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Scale-bearing chrysophytes in the south basin of Lake Biwa, Japan

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In the south basin of Lake Biwa, 42 taxa of scale-bearing chrysophytes belonging to Mallomonadaceae and Paraphysomonadaceae; 14 species of *Mallomonas*, 5 of *Synura*, 1 of *Chrysosphaerella*, 5 of *Spiniferomonas* and 15 species, 1 subspecies and 1 forma of *Paraphysomonas* were found. Among them, 17 taxa; *Mallomonas portae-ferreae*, *M. pseudocoronata*, *M. striata* var. *striata*, *Spiniferomonas takahashii*, *Paraphysomonas caelifrica*, *P. capreolata*, *P. circumvallata*, *P. coronata*, *P. corynephora*, *P. glandiata*, *P. poteriophora* ssp. *manubriata*, *P. punctata*, *P. quadrispina*, *P. runcinifera*, *P. stelligera*, *P. subquadrangularis* and *P. undulata* were new to Japan.

Key Index Words: *Chrysophyceae*—Chrysosphaerella—*Lake Biwa*—*Mallomonadaceae*—Mallomonas—*Paraphysomonadaceae*—Paraphysomonas—Spiniferomonas—Synura—*Synurophyceae*.

Lake Biwa, with the surface area of 674 km^2 and the maximum depth of 104 m, is the largest lake in Japan and classified as the mesotrophic lake (Tezuka 1984). It is composed of two parts; a large and deep north basin, and a small and shallow south basin.

Of the scale-bearing chrysophytes only 3 species; *Mallomonas fastigata*, *M. helvetica* and *Synura uvella* have been recorded by a light microscopical study (Mori 1945; Negoro 1968). The scale-bearing chrysophytes such as *Mallomonas* and *Synura* (Mallomonadaceae) and *Paraphysomonas* (Paraphysomonadaceae) possess their charactaristics of species on their minute scales and bristles as well as their lorica form, therefore the electron microscopy is the most useful method to identify them accurately. Of the scale-bearing chrysophytes 55 taxa have been recorded from about 100 lakes and ponds excepting Lake Biwa in Japan by Takahashi (1978). Ito *et al.* (1981) found 12 taxa of scale-bearing chrysophytes by the electron microscopical investigation of one water sample which was collected from the south basin and they concluded that further study must give more new knowledge on the chrysophyte flora of this lake. Thereafter the author has carried out the floristic study on the scale-bearing chrysophytes in Lake Biwa. This paper deals with results of survey in the south basin of Lake Biwa during the period from 1980 to 1984.

Materials and Methods

Twenty five water samples were collected in 1 *l* bottles from the surface at 10 stations of the south basin of Lake Biwa (Fig. 1) in four seasons between January 1980 and July 1984 (Table 1). The water temperature at sampling sites ranged from 3.0 to 30.6°C and the pH from 7.0 to 9.5 throughout the study period. 0.5 *l* of each unfixed water sample was centrifuged at 3,000 r.p.m. for 10 min. and then concentrated to 1 m*l*. For transmission electron microscopy, 10 μl of each concentrated water sample was mounted on collodion-carbon coated grids,

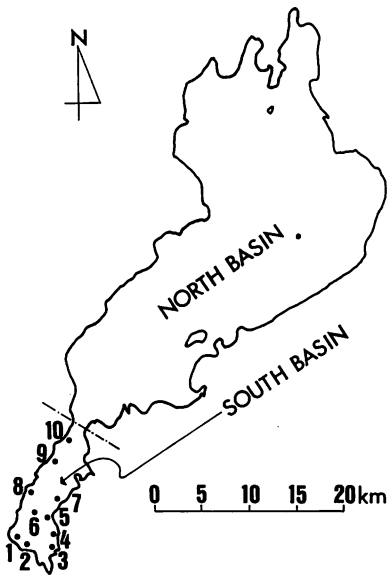

Fig. 1. Map showing Lake Biwa and ten sampling stations in the south basin.

Table 1 Sampling stations and dates in the south basin of Lake Biwa (1980–1984).

Stations	Dates	
Sta. 1	May 26, 1981	May 25, 1982
	Jul. 2, 1982	Aug. 20, 1982
	Sep. 3, 1982	Jan. 21, 1983
	May 20, 1983	Aug. 19, 1983
	Sep. 16, 1983	Oct. 21, 1983
	Apr. 2, 1984	
Sta. 2	Jul. 6, 1984	
Sta. 3	May 29, 1981	
Sta. 4	Jan. 25, 1980	Oct. 24, 1980
	Jan. 23, 1981	Mar. 26, 1981
	Jan. 22, 1982	Mar. 19, 1982
Sta. 5	Oct. 16, 1981	
Sta. 6	Aug. 21, 1981	
Sta. 7	Sep. 22, 1981	
Sta. 8	Sep. 22, 1981	
Sta. 9	Sep. 22, 1981	
Sta. 10	May 29, 1981	

desiccated in an oven, and then shadowed at about 20 degrees with Pt-Pd alloy. These samples were examined with a transmission electron microscope (JEM-100B). For scanning electron microscopy, 20 m*l* of each unfixed water sample was filtered with nuclepore filter (25 mm in diameter, 0.4 μm in pore size) and sometimes millipore filter (47 mm in diameter, 0.45 μm in pore size), desiccated in an oven and then coated with gold. These samples were examined with a scanning electron microscope (JEM-T200).

Results and Discussion

Out of 42 taxa found in the south basin of Lake Biwa;

Total 42 taxa; 14 species belonged to *Mallomonas*, 5 to *Synura*, 1 to *Chrysosphaerella*, 5 to *Spiniferomonas* and 15 species, 1 subspecies and 1 forma to *Paraphysomonas* (Table 2). The species whose distribution is not shown are widely distributed in the world.

Family Mallomonadaceae DIESING (1866)
Genus *Mallomonas* PERTY (1851)

Three species; *M. portae-ferreae*, *M. pseudocoronata* and *M. striata* var. *striata* were new to Japan.

M. acaroides PERTY emend. IVANOV (1899) Figs. 2, 3

Cells and scales were found in summer. This species generally occurs in summer (CRONBERG and KRISTIANSEN 1980).

M. akrokomos RUTTNER in PASCHER (1913) Fig. 4

Cells were found in winter and spring, and scales in summer. Although this species is classified as eurythermal (TAKAHASHI 1978), it has a preference for a low temperature (HARRIS 1958; KRISTIANSEN 1985; ROIJACKERS 1986; TAKAHASHI 1978).

M. alpina PASCHER et RUTTNER in PASCHER (1913) Fig. 5

Syn. *M. monograptus* HARRIS et BRADLEY (1960).

Cells and scales were found in spring. This species has also occurred during Feburary and April in a pond in The Netherlands (ROIJACKERS 1984).

M. annulata (HARRIS et BRADLEY) HARRIS (1967)

Cells were found in winter, and scales in spring.

M. caudata IVANOV emend. KRIEGER (1930)

Table 2. Scale-bearing chrysophytes collected from the south basin of Lake Biwa (1980–1984).

Season	W.		Spring					Summer				Autumn						
Month and sampling stations / Taxa	Jan. Sta. 1	Jan. Sta. 4	Mar. Sta. 4	Apr. Sta. 1	May Sta. 1	May Sta. 3	May Sta. 10	Jul. Sta. 1	Jul. Sta. 2	Aug. Sta. 1	Aug. Sta. 6	Sep. Sta. 1	Sep. Sta. 7	Sep. Sta. 8	Sep. Sta. 9	Oct. Sta. 1	Oct. Sta. 4	Oct. Sta. 5
Mallomonas acaroides									●	○								
M. akrokomos	○	●	●					○										
M. alpina				●	○													
M. annulata	●	●	○		○													
M. caudata		●														○		
M. crassisquama	○	○	○		○													
M. elongata	○	●			○				●	○								
M. heterospina		○																
M. parvula			○															
*M. portae-ferreae**				○								○				○		
*M. pseudocoronata**									●									
M. punctifera		○	○															
M. striata var. *striata**			●															
M. tonsurata	●	●	○	●	○		○	○	●	○				○		○	○	○
Synura curtispina			○														○	
S. glabra	○	●	●		○		○			○							○	
S. petersenii	○	○	○															
S. sphagnicola																	○	
S. spinosa		○																
Chrysosphaerella brevispina		○	○					●		○								
Spiniferomonas bourrellyi	●	●	○		●		○	●				○	○			●	○	
S. cornutus	●		●		○												○	
S. coronacircumspina					○			○									○	
*S. takahashii**		○	○								●							
S. trioralis	○	●	●		●		○	○		○	○	○	○	○	○	○		○
Paraphysomonas bandaiensis		○			●			●			○	●					●	
*P. caelifrica**							○				○		○		○		○	
*P. capreoiata**																	○	
*P. circumvallata**					○						○				○			
*P. coronata**	●																	
*P. corynephora**		○									○							
P. diademifera					○			○				●					●	
*P. glandiata**	○	○	○		○													
P. imperforata forma No. 2	○	●	○		●	○		○						○	○	○	●	
*P. poteriophora ssp. manubriata**		●	●															
*P. punctata**		○																
*P. quadrispina**			○								○							
*P. runcinifera**													○		○			
*P. stelligera**		○	●															
*P. subquadrangularis**		●						○										
*P. undulata**								○			○	○	○			●	●	
P. vestita	○	●	●		●	○	○	○		○	○	○	○		○	●	●	●
Number of taxa	14	24	21	3	16	2	6	12	4	7	9	8	5	3	6	8	14	3

● showing cells collected
○ showing scales collected
* showing taxon new to Japan
W. showing Winter

Fig. 6

Syn. *M. fastigata* ZACHARIAS (1903).

Cells were found in winter, and scales in autumn. This species has been recorded as *M. fastigata* in the previous papers (ITO, YANO and HARIMAYA 1981; MORI 1971; NEGORO 1968). MORI (1971) reported that it was a dominant species in the north basin of Lake Biwa in Feburary 1968.

M. crassisquama (ASMUND) FOTT (1962)

Scales were found in winter and spring.

M. elongata REVERDIN (1919)

Cells were found in winter and summer, and scales in spring.

M. heterospina LUND (1942) Fig. 7

Scales were found in winter.

M. parvula DÜRRSCHMIDT (1982) Fig. 8

Scales were found in spring.

M. portae-ferreae PETERFI et ASMUND (1972) Fig. 9

Scales were found in spring and autumn.

M. pseudocoronata PRESCOTT (1944) Fig. 10

Cells were found in summer.

Distribution: Canada, USA (ASMUND and KRISTIANSEN 1986), Panama (WUJEK 1986).

M. punctifera KORSHIKOV (1941)

Syn. *M. reginae* TEILING (1946).

Scales were found in winter and spring. This species has been recorded as *M. reginae* in the previous paper (ITO, YANO and HARIMAYA 1981).

M. striata ASMUND (1959) var. *striata* Figs. 11, 12

Cells were found in spring. Var. *striata* differs from var. *serrata* in having smooth bristle. Var. *serrata* has been recorded from NE Japan (TAKAHASHI 1978).

M. tonsurata TEILING emend. KRIEGER (1959)

This species occurred in four seasons. Cells were found in winter, spring and summer, and scales in autumn. This species has also occurred almost all the year round in a pond in Tsuruoka Park, Yamagata Prefecture, Japan (TAKAHASHI 1978).

Genus *Synura* EHRENBERG (1835)

S. curtispina (PETERSEN et HANSEN) ASMUND (1968) Fig. 13

Scales were found in spring and autumn.

S. glabra H-PESTALOZZI (1941) Fig. 14

This species occurred in four seasons. Cells were found in winter and spring, and scales in other seasons.

S. petersenii KORSHIKOV (1929)

Scales were found in winter and spring.

S. sphagnicola (KORSHIKOV) KORSHIKOV (1929)

Scales were found in autumn.

S. spinosa KORSHIKOV (1929)

Scales were found in winter.

Family Paraphysomonadaceae PREISIG et HIBBERD (1983)

Genus *Chrysosphaerella* LAUTERBORN (1896)

C. brevispina KORSHIKOV emend. HARRIS et BRADLEY (1958) Fig. 15

Dissociated cells were found in summer, and scales in winter and spring.

Genus *Spiniferomonas* TAKAHASHI (1973)

A species; *S. takahashii* was new to Japan.

S. bourrellyi TAKAHASHI (1973) Fig. 16

This species occurred in four seasons. In a pond on Mt Rokko, it has also occurred all the year round (ITO and TAKAHASHI 1982).

S. cornutus BALONOV (1978)

Cells were found in winter and spring, and scales in autumn. In a pond on Mt. Rokko, it has also occurred between these seasons (ITO and TAKAHASHI 1982).

S. coronacircumspina (WUJEK et KRISTIANSEN) NICHOLLS (1984) Fig. 17

Syn. *Chrysosphaerella coronacircumspina* WUJEK et KRISTIANSEN (1977), *C. solitaria* PREISIG et TAKAHASHI (1978).

Scales were found in spring, summer and autumn.

S. takahashii NICHOLLS (1981) Fig. 18

Cells were found in summer, and scales in winter and spring.

Distribution: Canada (NICHOLLS 1981; KLING and KRISTIANSEN 1983), Norway (SKOGSTAD 1986).

S. trioralis TAKAHASHI (1973) Fig. 19

This species occurred in four seasons. Cells were found in winter and spring, and scales in other seasons.

Genus *Paraphysomonas* DE SAEDELEER (1929)

Thirteen taxa; *P. caelifrica*, *P. capreolata*, *P. circumvallata*, *P. coronata*, *P. corynephora*, *P. glandiata*, *P. poteriophora* ssp. *manubriata*, *P. punctata*, *P. quadrispina*, *P. runcinifera*, *P. stelligera*, *P. subquadrangularis* and *P. undulata* were new to Japan.

P. bandaiensis TAKAHASHI (1976) Fig. 20

This species occurred in four seasons. Cells were found in spring, summer and autumn, and scales in winter.

P. caelifrica PREISIG et HIBBERD (1982) Fig. 21

Scales were found in spring, summer and autumn.

Distribution: Denmark, England (PREISIG and HIBBERD 1982a).

P. capreolata PREISIG et HIBBERD (1982) Fig. 22

Scales were found in autumn.

Distribution: England (PREISIG and HIBBERD 1982a), Greece (KRISTIANSEN 1983).

P. circumvallata THOMSEN (1981) Fig. 23

Scales were found in spring, summer and autumn.

Distribution: Canada (KLING and KRISTIANSEN 1983), Denmark (THOMSEN *et al.* 1981), England (PREISIG and HIBBERD 1982b), Greece (KRISTIANSEN 1983).

P. coronata MOESTRUP et ZIMMERMANN (1981) Fig. 24

Cells were found in winter.

Distribution: Canada (NICHOLLS 1984), Denmark (KRISTIANSEN 1985; THOMSEN *et al.* 1981), England (PREISIG and HIBBERD 1982b), Greece (KRISTIANSEN 1983).

P. corynephora PREISIG et HIBBERD (1982) Fig. 25

Scales were found in winter and summer.

Distribution: Canada (NICHOLLS 1984), England (PREISIG and HIBBERD 1982a).

P. diademifera (TAKAHASHI) PREISIG et HIBBERD (1982) Fig. 26

Syn. *Ochromonas diademifera* TAKAHASHI (1972), *Lepidochromonas diademifera* (TAKAHASHI) KRISTIANSEN (1980).

Cells were found in autumn, and scales in spring and summer.

P. glandiata PREISIG et HIBBERD (1982) Figs. 27, 28

Scales were found in winter and spring.

Distribution: Canada (NICHOLLS 1984), Denmark (KRISTIANSEN 1985), England (PREISIG and HIBBERD 1982a).

P. imperforata LUCAS (1967) forma No. 2 sensu TAKAHASHI (1978) Fig. 29

This species occurred in four seasons. Cells were found in winter, spring and autumn, and scales in summer. This forma differs from the type in having the spine with acutely pointed tip, and PREISIG and HIBBERD (1982a) and TAKAHASHI (1987) suggested that it may be a separate taxon.

P. poteriophora ssp. *manubriata* PREISIG et HIBBERD (1982) Fig. 30

Cells were found in winter and spring.

Distribution: Denmark (THOMSEN *et al.* 1981), England (PREISIG and HIBBERD 1982b), Greece (KRISTIANSEN 1983).

P. punctata ZIMMERMANN (1981) Fig. 31

Scales were found in winter.

Distribution: Canada (NICHOLLS 1984), Denmark (THOMSEN *et al.* 1981), England (PREISIG and HIBBERD 1982b).

P. quadrispina THOMSEN et KRISTIANSEN (1981) Fig. 32

Scales were found in spring and summer.

Distribution: Denmark (THOMSEN *et al.* 1981), England (PREISIG and HIBBERD 1982b), Greece (KRISTIANSEN 1983).

P. runcinifera PREISIG et HIBBERD (1982) Fig. 33

Scales were found in autumn.

Distribution: Denmark, England (PREISIG and HIBBERD 1982b).

P. stelligera PREISIG et HIBBERD (1982) Fig. 34

Cells were found in spring, and scales in winter.

Distribution: Denmark (THOMSEN *et al.* 1981), England (PREISIG and HIBBERD 1982b), Greece (KRISTIANSEN 1983), The Netherlands (ROIJACKERS and KESSELS 1981).

P. subquadrangularis PREISIG et HIBBERD (1982) Fig. 35

Cells were found in winter, and scales in summer.

Distribution: England (PREISIG and HIB-

BERD 1982b), Greece (KRISTIANSEN 1983).

P. undulata PREISIG et HIBBERD (1982) Fig. 36

Cells were found in autumn, and scales in summer.

Distribution: Denmark, England (PREISIG and HIBBERD 1982b).

P. vestita (STOKES) DE SAEDELEER (1929) Fig. 37

This species occurred in four seasons. Cells were found in winter, spring and autumn, and scales in summer.

By the present study, 42 taxa of scale-bearing chrysophytes and the seasons of occurrence of them in the south basia of Lake Biwa were revealed, and 30 taxa among them, 17 new to Japan and 13 previously recorded, were added to the algal flora of this lake. These 17 taxa might be also distributed widely in Japan and occur in the same season as that in Lake Biwa.

Almost all taxa of scale-bearing chrysophytes previously recorded in Japan are widely distributed in the world (ASMUND and KRISTIANSEN 1986; PREISIG and HIBBERD 1982a, 1982b; STARMACH 1985; TAKAHASHI 1978). Among 17 taxa new to Japan, 2 species of *Mallomonas; M. portaeferreae* and *M. striata* var. *striata* have been recorded from many countries of the world (ASMUND and KRISTIANSEN 1986), whereas, *M. pseudocoronata, Spiniferomonas takahashii* and 13 taxa of *Paraphysomonas* from a few countries of Europe and/or N America. Recently 22 new taxa of *Paraphysomonas* were discovered in the Cambridge area, England by PREISIG and HIBBERD (1982a, 1982b). This fact shows that these taxa have been overlooked for a long time because their cells are very small and easily broken by fixatives. Finding of these 17 taxa new to Japan which is far away from Europe, N America, SE Asia (Bangladesh) and W Africa (Cameroun) indicates that they are widely distributed in the world as well as other scale-bearing chrysophytes.

The north basin of Lake Biwa has less eutrophic waters and volume about 140 times larger than the south one (ICHISE and WAKABAYASHI 1985; TEZUKA 1984). The species composition and the seasons of occurrence of scale-bearing chrysophytes in the north basin has not yet been clarified, therefore such floristic study in this basin is necessary and will produce many interesting results.

PALMER (1959) has pointed out that naked and scale-bearing chrysophytes are the most significant cause of the fishy odor in waters. As Lake Biwa is the most important water resource for 13 million people living in four prefectures; Shiga, Kyoto, Oosaka and Hyogo, the multiplication of these chrysophytes in this lake is a great concern for waterworks at present. Actually a bloom of *Uroglena americana* (Ochromonadales, Chrysophyceae) has appeared during the period from late spring to early summer in both south and north basins since 1977 and done much damage to both the water supply and fresh-water fishery (YOSHIDA *et al.* 1983). Recently, a great bloom, not so great, of *Mallomonas tonsurata* has appeared in the south basin and produced fishy odor (NEGORO and TAKAGI 1985). Accordingly it is an important and urgent subject to elucidate their quantitative seasonal fluctuation as well as to make clear the chrysophyte flora in this lake.

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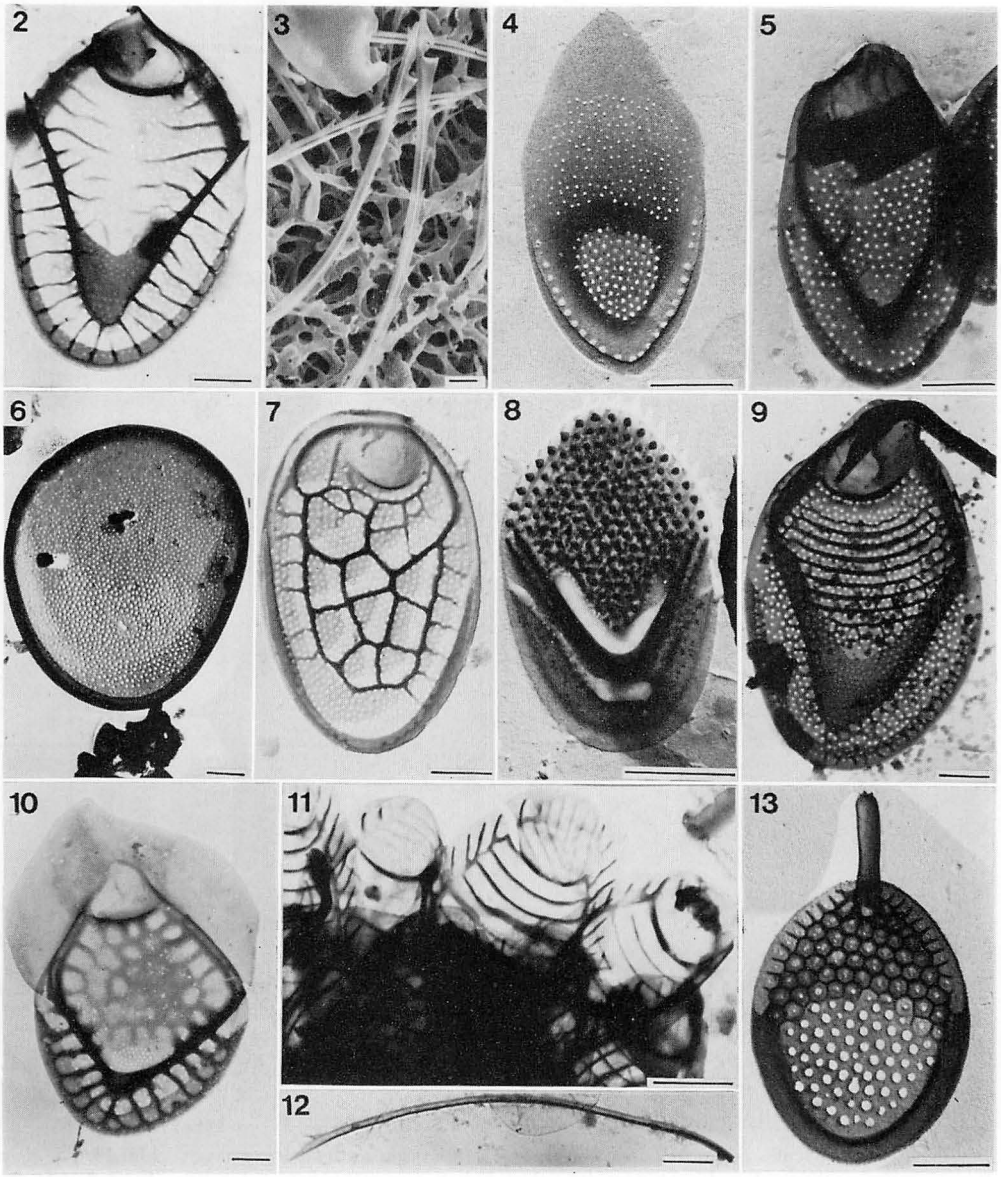
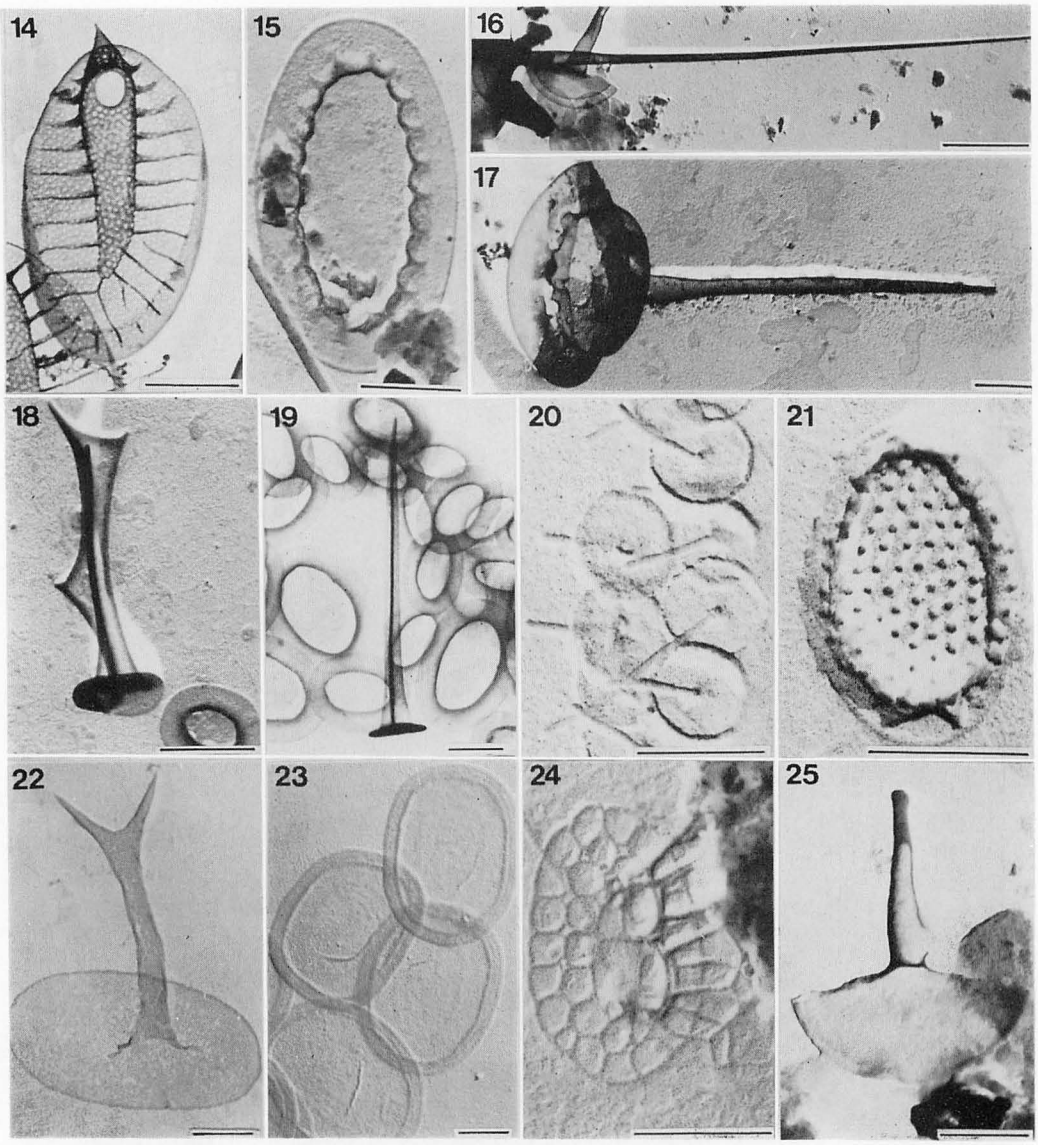
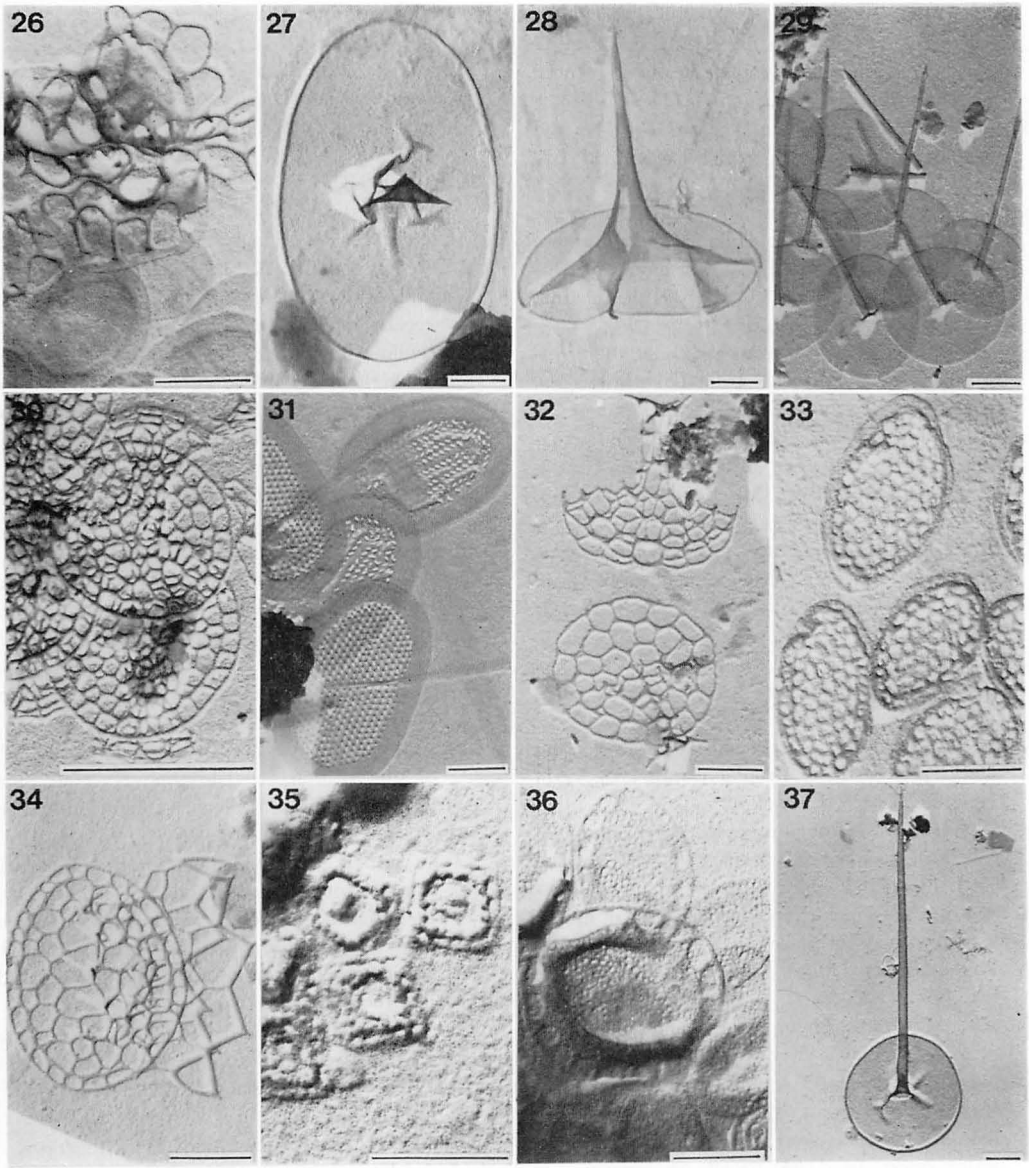


Figs. 2–13. Scales and bristles of *Mallomonas* and *Synura*: Figs. 2, 3. *M. acaroides*. Fig. 4. *M. akrokomos*. Fig. 5. *M. alpinn*. Fig. 6. *M. caudata*. Fig. 7. *M. heterospina*. Fig. 8. *M. parvula*. Fig. 9. *M. portae-ferreae*. Fig. 10. *M. pseudocoronata*. Figs. 11, 12. *M. striata* var. *striata*. Fig. 13. *S. curtispina*. (Scales: 1 μm).



Figs. 14–25. Scales of *Synura*, *Chrysosphaerella*, *Spiniferomonas* and *Paraphysomonas*: Fig. 14. *S. glabra*. Fig. 15. *C. brevispina*. Fig. 16. *S. bourrellyi*. Fig. 17. *S. coronacircumspina*. Fig. 18. *S. takahashii*. Fig. 19. *S. trioralis*. Fig. 20. *P. bandaiensis*. Fig. 21. *P. caelifrica*. Fig. 22. *P. capreolata*. Fig. 23. *P. circumvallata*. Fig. 24. *P. coronata*. Fig. 25. *P. corynephora*. (Scales: Figs. 14–19, 1 μm; Figs. 20–25, 0.5 μm).



Figs. 26–37. Scales of *Paraphysomonas*: Fig. 26. *P. diademifera*. Figs. 27, 28. *P. glandiata*. Fig. 29. *P. imperforata* forma No. 2. Fig. 30. *P. poteriophora* ssp. *manubriata*. Fig. 31. *P. punctata*. Fig. 32. *P. quadrispina*. Fig. 33. *P. runcinifera*. Fig. 34. *P. stelligera*. Fig. 35. *P. subquadrangularis*. Fig. 36. *P. undulata*. Fig. 37. *P. vestita*. (Scales: 0.5 μm).

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伊藤裕之：琵琶湖南湖の鱗片を有する黄金藻

1980年1月から1984年7月まで，琵琶湖南湖10地点から25試料を得た。この試料から *Mallomonas* 属14種，*Synura* 属5種，*Chrysosphaerella* 属1種，*Spiniferomonas* 属5種，*Paraphysomonas* 属15種1亜種1品種，計42種類の鱗片を有する黄金藻が見出された。その中で17種類（*Mallomonas portae-ferreae*, *M. pseudocoronata*, *M. striata* var. *striata*, *Spiniferomonas takahashii*, *Paraphysomonas caelifrica*, *P. capreolata*, *P. circumvallata*, *P. coronata*, *P. corynephora*, *P. glandiata*, *P. poteriophora* ssp. *manubriata*, *P. punctata*, *P. quadrispina*, *P. runcinifera*, *P. stelligera*, *P. subquadrangularis*, *P. undulata*）は日本新産であった。（652　神戸市兵庫区楠谷町37-1　神戸市水道局水質試験所）