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Holocene environmental change according to lake core in Fildes Peninsula of King George Island, Antarctica

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Abstract Lake core sampled from Xihu in Fildes Peninsula of King Gorge Island, Antarctica could reveal the environmental change of the district. The lake core(GA7), 9.28 meters long, was sectioned at an interval of 2 cm. Through measuring the organic carbon, magnetic susceptibility, granularity and organic carbon isotope of GA7, by use of ^{14}C age it was estimated that there were four periods of high temperature in Fildes Peninsula: 4800 – 4400 aB. P., 3600 – 3350 aB. P., 2100 – 1800 aB. P. and 900 aB. P. – present. Meanwhile, results showed that there was a strikingly positive correlation between the content of organic carbon and that of organic carbon isotope (δC^{13}_{org}) which could be the substitute indicators of environmental temperature.

Key words Antarctica, Holocene, environmental change

1 Preface

Lake sediment formed whether in ancient geological condition or in modern time, recorded and preserved all kinds of geochemical informations such as its evolutive history, also traced the natural environment's rhymes. So lake core was regarded as not only the sensitive indicator of climate change or the high-resolution natural file, but also the information base of climate fluctuation (Keits 1991). As for the Antarctic environmental change, ice core was usually taken as the best material for recovering the long-time climate curve (Kang and Wen 1997), while lake core for the short-time detailed environmental curve(Xie and Cui 1990; Lorius *et al.* 1985; Zhao 1991a, 1991b, 1991c; Liu *et al.* 1998). By lake core, environmental change of recent 4000 years in Chinese Great Wall Station, Antarctica had been researched by professor Zhao Junlin(Zhao 1991a, 1991b, 1991c). Moreover, Holocene climate change of Antarctica had been tentatively involved during recent 10 years(Liu 1998). In this paper, GA7 was chemically measured for discussing the detailed curve of Holocene environmental change.

2 Materials and methods

Through China-made drilling equipment typed XY1(100 meters long, the open hole's diameter was 150 mm), the 9.28 meters lake core was sampled from Xihu lake, Fildes Peninsula, Antarctica, by Professor Yuan Baoyin during the 9^{th} China Antarctica Science Expedition. GA7 core was sectioned at an interval of 2 cm into 345 specimens by removing of the big gravels or lost sediment layers. The specimens were chemically analysed on organic carbon, carbon isotope(δC^{13}_{org}(‰)), granularity (grain size) and magnetic susceptibility.

Organic carbon was analyzed through oil calefaction with oxidant $KCrO_4$-H_2SO_4, δC^{13}_{org} was analyzed under high temperature for oxygenation in branch tube of organic carbon by use of MAT252 isotopic mass spectrograph (made in Germany). Granularity and susceptibility were respectively measured through granularmetric instrument and susceptibility recorder. Organic carbon isotope, granularity and susceptibility were operated in Institute of Geology and Geophysics, China Academy of Sciences, Beijing, organic carbon was fulfilled in the center laboratory of environment monitoring , Shanxi Agricultural University.

3 Result

3.1 Age of GA7

In the paper, GA7 lake core's age came from three resources. One was the original ^{14}C measurement value (Liu *et al.* 1998), which was taken out the 1300 aging years for the lack of ^{14}C in Antarctica Ocean or the ineffective exchange of ^{14}C among ocean water, air and thaw snow(Ohmoto 1983). One was referred to the ^{14}C age of Prof. Zhao Junlin's lake core(Zhao 1991c). The last was deduced from the history of Xihu Lake's evolvement and ice receding, so the lake core's bottom on base rock was aged 12600 years old (Cheng *et al.* 1998).

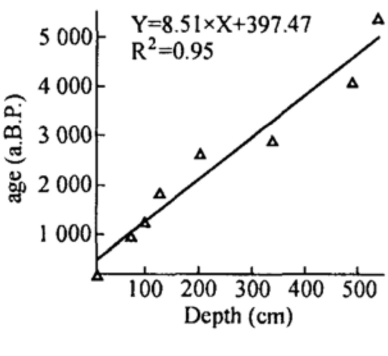

Fig. 1. Relationship between the depth of GA7 lake core and its ^{14}C age.

To relate the lake core's depth with its age and make a curve(Fig. 1), it was found that Xihu Lake was aggraded at different speed, the average pileup rate above GA7's 548 cm was 11.74 cm in one century, while 4.80 cm in one century below 548 cm.

3.2 Organic carbon of the lake core

Fig. 2 showed the sequence that the age, susceptibility, grain medium, organic carbon and carbon isotope changed from up to down on the section of the lake core, Fig. 3 described the rock trait in details. From these indexes or rock trait of the core, it could extract the environmental change information.

Organic carbon of the core changed from 0.07% to 4.18%, the average content was 0.46%. Fig. 2 demonstrated that organic carbon peaked at 0 – 70 cm、345 – 390 cm and

468 – 514 cm while it dropped at the other layers whose average content was 0.21%. Generally, the organic carbon content of lake sediment reflected the biomass. When it was warm, the biomass could be great. Otherwise, lake plant outputs could drop in cold condition. Therefore, it was deduced that warm periods may take place in the years when lake core was deposited on 0 – 70 cm、345 – 390 cm and 418 – 514 cm layers.

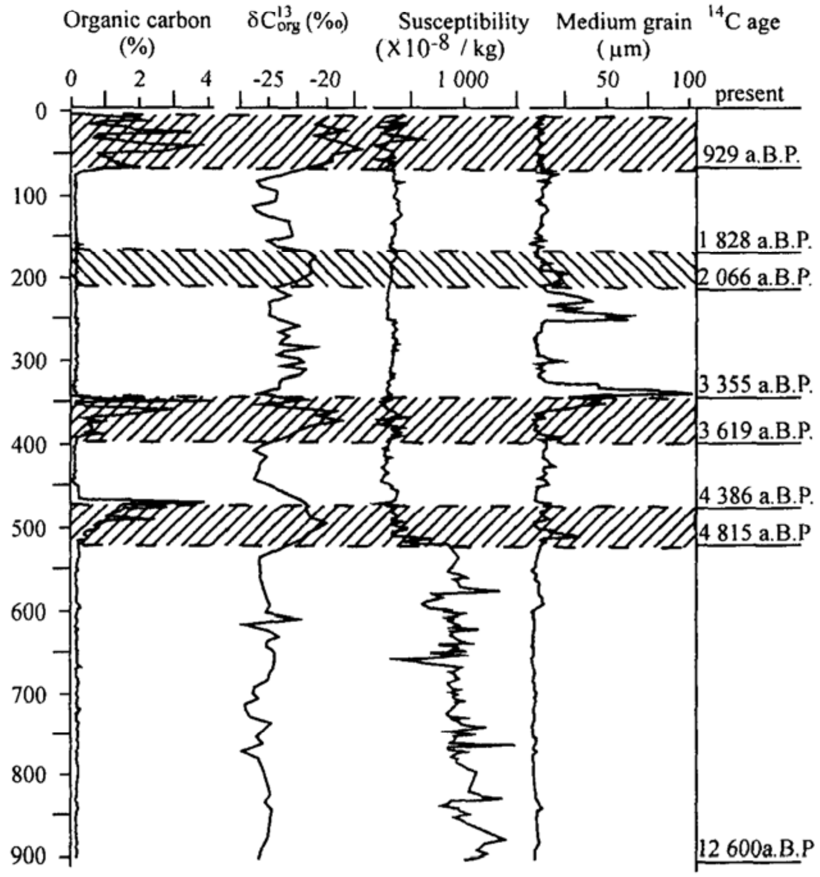

Fig. 2. Sequence of Environmental indicators in GA7 core, Antarctica.

3.3 *Carbon isotope* (δC^{13}_{org}) *of GA7 core*

Content of lake core's carbon isotope was regarded to be related with carbon dioxide in air, photosynthesis effect which represented illumination and air temperature. High carbon isotope was usually linked with high carbon dioxide in air, for example, carbon dioxide in glacial ages was lower than that in interglacial stages. Therefore, carbon isotope is usually thought to be the indicator of climate change (Liu *et al.* 1988).

The variance range of GA7 core's carbon isotope was from – 27.06‰ to – 17.17‰ with the average value – 23.65‰。Fig. 2 displayed that a distinct boundary lay at 514 cm. Above the boundary the average value was – 22.88‰, while below the boundary that was – 25.27‰. The high value emerged at 0 – 64 cm、347 – 378 cm and 466 – 514 cm layers, the lower value appeared at 168 – 204 cm layer. It was also found that GA7 core's carbon isotope was in accordance with its organic carbon content, but carbon isotope could imply environmental information in details.

According to the comprehensive results of organic carbon, carbon isotope and lake core's age, it was concluded that during 0 - 900 aB. P., 3360 - 3600 aB. P. and 4400 - 4800 aB. P., Fildes Peninsula may be of warm periods, while during 900 - 3000 aB. P. the peninsula may be of colder time except in 2200 - 2600 aB. P. which may be a short temperate period.

3.4 Granularity of GA7 core

Fig. 4 showed the vertical variance of granularity including clay (<2 μm), fine silt (<50 μm), coarse silt(<100 μm), sand(<1000μm) and grain medium size. Generally, Xihu Lake core was composed of the coarse grains. The reason was that Xihu as a small and shallow lake, was surrounded with the rough material wheathered by weakly natural chemical force (Xie 1993). The lake core's granularity curve displayed that the grain sizes changed greatly from 190 cm to 519 cm while above 190cm or below 519 cm grain sizes kept steady (Table 1). Because the granularity results were referred to grains less than 1 mm without regard to the grains larger than 1 mm, the curve should be linked with the rock description of Fig. 3 for a reasonable conclusion.

Table 1. Granularity of GA7 core

Depth/cm	clay /%	fine silt/%	Coarse silt/%	Sand/%	Medium size/μm
0 - 190	19.50	71.41	7.82	1.28	10.57
190 - 249	14.16	57.32	20.20	8.32	29.43
249 - 325	20.14	73.69	5.77	0.40	10.59
325 - 356	9.27	40.46	26.90	23.37	51.39
356 - 519	17.55	70.77	9.51	2.16	12.58
519 - 900	26.25	64.23	7.54	1.98	7.08

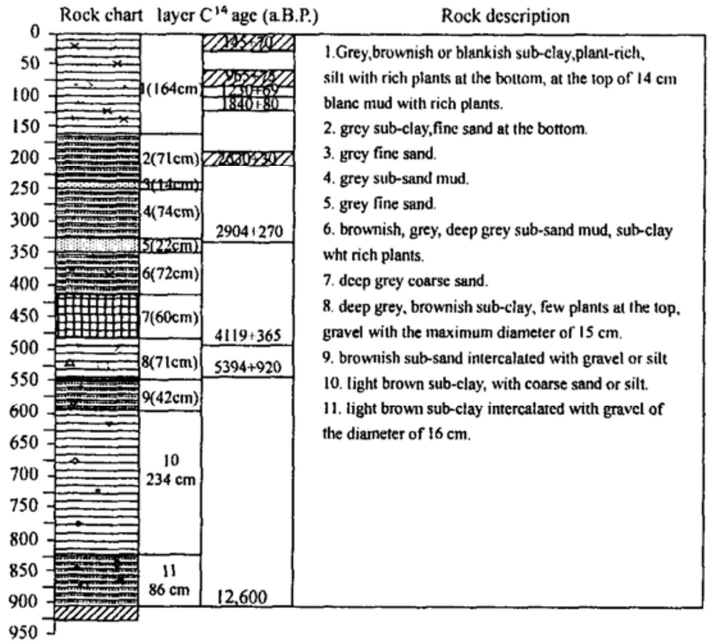

Fig. 3. Rock description of Core GA7.

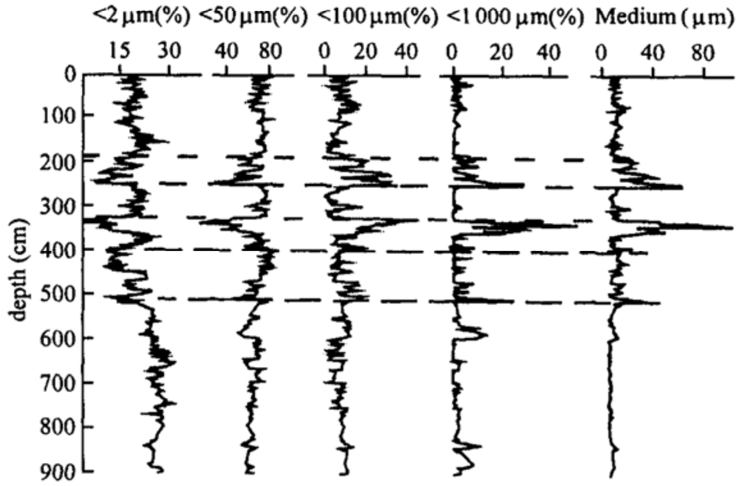

Fig. 4. The distributional features of GA7 core's grain size.

The lake core's granularity reflected the transportation and deposition of lake material (Xie 1993). For GA7 core, grain at 0 – 164 cm was fine and mainly made of fine silt or clay in addition to the sub-clay and plant remains, it was guessed that the temperature of this period might be comfortable. At 164 – 249 cm, the grain was rough with a small amount of fine silt or clay and more coarse silt. At 249 – 325 cm, grain size became fine and mainly made of fine silt, the grain medium size was similar to that of 0 – 164 cm. At 325 – 356 cm the grain was composed of the roughest grain, the coarse silt content was at peak and fine silt content was at the lowest point. The results was in agreement with that of rock description. But at 356 – 519 cm, granularity results of fine silt was not in accordance with the rock character of rough silt because of the lost samples at 422 – 477 cm. Moreover, below 519 cm the granularity results of high composition of fine silt or clay was opposite to that of the rock description, because large grains(> 1 mm) were prevailing at the layer, which was developed in the early period of lake and effected by the unsteady of ice cap's retreating. Therefore, at this layer, the fine grains were accompanied with the big rock.

It was found that the granularity wave at 190 – 396 cm was the response to the climate change from warm to cold, while the steady granularity was coincident with the stable climate either warm or cold. Therefore, it was believed that granularity waved after the climate change. Generally, the lake core's large medium size might reflect the cold weather just after the climate wave, otherwise, the small medium size of lake core might be in accordance with the steady climate state.

3.5 Susceptibility of the lake core

Susceptibility index was usually used in the paleo-climate study on the loess, it was thought to be related with the strength of soil formation, also regarded as a substitute index of paleo-environment(Liu 1997). Susceptibility of Xihu Lake core was high, because the core was composed of large amount of primitive minerals without deep weathering. Therefore, the susceptibility reflected that the resource rock might have a lot of ferromagnetic matters, and may vary greatly when environment changes.

Fig. 2 showed that an obvious boundary of the susceptibility curve lay at 519 cm, of which the average value was 330.1×10^{-8} m^3/kg in the above and 948.7×10^{-8} m^3/kg in the below. Therefore, the core's character, especially the ferromagnetic matter's content, may vary greatly at 519 cm. The variance coefficient of susceptibility waved on the different deposit layer and might be identical with the core's organic carbon content (Table 2). When susceptibility variance coefficient was high, the organic carbon was high at the same layer. It was concluded that biologic matters reconstructed not only the core's component but also its ferromagnetic character.

Thus, it could be concluded that susceptibility wave might reflect the milestone of Antarctica climate change, and variance coefficient of susceptibility was in accordance with the change of environmental temperature. Higher was the variance coefficient, warmer it might be, otherwise, colder it might be. The susceptibility curve showed that 4800 aB. P. might be considered to be the important boundary of climate change, before which it might be of the cold period and the young Xihu Lake was influenced by the unsteady snow line, and made of coarse grains with higher value of susceptibility; After 4800 aB. P., all changed greatly, the snow line retreated to the present position, element Fe might be lost with the ferromagnetic matters mineralized.

Table 2. Variance of susceptibility and organic carbon in GA7 core

Depth/cm	Std. of susceptibility	Variance coefficient of susceptibility	Organic carbon content
0 - 70	969	30.4	1.591
70 - 345	330	9.99	0.178
345 - 390	721	22.0	1.150
390 - 468	396	13.9	0.238
468 - 519	1398	34.4	1.247

3.6 Correlation among the environmental indicators of the lake core

Through the relativity analysis, results showed that between two of the three indicators: organic carbon, carbon isotope and susceptibility (Table 3), there existed linear relationships. Organic carbon and carbon isotope reflected the fluctuation of temperature. Susceptibility was related with the core's components, especially the amount of ferric minerals, and resource minerals had been subjected to. Moreover, change of the core's components was driven by the wave of environmental temperature. Because of the same environmental meaning for revealing the change of temperature, the three indicators related closely with each other. Grain medium size might showed the character of deposit dynamics and could record the minerals' migration motivated by water during the process of lake's development, so the change of the core's grain size could better reveal the swing of rainfall or surface runoff around the lake and even the history of ice retreating in long term.

Table 3. Relationship between environmental indicators of GA7 core

	Organic carbon	δC^{13}_{org}	susceptibility	Medium size
organic carbon	1	0.697	-0.266	-0.15
δC^{13}_{org}	0.697	1	-0.503	0.021
susceptibility	-0.266	-0.503	1	-0.364

3.7 Holocene environmental change series of Fildes Peninsula, Antarctica

According to the above analysis of the lake core's four indexes and their environmental meanings, combined with the core's rock description, results showed the Holocene environmental series of Fildes Peninsula, Antarctica:

12600 – 4800 aB. P. ,cold climate with low productivity of lake plants.

4800 – 4400 aB. P. , warm period with high productivity of lake plants.

4400 – 3600 aB. P. , cold climate with fewer lake plants.

3600 – 3360 aB. P. ,warm period with prosperous lake plants.

3360 – 2070 aB. P. , cold climate with fewer lake plants.

2070 – 1800 aB. P. , moderate climate with a few lake plants.

1800 – 900 aB. P. , colder climate with fewer lake plants.

900 aB. P. -present, warm climate with prosperous lake plants.

The oxygen isotope results of the Vostok ice core showed that the Holocene warm period of Antarctica began at about 9900 aB. P. (Kang and Wen 1997). At about 6200 aB. P. , came the warm period of south Georgia of Antarctica (Clapperton 1989) , but it was believed in the paper that the Holocene warm period in Fildes Peninsula began at about 5000 aB. P..

4 Conclusion

1. Since 12600 aB. P. , there might have been four warm periods with high biomass in Fildes Peninsula: 4800 – 4400 aB. P. 、3600 – 3360 aB. P. 、2070 – 1800 aB. P. and 900 aB. P. -present.

2. The lake core's organic carbon contents were positively related with carbon isotope (δC^{13}_{org}) which could be taken as the substitute indexes of environmental climate.

3. The lake core showed that the Holocene climate turning point was 4800 aB. P. , before which the lake core's susceptibility varied greatly and Xihu Lake was functioned by the repeatedly swing of snow lines, but after which the snow line retreated to the present position , the minerals, especially the ferromagnetic minerals, underwent weathering with the lost of element Fe.

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