

**Loricata and scale-bearing protists from Lützow-Holm Bay,  
Antarctica II. Four marine species of *Paraphysomonas*  
(Chrysophyceae) including two new species from the  
fast-ice covered coastal area\***

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In a one year survey carried out from February 1983 to January 1984 at four sampling sites in the fast-ice covered coastal area north of East Ongul Island (69°00'S, 39°35'E), Antarctica, four marine species of *Paraphysomonas* (Paraphysomonadaceae, Chrysophyceae) were found. They were recorded for the first time in the Antarctic, and two of these species are new to science. One of these, *P. antarctica* n. sp., belongs to the *imperfurata* group, and the other, *P. oligocycla* n. sp., to the *foraminifera* group. The two previously described species are *P. vestita* and *P. butcheri*.

*Key Index Word:* Antarctic Ocean; Fast-ice covered coast; Chrysophyceae; East Ongul Island; New marine species; *Paraphysomonas*; Taxonomy.

Since the time that two new marine species of the originally monospecific genus *Paraphysomonas* were described by LUCAS in 1967 (LUCAS 1967), many freshwater and marine species of this genus have been found in many parts of the world. Until now, 48 taxa in total have been described. Among them, 39 have been found in freshwater, 6 in seawater, and 3 in both fresh and sea-water (REES et al. 1974; PREISIG and HIBBERD 1982a, 1982b; WUJEK 1983). They were classified into 11 groups based on their scale structures (PREISIG and HIBBERD 1982b, 1983). One of the marine taxa, *P. imperfurata* is widely distributed in brackish water and seawater from the coast of Norway in the Northern hemisphere (LEADBEATER 1972) to the

coast of New Zealand in the Southern hemisphere (MOESTRUP 1979). This organism, showing little variation in scale structure, have been recorded from freshwater lakes and ponds in many countries between Sweden in the Northern hemisphere (CRONBERG and KRISTIANSEN 1980) and Chile in the Southern hemisphere (DÜRRSCHMIDT 1980). The type species of this genus, *P. vestita*, is also recorded from many freshwater and some seawater localities throughout the world (PREISIG and HIBBERD 1982a). Altogether, this genus is widely distributed in both freshwater and seawater all over the world from ca. 65°N to 40°S.

Furthermore, four marine species of this genus, two of them new to science, were found in the fast-ice covered coastal area north of East Ongul Island, Antarctic Ocean. One of the new species belongs

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to the *imperfurata* group and other to the *foraminifera* group.

Their characteristics are described and the taxonomy of the *imperfurata* group is discussed in this paper.

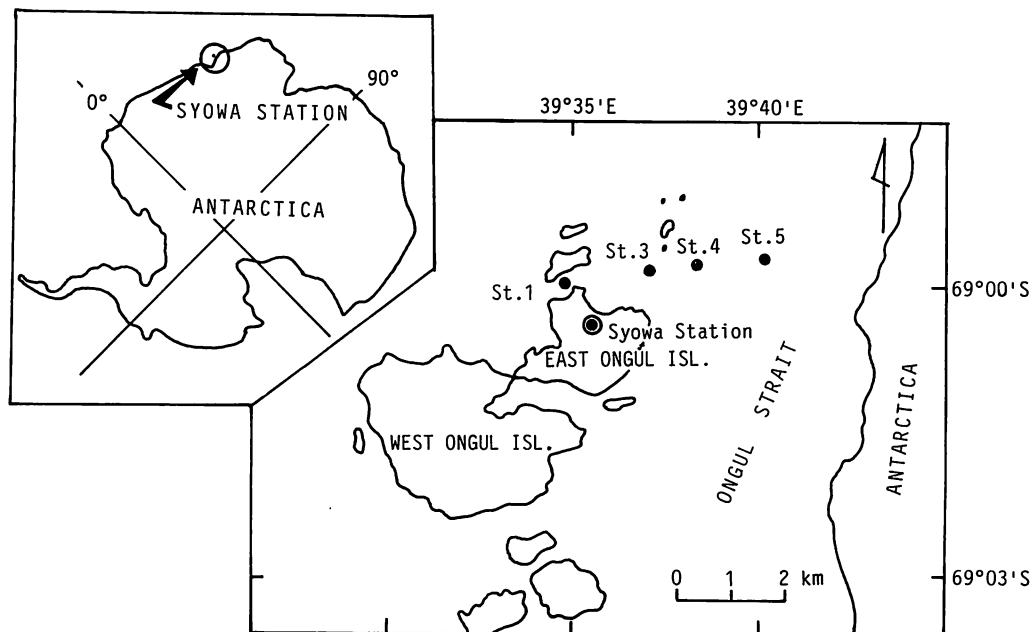
### Materials and Methods

Seawater and sea ice core samples were collected at four sampling sites (Stations 1, 3, 4 and 5) on the fast-ice at the coastal area north of the Syowa Station, East Ongul Island (69°00'S, 39°35'E) in the Lützow-Holm Bay, from February 1983 to January 1984 (Map. 1). The depth to the sea bottom at Stations 1, 3, 4 and 5 were ca. 12, 38, 160, and more than 700 meters respectively. Seawater samples were collected with a Van Dorn bottle from the following depths at each station: 2, 5, 8 and 11 m at St. 1; 2, 5, 10, 15, 25 and 35 m at St. 3; 2, 5, 10, 25, 50, 75, 100 and 150 m at St. 4; 2, 5, 10, 25, 50, 75,

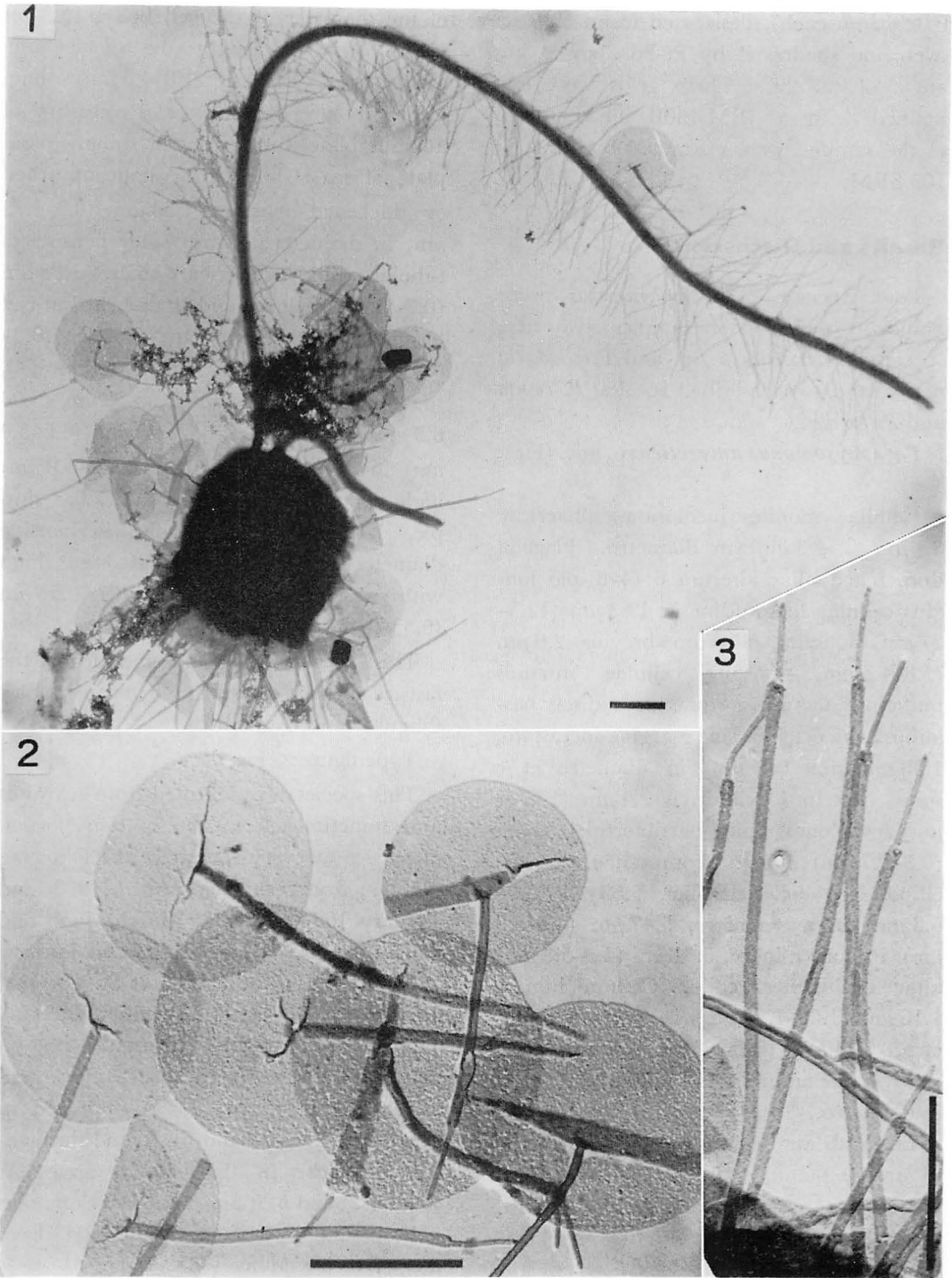
100, 150, 200, 400 and 600 m at St. 5. In addition to these samples, surface water samples were taken in 0.5 l polyethylene bottles from a depth of ca. 10 cm at the sampling hole at each station. Fast-ice cores were taken with a SIPRE electric ice core sampler from each sampling station. The thickness of sea ice varied from ca. 50 to 120 cm. Except for one day, May 3 1983, when the pack ice was blown offshore, the Ongul Islands remained icebound.

The climatic and oceanographic conditions in this area have been described in another paper (WATANABE et al. 1986).

The method used to examine the seawater and sea ice samples by use of the scanning electron microscope (SEM) is described in a previous paper (TAKAHASHI et al. 1986). For transmission electron microscopy (TEM), both live and fixed concentrated water samples were mounted on collodion carbon coated grids (ca.



Map. 1. Map showing four sampling sites on the fast-ice in the coastal area north of East Ongul Island, Antarctica.



Figs. 1-3. *Paraphysomonas antarctica* n. sp.; Fig. 1. an intact cell, Fig. 2. typical scales, Fig. 3. shafts and rod-like tips of spines. (all scale bar shows 1  $\mu$ m)

0.02 ml on each), desiccated in an electric oven and shadowed by Pt-Pd alloy at an angle of ca. 20°. These grids were examined with a JEM-100B TEM. Part of the samples were examined by JSM-T-100 SEM.

## Results and Discussion

Four species of *Paraphysomonas* were found in these water samples: two new species, *P. antarctica* n. sp. and *P. oligocycla* n. sp., and two described species, *P. vestita* and *P. butcheri*.

*Paraphysomonas antarctica* sp. nov. (Figs. 1–5)

Cellulae mobiles incolorata, sphaericae 3.1  $\mu\text{m}$  (2–4.3  $\mu\text{m}$ ) in diametro. Flagella duo, inaequalia; alterum 6 (4–8)-plo longius cellulae longitudine et 19.3  $\mu\text{m}$  (12.5–27  $\mu\text{m}$ ) longum, alterum brevius 2.9  $\mu\text{m}$  (1.8–4.5  $\mu\text{m}$ ). Corpus cellulae squamis numerosis tectum. Squamae e discis basilibus orbicularibus sine margine incrassato, 1.38  $\mu\text{m}$  (0.9–1.75  $\mu\text{m}$ ) in diametro et e spinis centribus cylindricis 2.4  $\mu\text{m}$  (1–3.25  $\mu\text{m}$ ) totis longis apice bacilliformi 0.52  $\mu\text{m}$  (0.3–0.7  $\mu\text{m}$ ) longo compositae. Cystae ellipsoideae collo simplici, 5.58  $\mu\text{m}$  (5.0–6.3  $\mu\text{m}$ ) in axe maiore, 5.47  $\mu\text{m}$  (4.6–5.9  $\mu\text{m}$ ) in axe minore, 5.31  $\mu\text{m}$  (4.9–5.8  $\mu\text{m}$ ) altae excludentes collo. Collum humile 1.16  $\mu\text{m}$  (1.06–1.27  $\mu\text{m}$ ) in externo diametro, 0.24  $\mu\text{m}$  (0.2–0.3  $\mu\text{m}$ ) altum, poro centrali sine annulo 0.56  $\mu\text{m}$  (0.55–0.65  $\mu\text{m}$ ) in diametro.

Lecta ab autore ipso in mari glaciolento in area septentrionali insulae Ongul orientalis, Antarctica: holotypus in herb. Inst. Biol. Kobe Univ. conservatus.

Iconotypus: Fig. 1.

Cell motile, colourless, spherical, 3.1  $\mu\text{m}$  (2–4.3  $\mu\text{m}$ ) in diameter. Flagella two, unequal; the longer flagellum pleuroneumatic, the length about 6 (4–8) times that

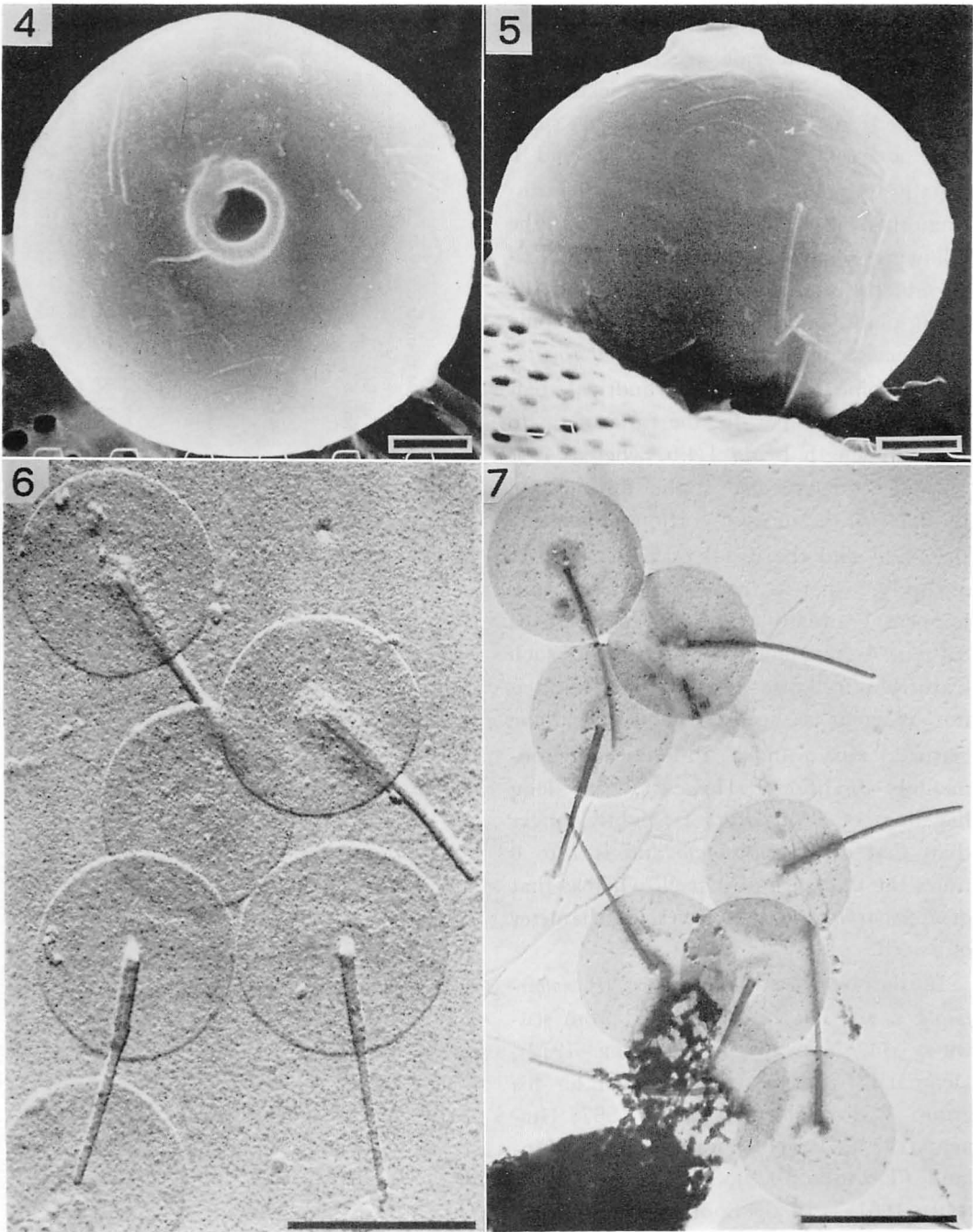
of the diameter of the cell body, 19.3  $\mu\text{m}$  (12.5–27  $\mu\text{m}$ ) in length; the shorter one acronematic, 2.9  $\mu\text{m}$  (1.8–4.5  $\mu\text{m}$ ) long. Cell body covered with scales consisting of a basal plate and a central spine. Basal plate of scale spherical without upturned or thickened margin, 1.38  $\mu\text{m}$  (0.9–1.75  $\mu\text{m}$ ) in diameter; central spine consists of tubular and cylindrical shaft, 1.88  $\mu\text{m}$  (0.7–2.55  $\mu\text{m}$ ) long, and thinner apical rod terminating in a round tip, 0.52  $\mu\text{m}$  (0.3–0.7  $\mu\text{m}$ ) long. Cyst slightly ellipsoidal, smooth, with a low collar, 5.58  $\mu\text{m}$  (5.0–6.3  $\mu\text{m}$ ) in major axis, 5.47  $\mu\text{m}$  (4.6–5.9  $\mu\text{m}$ ) in minor axis, 5.31  $\mu\text{m}$  (4.9–5.8  $\mu\text{m}$ ) high excluding collar height. Collar simple, 1.16  $\mu\text{m}$  (1.06–1.27  $\mu\text{m}$ ) in outside diameter and 0.24  $\mu\text{m}$  (0.2–0.3  $\mu\text{m}$ ) high with a pore without annulus 0.56  $\mu\text{m}$  (0.55–0.65  $\mu\text{m}$ ) in diameter.

This species was collected from the fast-ice covered coastal area north of East Ongul Island, Antarctica.

Type figure: Fig. 1.

This species was collected from seawater and sometimes from the bottom portion of sea ice at every station in the following months; from seawater, April 1983 and January 1984 at St. 1; March, June and September to December 1983 and January 1984 at St. 3; March 1983 at St. 4; June, July and September to December 1983 and January 1984 at St. 5; from the bottom portion of sea ice, April 1983 at St. 1, and January 1984 at St. 3. It appeared in every sampling site and was found throughout the year in this coastal area. At Stations 3 and 5, it appeared as a dominant phytoplankton during the period from August to December 1983.

As all the cells collected from every sampling site during the period surveyed were covered with monotypic scales of a homogeneous structure, this scale structure



Figs. 4, 5. a cyst of *P. antarctica* n. sp.; in upper view (Fig. 4, SEM) and in side view (Fig. 5, SEM).  
Figs. 6, 7. *P. imperforata*; Fig. 6. scales from L. Saroma, Japan, Fig. 7. scales from Western Australia.  
(all scale bar shows 1  $\mu$ m)

can be considered stable.

*P. antarctica* is classified in the *imperforata* group based on a scale structure consisting of a basal disc plate without a thickened or upturned margin and a central spine with a basally thickened portion and a distally thinner portion. It can be distinguished from *P. imperforata* by the following characteristics: 1) in *P. antarctica*, the diameters of the cyst and the basal plate, and the length of the spine are twice as much as those in *P. imperforata*; 2) the spine consists of a cylindrical shaft and a thin rod-like tip, the ratio of tip to spine in length being 1/4.6, whereas it is 1/2 in *P. imperforata*; 3) the thickness of the spine at the median portion, in between the basal and the distal portions, changes abruptly, whereas in *P. imperforata* this happens gradually within a length of ca 0.1  $\mu\text{m}$ ; 4) taxonomical weight of such features as cell size and flagellar length is not as great as scale structure, as these features vary under different environmental conditions. However, the long flagellum of *P. antarctica* is slightly longer than that of *P. imperforata* and is 4 to 8 times the diameter of its cell, whereas that of *P. imperforata* 3 to 4 times the diameter of its cell.

In the Northern hemisphere, *P. imperforata* s. str. has been recorded from seawater in Norway (LEADBEATER 1972), Denmark (THOMSEN 1975, except for his group 2), England (LUCAS 1967; HIBBERD 1979), Israel (THOMSEN 1978), Finland (THOMSEN 1979), and Japan (TAKAHASHI 1981). In the Southern hemisphere, it has been recorded in New Zealand (MOESTRUP 1979) and Western Australia (this paper). Among cells and scales found in Denmark and designated as *P. imperforata* by THOMSEN (1975), a cell (his figure 11) and a scale (his figure 8) differ

Table 1. Dimensional characteristics of *P. antarctica* n. sp. and of the *P. imperforata* complex.

Species	Cell diam. ( $\mu\text{m}$ )	Scale: Form*1	Base plate diam. ( $\mu\text{m}$ )	Spine length (total l.) ( $\mu\text{m}$ )	Spine Tip length ( $\mu\text{m}$ )	Spine l./Base plate diam.	Tip l./Spine l.	Locality*2	References
<i>antarctica</i>	3.1 (2-4.3)	C	1.38 (0.9-1.75)	2.4 (1.0-3.25)	0.52 (0.3-0.7)	1.73 (0.9-2.5)	1/4.6	M.	coastal area, Antarctic
<i>imperforata</i>	4.5 (3.8-5.1)	C	0.77 (0.7-0.85)	1.0 (0.88-1.13)	ca. 0.5	1.25 (5:4)	1/2	M.	LUCAS (1967)
do.	3.5 (1.7-4.3)	C	0.7 (0.64-0.76)	0.76 (0.7-0.82)	0.45 (0.4-0.52)	1.1 (0.99-1.22)	1/1.7	M.	Japan (Lake Saroma)
do.	—	C	0.86 (0.72-0.97)	1.34 (1.0-1.68)	0.8 (0.67-1.03)	1.56 (1.17-2.15)	1/1.7	M.	W-Australia (TAKAHASHI)
do. (group 1)	—	C	0.7 (0.5-0.9)	1.17 (0.8-1.6)	0.43 (0.4-0.6)	1.9 (1.1-2.7)	1/2.7	M.	THOMSEN (1975)
do. (group 2)	—	C	1.08 (0.7-1.5)	3.18 (2.6-4.2)	0.38 (0.2-0.6)	3.2 (1.9-4.1)	1/8	M.	THOMSEN (1975)
do. (fo. no. 1)	—	C	1.4-1.5	3.9 (2.8-4.2)	0	ca. 2.7	0	F.	TAKAHASHI (1976)
do. (fo. no. 2)	—	E	2.2-2.5 $\times$ 1.9-2.0	7.0 (5.1-8.5)	0.2-0.25	3-3.6	1/30	F.	TAKAHASHI (1976)
do.	(1.7-5.1)	E	—	(0.8-4.2)	—	—	—	F.	PREISIG & HIBBERD (1982)
do. (fo. no. 3)	—	E	2.1-3.0 $\times$ 1.6-1.9	4.1-5.1	—	—	—	F.	KLING & KRISTANSEN (1983)

(\*1, C=circular, E=elliptical; \*2, M=marine, F=freshwater)

from other scales described as *P. imperforata* and resemble more those of *P. antarctica* than those of *P. imperforata*. His scales have the same three dimensional characteristics as scales of *P. antarctica* (Table 1). This suggests the existence of an *antarctica*-like taxon in the Northern polar region.

Besides the above seawater localities, scales and cells of *P. imperforata* have been recorded from many freshwater localities (ANDERSEN 1978; CRONBERG and KRISTIANSEN 1980; DÜRRSCHMIDT 1980; HIBBERD 1979; JACOBSEN 1985; KLING and KRISTIANSEN 1983; KRISTIANSEN 1976, 1978, 1980, 1983, 1985, 1986; NICHOLLS 1981a; PREISIG and HIBBERD 1982a; ROIJACKERS 1981; ROIJACKERS and KESSELS 1981; SKOGSTAD 1982; TAKAHASHI 1976, 1978; WAWRZYNIAK and ANDERSEN 1985; WEE 1982; WUJEK 1983, 1984). These freshwater specimens designated as *P. imperforata* deviate from the type by distinctive differences in scale structure. They are divided into three groups based on scale structure; Forma no. 1 contains scales consisting of a circular plate and a long curved spine terminating in a round tip; Forma no. 2 contains scales consisting of an elliptical plate and a long, straight, cylindrical spine terminating in an abruptly and acutely pointed minute tip (TAKAHASHI 1976, 1978); and Forma no. 3, which consists of an elliptical base plate and a curved long spine terminating in a round tip, has been found in Canada by KLING and KRISTIANSEN (1983). PREISIG and HIBBERD (1982a), the first to examine cells of Forma no. 2, considered that this organism might be a separate taxon. Whereas, THOMSEN (1975) and LEE (1978) questioned the separation of species of *P. vestita* and *P. imperforata* because scale and spine structure shows a gradual transition

from one species to the other. In another study many cells of *P. imperforata* Forma no. 2 which were collected from lakes and ponds in Alaska were examined. It is concluded that Forma no. 2 should be considered a separate species because all the scales of examined cells were homogeneous and stable in structure. A taxonomic treatment of Forma no. 2 will be published in a subsequent paper. As for Forma no. 1 and Forma no. 3, two different kinds of scales may characterize two separate species. Further investigation is necessary.

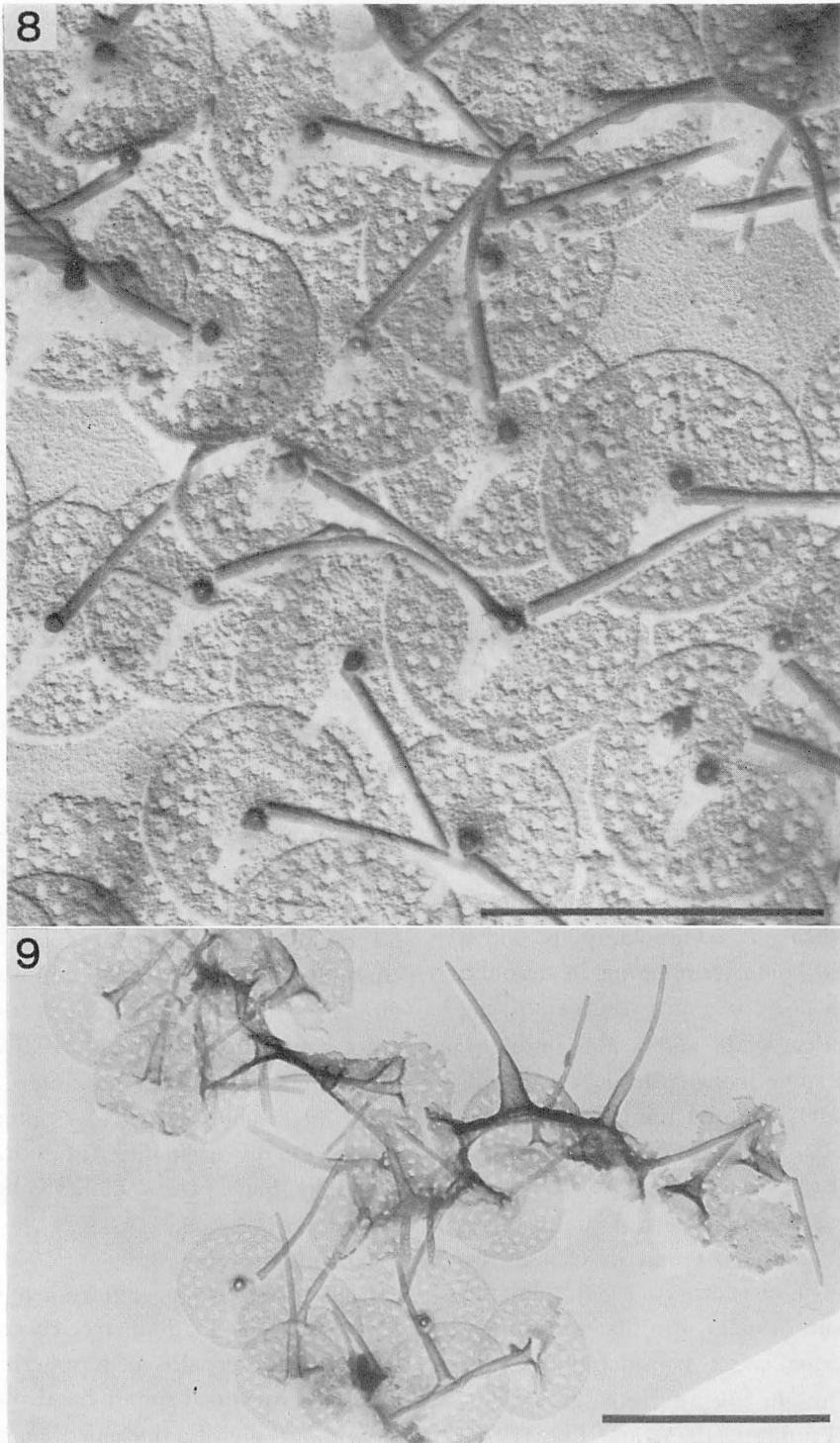
The cyst shown in a previous paper (TAKAHASHI et al. 1986, figure 24) is not that of *P. imperforata* but belongs to *P. antarctica*.

***Paraphysomonas oligocyclus* sp. nov.** (Figs. 8, 9)

Cellulae mobiles incoloratae, sphaericae,  $6.2 \mu\text{m}$  ( $6\text{--}6.5 \mu\text{m}$ ) in diametro. Corpus cellulae squamis numerosis tectum. Squamae e discis basalibus orbicularibus margine complanato vel leviter incrassato  $0.6 \mu\text{m}$  ( $0.47\text{--}0.8 \mu\text{m}$ ) in diametro a duobus ad quattuor annulis concentricis paribus constantibus numerosis foraminibus perforatis et e spinis centralibus deminutis apice rotundato  $0.78 \mu\text{m}$  ( $0.5\text{--}0.9 \mu\text{m}$ ) longis compositae. Lecta ab autore ipso in mari glaciolento in area septentrionali insulae Ongul orientalis, Antarctica: holotypus in herb. Inst. Biol. Kobe Univ. conservatus.

Iconotypus: Fig. 8.

Cells spherical to slightly ovoidal,  $6.2 \mu\text{m}$  ( $6\text{--}6.5 \mu\text{m}$ ) in diameter, covered with scales. Scale consists of a spherical basal plate and a central spine; basal plate with or without slightly thickened margin,  $0.6 \mu\text{m}$  ( $0.47\text{--}0.8 \mu\text{m}$ ) in diameter, ornamented with two to four concentric rings of irregularly shaped perforations; spine slight-



Figs. 8, 9. *P. oligocycla* n. sp.; Fig. 8. typical scales, Fig. 9. scales with spine having swollen basal portion. (all scale bar shows 1  $\mu$ m)



ly tapering, with or without swollen basal part, terminating in a round tip,  $0.78\ \mu\text{m}$  ( $0.5\text{--}0.9\ \mu\text{m}$ ) in length. Cyst unknown.

It was collected from the fast-ice covered coastal area north of East Ongul Island, Antarctica.

Type figure: Fig. 8.

This species was collected from seawater in January 1984 at St. 1 and St. 5, and in March 1983 at St. 4, and also from the bottom portion of sea ice in April 1983 at St. 1.

*P. oligocycla* is placed in the *foraminifera* group together with *P. foraminifera* LUCAS 1967, *P. circumforaminifera* WUJEK 1983, and *P. takahashii* CRONBERG et KRISTIENSEN emend. THOMSEN et al. 1981. It is distinguished from the others by structural differences of the scales: three outer and five inner rings of perforations in the basal plate in *P. foraminifera*; only one ring of perforations just inside the upturned margin in *P. circumforaminifera*; and evenly and closely distributed perforations in the basal plate and three-forked spine base in *P. takahashii*.

Between two to four rings of perforations were found in the basal plate of *P. oligocycla*. A basal plate with three rings of perforations was 54.3% of all scales examined, that with two rings 34.3%, and that with four rings 11.3%. The number of perforations in the outer ring of the basal plate with three rings of perforations was 27 (20–30), that in the middle ring 18 (6–22), and that in the innermost one 13 (4–16). The perforations in the middle and innermost rings were arranged irregularly and varied in number. Scales of some cells possessed a central spine with a swollen basal portion as observed in *Spiniferomonas bourrellyi* (NICHOLLS 1981b). The swollen portion varied from 8 to 41% (mean 24%) of the whole spine length.

***Paraphysomonas vestita*** (STOKES) DE SAEDELEER 1929

(Figs. 10, 11)

This species, one of the most widely distributed species of this genus, has been recorded mainly in freshwater. At Station 1, many scales were collected from the middle and bottom parts of sea ice in April 1983, and from seawater in April 1983 and January 1984. Cysts were collected from the middle part of sea ice in April 1983.

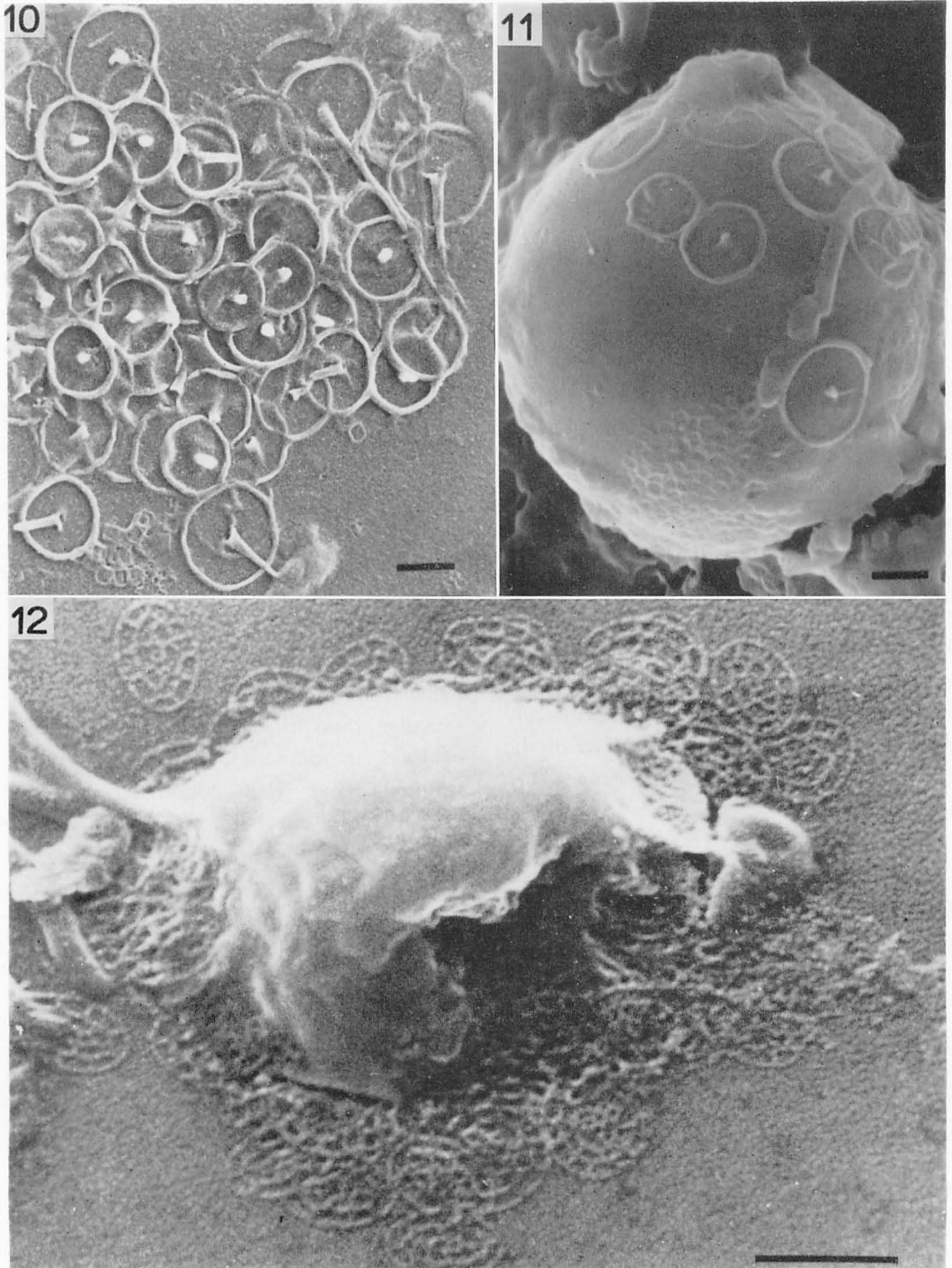
The scale consists of a circular basal plate with a wide upturned margin and a tapering central spine terminating in a pointed tip. Spines of Antarctic specimens varied from  $0.1\ \mu\text{m}$  to  $4.2\ \mu\text{m}$  in length, which was shorter than those in other localities; e.g. Japanese specimens varied from  $1.3\ \mu\text{m}$  to  $7.0\ \mu\text{m}$  in length (TAKAHASHI 1978). The cyst,  $8.6\ \mu\text{m}$  in diameter in the Antarctic material, was also smaller than that in Japanese material ( $11\ \mu\text{m}$  in diameter, TAKAHASHI 1978). Although LEE (1978) found that *P. vestita* is capable of euryhaline growth in a wide range of salinities, records for this species in seawater are very few (LEADBEATER 1972; THOMSEN 1975, 1978; LEE 1978; TAKAHASHI 1981). The salinity of seawater at Station 1 was 3.296–3.407% throughout the year.

This is the first record of *P. vestita* in the Antarctic.

***Paraphysomonas butcheri*** PENNICK et CLARKE 1972

(Fig. 12)

A few cells of this species were collected from seawater in March 1983 at Stations 1 and 4. All of them were covered with plate scales only. Cells were spherical and  $2.85\ \mu\text{m}$  ( $2.4\text{--}3.2\ \mu\text{m}$ ) in diameter, and plate scales were elliptical and  $0.79\ \mu\text{m}$  ( $0.7\text{--}0.82\ \mu\text{m}$ )  $\times$   $0.55\ \mu\text{m}$  ( $0.5\text{--}0.63\ \mu\text{m}$ ).



Figs. 10, 11. *P. vestita*; scales (Fig. 10, TEM) and a side view of cyst (Fig. 11, SEM). Fig. 12. SEM image of *P. butcheri*. (all scale bar shows 1  $\mu$ m)

The scales were slightly smaller than those in the type material (PENNICK and CLARKE 1972).

This is the first record of *P. butcheri* in the Antarctic.

The distribution of marine species of *Paraphysomonas* in the Southern hemisphere has not been fully described. Prior to 1984, only two records of this genus had been made in this area. *P. vestita* was discovered at Durban, Natal, RSA (LEE 1978), and *P. imperforata* s. str. and *P. butcheri* in the coast of New Zealand by MOESTRUP in 1979 (MOESTRUP 1979). The four species recorded in this paper and collected from the Antarctic Ocean, and *P. imperforata* s. str. collected from the Mundura Estuary near Bunbury, Western Australia, comprise the third and most recent record of this genus in the Southern hemisphere. These collections suggest a distribution of this genus as wide in the Southern hemisphere as in the Northern hemisphere. If adaptation to severe environmental conditions promotes a wide distribution, then the four marine species, reported in this paper as living under low water temperature and low light intensity beneath the Antarctic fast-ice, must indeed be widely distributed.

In the past, they were overlooked because they are easily destroyed or transformed by fixatives, and too small to be examined alive under a light microscope.

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高橋永治：南極，リュツオ・ホルム湾産の有殻・有鱗片原生動物 II。

2 新種を含む 4 種の氷海産パラピソモナス

オングル島，昭和基地北方の氷海産の黄金藻綱パラピソモナス科，パラピソモナス属の 2 新種を含む 4 種を記載し，インペルフォラータ群の分類について論議した。本報告は本属の海産種についての南半球から 3 番目の記録であり，南極海域からの最初の記録である。新種の一つ，パラピソモナス アンタルクチカはほぼ周年にわたって出現した。(657 神戸市灘区六甲台1-1 神戸大学理学部生物学科)