QUATERNARY DIATOMS AND CYSTS FROM XIHU LAKE ON FILDES PENINSULA OF KING GEORGE ISLAND, ANTARCTICA AND THEIR PALAEOENVIRONMENTS

Li Jiaying¹ and Zhang Yucai²

¹Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037
²Institute of Mineral Deposit, Chinese Academy of Geological Sciences, Beijing 100037

Abstract The Xihu Lake is located on the southern Fildes Peninsula. A drill hole is 2.6 m deep and total 102 samples were collected by Dr. Xie Youyu during 1985—1986. The samples from drill hole in the Xihu Lake contain abundant and well—preserved diatoms and Cysts (Chrysophyta), 137 species and varieties of diatoms belonging to 21 genera were recognized. As a result of the detailed research on the diatom assemblages from the Xihu Lake sediments, 9 diatom assemblages were distinguished. From diatom and Cysts (Chrysophyta) data, the changes of the palaeoenvironments and palaeoclimate and their age are discussed.

Key words Diatoms, Cysts, palaeoenvironment, palaeoclimate.

Stratigraphic Profile and Research Methods

The Xihu Lake is located in an ice—free area of the King George Island, which is the biggest one of Southern Shetland Islands. It is one source for drinking water in the Great Wall Station area. The Xihu Lake is 160m long from north to south and 100m wide from east to west, with a maximum water depth of 10 m. Only a small delta with gentle slope is in the west part through which water runs into the lake. The delta is composed of the fine—grained materials, mainly loess—like silt and fine sand. On the other three sides the debris of frost—weathered rocks had collapsed into the lake, so all the successfully sampled holes were sited in the western part of the lake. Dr. Xie Youyu made a drill through the 3.5—4 m deep water in the Xihu Lake by using a gravity rig. The drill hole is 2.6 m deep (Fig. 1) and 102 samples was collected there.

A drill core of 2.6m was taken from the depression of the Xihu Lake, Antarctica, and studied for its diatom content. All Holocene sediments are present in four cores. Analysis of diatom was made on in thin slices of the core samples every 3—8cm. Organic
mater was removed using the method of Van der Werff (1955). Carbonate particles were dissolved in HCl. Only the coarser sand grains were removed by decanting carefully, as the risk of altering the fossil assemblages is otherwise substantial.

Diatoms are interesting organisms because they can provide very accurate information on the habitat in which they lived. In the present case, the following characteristics were studied: lifeforms (planktonic to sessile), hydrogen—ion requirements (alkalobiontic to acidobiontic), behaviour towards currents (rheophilous to limnophilous).

As percentages of the total sum of taxa and grouping according to “life-form”, the percentages of selected individual taxa are calculated.

Profuse and well-preserved assemblages of diatoms and Cysts (Chrysophyta) are present in most of 43 samples from the Xihu Lake on Fildes Peninsula of King George Island, Antarctica.

21 genera, 131 species and varieties of diatoms are recognized. Using a method of fuzzy mathematics this comprehensive study of the diatom assemblages graphically shows the evolution trend and variations of the diatoms.

The Characteristic of Diatom Flora

There are very abundant diatoms well preserved in the 43 samples of the core, and the diatom flora includes 21 genera, 131 species and varieties (see p69, plate 1, 2, 3). Using a method of fuzzy mathematics this comprehensive study of the diatom assemblages graphically shows the development and variations of the diatoms.

The diatoms and Cysts (Chrysophyta) from the sediments in the Xihu Lake are composed of 9 diatom assemblage distinguished in W₁, W₂, W₃, W₄ and W₅ of the core from bottom to top as follows:

1. Fragilaria construens var. subarctica — Frag. construens var. venter — Melosira italica
   subsp. subarctica assemblage (250 — 245 cm, No: W₂ 10 — 7)

This assemblage contains a great number of genera and species, including 15 genera and 59 species and varieties. The assemblage is characteristically dominated by Fragilaria construens var. subarctica which often accounts to 18.09%, and Frag. construens var. venter 14.5%, Frag. construens var. binodis 11.0%, and Frag. pinnata var. lanceolata 14.0% of the total.

2. Fragilaria construens var. binodis — Frag. vaecheriae — Syndra rampens assemblage
   (245 — 230 cm, No: W₂ 6 — 4)

This assemblage includes 16 genera, 48 species and varieties. Assemblages assigned to this zone are characteristically dominated by Fragilaria construens var. binodis (12.
5%, \textit{Fragilariopsis vaceheriae} (9.6%), \textit{Synedra rampens} (10.0%), the epiphyllous diatoms are greatly increases in abundance, such as \textit{Navicula mucicopsis} (13.5%), and planktonic diatom \textit{Melosira italica} varies slightly.

3. \textit{Opephora martyi} — \textit{Achnanthes delicatula} — \textit{Fragilariopsis vaceheriae assemblage} (2.25—2.1 cm, No: \textit{W} \text{5–3})

This assemblage is composed of 14 genera, 45 species and varieties. The assemblage is marked by the incoming of several new elements, \textit{Fragilariopsis vaceheriae} accounts to 10.0%, and \textit{Achnanthes delicatula} 11.0%. The assemblage is characterized by the successive appearance of many taxa of the second assemblage and great increase in \textit{Opephora martyi} (19.0%) and other.

This zone is characterized by an abundant Cysts (Chrysophyta).

4. \textit{Opephora martyi} — \textit{Navicula pseudoscutoformis} — \textit{Melosira roeseliana assemblage} (214—182 cm, No: \textit{W} \text{4} \text{25–22})

This assemblage consists of 14 genera, 50 species and varieties. Assemblages from this zone are characterized by presence of many forms in the underlying diatom assemblage i.e. \textit{Opephora martyi}, and by the disappearance of \textit{Achnanthes delicatula} and Cys. (Chrysophyta).

The base of this assemblage is defined by the first appearance of \textit{Navicula pseudoscutoformis}, together with \textit{Melosira roeseliana}.

5. \textit{Achnanthes lanceolata} var. \textit{rostrata} — \textit{Navicula hungarica} — \textit{Pinnularia subcapitata assemblage} (181—178 cm, No: \textit{W} \text{4} \text{20})

This assemblage includes 10 genera, 37 species and varieties. This assemblage is characterized by abundant specimens of \textit{Achnanthes lanceolata} var. \textit{rostrata} (7.5%), \textit{Navicula hungarica} (9.0%), and \textit{Pinnularia subcapitata} (4.5%), the stenothermal cold diatoms accounts for 25% of the total.

The Cysts (Chrysophyta) is very abundant.

6. \textit{Melosira roeseliana} var. \textit{epidendron} — \textit{Comphonema var. subclavata} — \textit{Achnanthes delicatula} — \textit{Achn. lanceolata} var. \textit{rostrata assemblage} (177—147 cm, No: \textit{W} \text{4} \text{19–9})

This assemblage is similar to preceding diatom zone, but richer in genera and species than the latter. The Cysts (Chrysophyta) almost disappear in this assemblage. The assemblage includes 14 genera, 73 species and varieties. The chief species in this zone includes \textit{Melosira roeseliana} var. \textit{epidendron} (12.5%), \textit{Comphonema logiceps} var. \textit{subclavata} (12.1%), \textit{Achnanthes delicatula} (11.5%), \textit{Achn. lanceolata} var. \textit{rostrata} (9.5%), \textit{Achn. sp.} (9.3%), \textit{Melosira roeseliana} (12.3%), and \textit{Pinnularia isostauron} (11.1%) in abundance.
Fig. 1. The percentage curve of main diatoms in the Xihu Lake sediments, Great Wall Station, Antarctica. (1) Achnanthes aureolata; (2) Ach. exiguus; (3) Ach. exiguus var. heterovalva (<da>); (4) Ach. hungarica; (5) Ach. sp. i; (6) Ach. lapicida; (7) Ach. lanceolata; (8) Ach. lanceolata f. capitata; (9) Ach. lanceolata var. rostrata; (10) Ach. linearis var. pusilla; (11) Amphora fragmentaria; (12) Cymbella minuta; (13) Eunotia alpina; (14) Eunotia prenuptialis var. inflata; (15) Eunotia tenella; (16) Fragilaria communis; (17) Frag. communis var. bidentis; (18) Frag. communis var. ventleri; (19) Frag. pseudotetrasymetrica; (20) Frag. vaucheriae; (21) Gomphonema elongatum; (22) Gomph. elongatum var. subincisa; (23) Gomph. parvulum; (24) Gomph. parvulum var. subtetrahedra; (25) Melosira italica subsp. subtetrahedra; (26) Melosira roeseliana; (27) Melosira roeseliana var. epidendron; (28) Melosira roeseliana var. roeseliana; (29) Nitzschia cicatriculata; (30) Navicula hungarica; (31) Navicula mutica; (32) Nav. pseudocostata; (33) Operculina triloba; (34) Pinnularia bermudensis; (35) Pinn. gibba f. subundulata; (36) Pinn. isocladon; (37) Pinn. latia; (38) Pinn. leptocerum; (39) Pinn. microstauron; (40) Pinn. microstauron var. brebissonii; (41) Pinn. medanor; (42) Staurodiscus anceps; (43) Syndra rumpens.

7. Fragilaria vaucheriae — Achnanthes delicatula — Achnanthes lanceolata var. rostrata assemblage (37–89 cm, No. W4 8–4)

This assemblage is similar to third assemblage Opechona martyi — Achnanthes delicatula — Fragilaria vaucheriae, but less in genera and species than the latter. The Cysts (Chrysophyta) is very abundant in this assemblage.

This assemblage is composed of 11 genera, 43 species and variaties. This assemblage contains elements rich and diverse in composition like Fragilaria vaucheriae (14.1%), Achnanthes delicatula (11.5%), Ach. lanceolata var. rostrata (8.1%), and Ach. linearis var. pusilla (14.5%) in abundance.

8. Syndra rumpens — Fragilaria vaucheriae — Melosira roeseliana var. epidendron — Achnanthes inflata assemblage (88–29 cm, No. W4 4–1, W3 8–4)

This assemblage contains 11 genera, 42 species and variaties. The diatom assemblages assigned to this zone are characterized by the appearance of Syndra rumpens (12.1%), Fragilaria vaucheriae (17.5%), and Achnanthes inflata (13.3%). The stenothermal cold diatoms are about 28% of the total. The Cysts (Chrysophyta) almost disappear in this assemblage.

9. Pinnularia gibba f. subundulata — Pinn. microtauron — Melosira epidendron — Fragilaria vaucheriae assemblage (28–0 cm, W3 3–1)

This assemblage is composed of 10 genera, 19 species and variaties. The assemblage from this zone is characterized by presence of forms in the underlying zone, but is distinguished by the presence of the Pinnularia gibba f. subundulata (13.5%), Pinn. microtauron (11.1%). The stenothermal cold diatoms are about 36% of the total.

The Palaeoenvironments of the Xihu Lake

Application of diatoms to palaeolimnological interpretation follows a variety of approaches that are all based on the modern observations on the life history, habitat, and ecological preferences of living diatoms. Occasionally, gross diatom morphology can be
used to imply palaeoenvironmental conditions.

The Xihu Lake is a glacial—erosion lake in the ancient glacial through which was formed on $T_4$ and $T_5$ marine erosion terraces.

There are very abundant diatoms well reserved in the 43 samples from drill hole in the Xihu Lake are the modern deep—water species widely distributed and mainly belong to Pinnularia type. The plant community of this diatom has the following features:

1. In the lowest zone of the Xihu Lake, *Fragilaria* is very abundant, it is littoral "plankton" or benthic diatom. The dominant species of this assemblage in the Xihu Lake are *Fragilaria construens* var. *subsalina*, *Frag. construens* var. *venter*, *Frag. construens* var. *bi nodis*, *Frag. pinnata* var. *lancetula* with a pH of about 6.5—7.8.

2. The abundant diatoms plant community is found in the sediments of four drill holes except minor samples, among the community there is no real plankton type, only the semi—plankton species of *Melosira roesenea* was found. The species of the most *Frag ilaria*, *Cocconeis*, *Achnanthes*, *Navicula*, *Pinnularia* and the other genus are the coastal benthic species, of which a plentiful amount of *Cocconeis* and *Achnanthes* belong to stationary or adhering type of diatoms. From the living type of diatom it is evident that the water body was shallow, with a small extent during sedimentation.

3. Most of the species in the whole plant community lived in the water environment with a pH value less than 7. Although some species, such as *Achnanthes hungarica*, *Ach. lanceolata*, *Cocconeis placenta*, are found in alkaline water, that is, they are living in the water body with a pH 7 or slightly more, the diatom plant belongs to a plant community on the fresh—water condition.

4. *Melosira roesenea* is a semi—planktonic diatom, it is living in the slow flow of marsh in the mountain area and a typical cold water diatom. Occurrence and amount of this species are different in the profile. This kind of cold water species is not found in the samples (from −200cm to −260cm) numbered with $W_5$, except for sample $W_5$ (−120cm) in which one or two *Melosira roesenea* are present. In the samples numbered with $W_4$ (−120cm to −192cm), *Melosira roesenea* generally occurring in large quantity indicates that the water temperature has decrease, only a few *Melosira roesenea* are found in the samples from the drill hole of $W_3$ (0—100cm), except for sample $W_3$ (−2.0—3.8cm) in which one or two individuals of this species are found. The variation feature of *Melosira roesenea* in the vertical profile reflects that the climatic fluctuation has taken place during sedimentation in the Xihu Lake. Combined with the depths of the samples containing the cold water species mentioned above in the cores from the lake bottom, the climatic status, warmer at two ends and cold in the middle, is concluded. This is in correspondence with the climatic conditions reflected by the grain—size characteristics mentioned above.

5. In assemblages 3, 5, 7, a larger number of the Chrysophyceae Cysts was found among few diatoms.

The fluctuation of the Cysts (Chrysophyta) forms as proportional to the total number of the Cysts throughout these zones, together with the change in the diatom assemblages, are interpreted as a reflection of palaeoenvironmental and palaeoclimatic changes.
6. The age of the sediments in the Xihu Lake, reflected by diatom species is very young and it is possibly late Holocene.

The diatoms in the sediments of Xihu Lake is dominated by *Pinnularia*, a presently existing species in the cold water extensively distributed. It is a lake facies diatom in the fresh-water, and the marine diatom has not been found, indicating that the lake basin was not influenced by trangression. The individuals of the diatom are small, stationary or cohereing. The secondary ones are the coastal benthic species. There are hardly any planktonic species, showing that the lake is small and short of nutrient. The age reflected by the diatom is late Holocene.

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Explanation of the Plates

Plate 1 (All magnifications showing LM)
1. *Achnanthes armata* var. *fomaria* (Kütz.) Grun., valve view, No. W1, 18(3), ×1500.
2. *Achnanthes armata* Kütz., valve view, No. W1, 17(4), ×1000.
4. *Achnanthidium lacustris* var. *rotundata* (Oestr.) Hust., Raphe valve view, No. W1, 16(5), ×1500.
5. *Achnanthes lacustris* var. *rostrata* (Oestr.) Hust., Raphe valve view, No. W1, 16(6), ×1500.
6. *Achnanthes lacustris* var. *rostrata* (Oestr.) Hust., Pseudoraphe valve view, No. W1, 16(4), ×1500.
7. *Achnanthes lacustris* var. *rostrata* (Oestr.) Hust., Pseudoraphe valve view, No. W1, 16(9), ×1000.
8. *Achnanthes delicaea* (Kütz.) Grun., Pseudoraphe valve view, No. W1, 18(4), ×1000.
10. *Achnanthes delicaea* (Kütz.) Grun., Raphe valve view, No. W1, 18(11-12), ×1500.

Plate 2 (All magnifications showing SEM)

Plate 3 (All magnifications showing SEM)
1. *Fragilaria construens* var. *penderi* (Ehr.) Grun., valve view, No. W2, 10(3).
2. *Achnanthes lacustris* var. *rotundata* (Oestr.) Hust., Internal view of pseudoraphe valve, No. W2, 12(6).
3. *Achnanthes lacustris* var. *rotundata* (Oestr.) Hust., Internal view of raphe valve, No. W2, 12(9).
5. *Achnanthes lacustris* var. *rotundata* (Oestr.) Hust., Internal view of pseudoraphe valve, No. W2, 12(33).
8. *Navicula pseudoaustriaca* Hust., Internal view of valve, No. W2, 8(5).