall and Dale (1968) and *S. elongatus* in Nehring (1997). Besides, *Spiniferites hyperacanthus, S. membranaceus* and *S. ramosus* have been recognized for the cysts of *G. spinifera*. According to Sonneman and Hill (1997), it is possible that *G. spinifera* encompasses several closely related species currently classified as one.

Genus *Operculodinium*

Spherical cysts ornamented with numerous processes. *Operculodinium centrocarpum* and *O. israelianum* were observed in the study.

Operculodinium centrocarpum sensu Wall et Dale

The diameter was 34.1 μm. Trapezoidal archeopyle was seen.

Photo: plate 1, fig. 8.

Distribution: stations 4, 6, 7, 8, 9, 11, 17, 18, 19, 20.

Equivalent thecate form: *Protoceratium reticulatum*.

Remark: *Protoceratium reticulatum* produces at least two morphologically different resting cysts, which correlate with the fossil species *O. centrocarpum* and *O. psilatum* (Wall and Dale, 1968). *Operculodinium israelianum* may be another kind of *P. reticulatum* cyst, because it is the intermediate member in a fossil morphological series which has *O. centrocarpum* and *O. psilatum* as its end members (Wall and Dale, 1968). According to Nehring (1997), a clear tendency for reduced process length (mainly 3~8 μm) in *P. reticulatum* cysts in shallower stations from the western Baltic was discernible when compared to the cyst processes from the marine German Bight (mainly 9~10 μm). Nehring (1997) suggested that *P. reticulatum* has morphological cyst variability in response to salinity regime.

Protoperidinioid Group

Genus *Brigantedinium*

Brigantedinium is characterized by a spherical form and brownish color. *Brigantedinium auranteum, B. cariacoense, B. simplex* and three types of other *Brigantedinium* were observed in the study.

Brigantedinium auranteum Reid

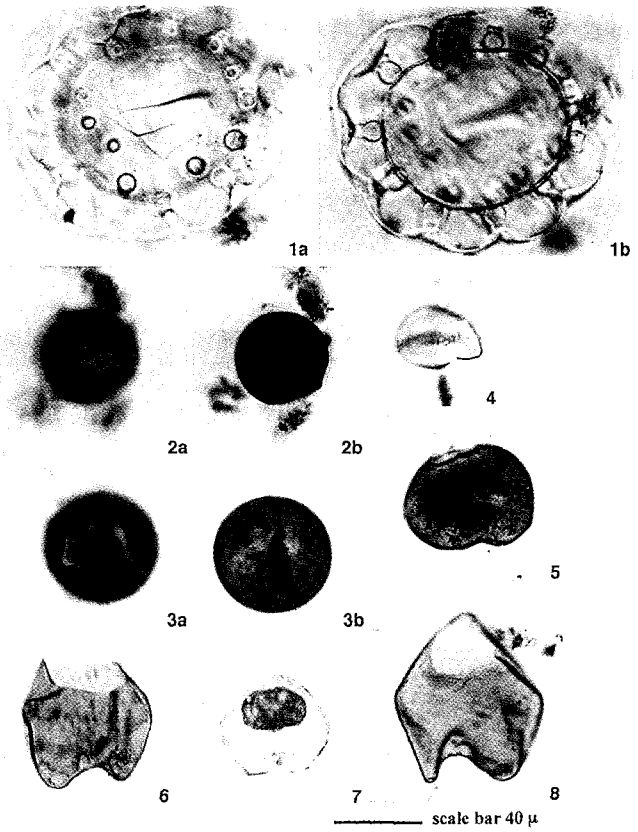
The cyst had a big archeopyle (19~24 μm in length, 26~39 μm in width), which was hexagonal and somewhat broadened toward the central part. Diameter of the cyst ranged from 44 to 54 μm.

Photo: plate 2, fig. 2.

Distribution: stations 6, 7.

Equivalent thecate form: unknown.

PLATE 2



Brigantedinium cariacoense (Wall) Reid

Laterally elongated hexagonal or elongated trapezoidal archeopyle (approximately 19 μm in length, 34 μm in width) was observed. Diameter of the cyst was 54 μm.

Photo: plate 2, fig. 3.

Distribution: stations 5, 9, 11, 12, 17.

Equivalent thecate form: *Protoperidinium avellanum, P. denticulatum, P. punctulatum.*

Brigantedinium simplex Reid

The cyst was pale brown with a trapezoidal archeopyle (17 μm in length, 24 μm in width). Diameter of the cyst was 41 μm.

Photo: plate 2, fig. 4.

Distribution: station 9.

Equivalent thecate form: *Protoperidinium conicoides.*

Remark: It is difficult to identify *Brigantedinium* species without observation of archeopyle. The shape of archeopyle is one of the most important criteria to identify *Brigantedinium*. In spite of active incubation experiments with *Brigantedinium*, a lot of confusion still leaves in correspondence with the motile cells. For example, *Protoperidinium avellana* germinated from *B. cariacoense* in Lewis et al. (1984), Matsuoka (1984) and Sonneman and Hill (1997), while *P. punctulatum* was also germinated from the cyst morphotype of *B. cariacoense* in Nehring (1997).

Genus ***Protoperidinium***

Protoperidinium latissinum (Kofoid) Balech

The cyst was dorso/ventrally compressed with a pale brown color. Two antapical horns were developed. The cyst body was 68 μm in length and 59 μm in width.

Photo: plate 4, fig. 1.

Distribution: station 7.

Equivalent thecate form: the same nomenclature.

***Protoperidinium* sp. 1**

This cyst was pale brown with a large archeopyle. It was characterized by two asymmetric antapical horns; right side one was thicker than the left in dorsal view.

Photo: plate 2, fig. 8.

Distribution: station 9.

Equivalent thecate form: unknown.

***Protoperidinium* sp. 2**

This cyst was pale brown and dorso/ventrally compressed (49 μm in length, 51 μm in width), and had a shrunken cytoplasm inside the cyst. Paracingulum was clear around the central part of the cyst. In ventral view, an excavated parasulcus was seen.

Photo: plate 2, fig. 7.

Distribution: station 14.

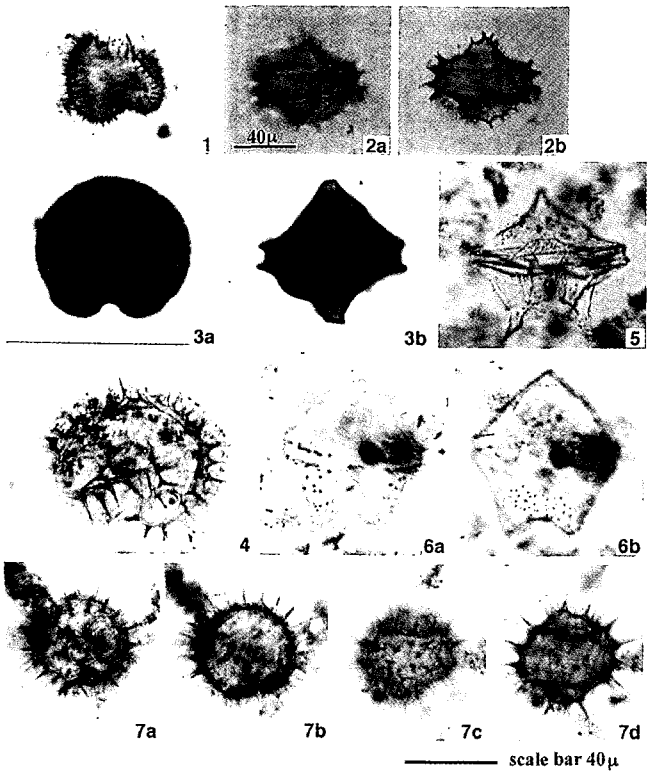
Equivalent thecate form: unknown.

Remark: A few motile cells of *Protoperidinium* share this genus name with the cysts. *Protoperidinium* cysts generally have a pentagonal shape and a brownish cyst wall. One apical horn and two antapical horns are characteristic.

Genus ***Selenopemphix***

Selenopemphix alticintum (Bradford) Matsuoka

PLATE 3



The cyst was brown and somewhat compressed apical/antapically (63 μm in length, 66 μm in width). Smooth surface and, no spine were found. Paracingulum was deeply excavated.

Photo: plate 3, fig. 3.

Distribution: station 12.

Equivalent thecate form: *Protoperidinium subinerme.*

Selenopemphix quanta **(Bradford) Matsuoka**

The cyst was also apical/antapically compressed, but it differed from *S. alticintum* in having numerous needle-like spines (up to 12 μm in length) on the cyst wall.

Photo: plate 3, fig. 4.

Distribution: station 9.

Equivalent thecate form: *Protoperidinium conicum.*

Selenopemphix **sp. 1**

This was differentiated from *S. quanta* in a smaller size and not compressed apical/antapically. The similar cyst type was already observed in Sonneman and Hill (1997) as the name of *Protoperidinium* cf. *nudum.*

Photo: plate 3, fig. 7.

Distribution: station 9.

Equivalent thecate form: *Protoperidinium* cf. *nudum* (?).

Selenopemphix **sp. 2**

The cyst was similar to *S. alticintum* with developed paracingulum. But this cyst was not apical/antapically compressed (46~49 μm in length, 39~44 μm in width), and two antapical horns were detectable. A large pentagonal archeopyle was seen.

Photo: plate 4, figs. 2, 3.

Distribution: stations 14, 17.

Equivalent thecate form: unknown.

Selenopemphix **sp. 3**

The cyst was similar to *S. quanta,* but shorter (about 5 μm in length) and not so pointed spines differentiated the cyst from *S. quanta.*

Photo: plate 3, fig. 2.

Distribution: station 5.

Equivalent thecate form: unknown.

Remark: *Protoperidinium subinerme* germinated from *Selenopemphix alticinctum* in Nehring (1997), while it could also germinate from a smooth, spherical and dark brown cyst in Lewis et al. (1984).

Genus *Trinovantedinium*

Trinovantedinium capitatum **Reid**

The cyst was entirely pentagonal and colorless with many short spines. It was easy to recognize paratabulation because the spines ornamented the cyst surface avoiding the parts of paracingulum and parasulcus.

Photo: plate 3, fig. 6.

Distribution: stations 7, 8.

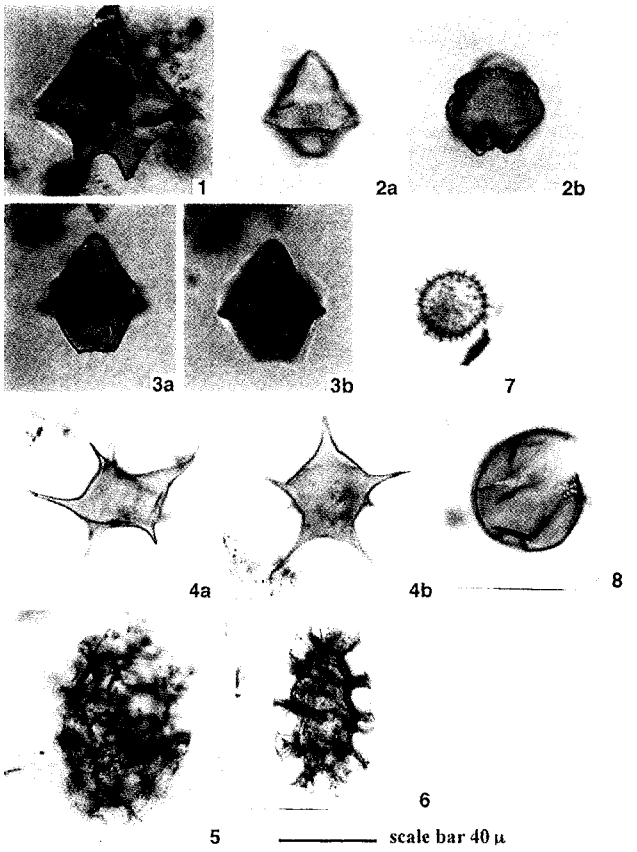
Equivalent thecate form: *Protoperidinium* sp., *P. pentagonum, Peridinium* sp. cf. *P. pentagonum.*

Trinovantedinium **sp. 1**

The cyst was similar to *T. capitatum,* but it had a prominently pointed apical horn and two sharp antapical horns. Particularly, parasulcus and paracingulum developed, which were not just marked by arrangement of spines as those of *T. capitatum.*

Photo: plate 3, fig. 5.

PLATE 4



Distribution: station 8.
Equivalent thecate form: unknown.

Remarks: Lewis et al. (1984) incubated a cyst of *Trinovantedinium capitatum* and found *Protoperidinium pentagonum* germinated from the cyst. But Inoue (1990) reported that the motile cell, which was germinated from *T. capitatum*, had a longer thecae than *P. pentagonum* and cingulum scarcely displaced. Inoue (1990) suggested that the germing cell probably differed from *P. pentagonum*. *Trinovantedinium capitatum* recovered in the study resembled the cyst of *Peridinium* sp. cf. *P. pentagonum* in Wall and Dale (1968).

Genus *Votadinium*

Votadinium is characterized by having a heart shape and compressed dorso/ventrally. *Votadinium calvum* and *V. spinosum* were identified in the study. The latter differs from the former in possession of the spines.

Votadinium calvum Reid

This cyst was a smooth heart shape (49 μm in length, 59 μm in width) with two round antapical horns. Large and broad archeopyle was often found.

Photo: plate 2, figs. 5, 6.
Distribution: stations 11, 12.
Equivalent thecate form: *Protoperidinium oblongum.*

Votadinium spinosum Reid

The cyst was a brownish heart shaped cyst (39 μm in length, 42 μm in width) with numerous short spines.

Photo: plate 3, fig. 1.
Distribution: station 13.
Equivalent thecate form: *Protoperidinium claudicans.*

Calciodinellid Group

Genus *Scrippsiella*

Scrippsiella trochoidea (Stein) Loeblich III

The cyst had calcareous processes, but the processes were melted after the hydrochloric acid treatment (10% HCl). Then a pockmarked cyst surface was left. Orange to red accumulation body often appeared.

Photo: plate 1, fig. 9.
Distribution: stations 4, 5, 6, 7, 8, 12, 17, 19, 20.
Equivalent thecate form: the same nomenclature.

Gymnodinioid Group

Genus *Polykrikos*

Polykrikos spp.

Two types of *Polykrikos* cysts were observed, *P. kofoidii* cyst with rod-like processes and *Polykrikos* sp. 1 with reticulum.

Photo: *P. kofoidii* (plate 4, fig. 6), *Polykrikos* sp. 1 (plate 4, fig. 5).
Distribution: stations 11, 12, 17.
Equivalent motile nomenclature: the same nomenclature (*P. kofoidii*), *P. kofoidii* and *P. schwartzii* (*Polykrikos* sp. 1).

Remark: The cyst of *P. schwartzii* was considered to be characterized by reticulate ornament, and that of *P. kofoidii* by separate, rod-like processes (Morey-Gaines and Ruse, 1980). Then, Matsuoka

and Cho (2000) suggested that the taxonomic criterion that *Polykrikos* cysts with reticulate ornament were identical to *P. schwartzii* and those with rod-like form to *P. kofoidii* was untenable, because cysts of *P. kofoidii* had not only variants with rod-like processes but also had a reticulum, and their intermediate forms existed. However, confusion still remains in the *Polykrikos* cyst morphology.

Discussion

Most dinoflagellate cysts are morphologically very different from the motile stages. Hence, their natural affinities remained unknown until the early 1960s, when paleontologists discovered living equivalents and showed these to be non-motile, benthic resting cysts of dinoflagellates (Wall and Dale, 1968; Dale, 1983). Wall and Dale (1968), as a pioneer research, established detailed correlation between many living and fossil dinoflagellates. The relationships for dinoflagellates are, however, not totally established and much confusion between the resting and motile stages still remains.

The cysts herein demonstrate that the above described cyst assemblages are commonly found in most of the East China Sea and the adjacent waters (e.g. Lee and Matsuoka, 1994, 1996; Qi et al., 1996; Matsuoka et al., 1999; Matsuoka and Kim, 1999). Three cyst morphotypes found in this survey have not been previously described from near the study area: *Selenopemphix* sp. 2 (plate 4, figs. 2, 3), *Selenopemphix* sp. 3 (plate 3, fig. 2) and *Trinovantedinium* sp. 1 (plate 3, fig. 5).

In the study, *Operculodinium centrocarpum, Spiniferites bulloideus* and ellipsoidal cysts of *Alexandrium* were observed from almost of the stations. According to Wilpshaar and Leereveld (1994), the *Spiniferites* group reached their highest abundance in open marine neritic conditions and *O. centrocarpum* was rather common in outer neritic condition. It coincides with the characteristic of the cyst distribution in this survey that the two cyst types were almost completely absent from the stations adjacent to the Changjiang River mouth, while abundantly distributed toward offshore stations (Table 2). *Alexandrium tamarense* and *A. catenella* which are causative species of paralytic shellfish poisoning at the coastal areas of west Japan (Kotani et al., 1998) share a common cyst type of the ellipsoidal form (Table 3). Therefore, it is difficult to determine the motile cell of ellipsoidal *Alexandrium* cysts. The ellipsoidal *Alexandrium* cysts occurred at all stations, except station 13 in the study. Qi et al. (1996) reported that the sediments collected from the stations along the coasts of the South and East China Seas had ellipsoidal *Alexandrium* cysts, and *A. tamarense* was successfully germinated from the cysts. It is not obvious that the motile forms of the ellipsoidal *Alexandrium* cysts found in the study were *A. tamarense*. It is, however, clear that they distributed not just restricted to the coastal area but also at the offshore stations far from the Changjiang River mouth. For the final confirmation of species, germination experiments on the ellipsoidal *Alexandrium* cysts and other unidentified cyst species collected from the present sampling stations should be warranted.

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