Chinese Journal of Polar Science, Vol. 9, No. 1, 1 – 8, June 1998

Silica oxygen isotope record of core PC10 diatoms from the Bransfield Strait, Antarctica and its application in sedimentology

Duan Weiwu (段威武) and Li Xuejie (李学杰)
Guangzhou Marine Geological Survey, MGMR, Guangzhou 510075, China

Shen Youlin (申佑林)
Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China

Received October 23,1997

Abstract 51 diatom samples taken from the piston core PC10 in the Bransfield Strait of West Antarctica were determined by using silica oxygen isotope analysis. The diatom-based results reveal that the 753 cm long core PC10 was deposited in the area in the last 112.5 ka B. P., representing 1 – 5 oxygen isotopic stages and including one incomplete glacial/interglacial cycle and a postglacial period. The sedimentation rate in interglacial period seems to be a little higher than that in glacial, owing to the more terrigenous supply by ice-rafting during the interglacial stages.
Key words Antarctica, Bransfield Strait, diatom oxygen isotope, sedimentology.

1 Introduction

Using of carbonate in the marine sediments for oxygen isotope analysis is one of the successful methods to study the Quarternary high resolution stratigrphy. Recently scientists make an attempt to use siliceous skeletons like diatom and radiolaria as the analysis materials (Department of Marine Geology, Tongji University 1989). However, the latter is limited in utilization due to the complicated processing technique of the biogenic siliceous(opel-A). Mikkelson *et al.* (1978) first made a comparative study on the oxygen isotope of diatom and foraminifera of the box core samples from the east Pacific during the last 20 ka. Results show that the two ones are almost parallel, only the limiting value of the former is bigger than that of the latter. Then Wang and Yeh (1984a) improved the analysis method and successful accomplished the diatom oxygen istope analysis, paleoenvironment evolution analysis. And also the comparasion between the isotopic records of diatoms and foraminifera at some layers and in the same site. The research indicated the diatom oxygen isotope could also be used in stratigraphical dividing and environment analysis.

The Bransfield Strait situated in the north-west area of Antarctic Peninsula is a active back-arc basin formed before 400 Ma(Anderson 1989). In order to obtain more geological environment information from the sediments, we use the diatom sample in place of rare suitable calcareous samples to analysis the oxygen isotope records and features.

2 Samples and analytical method

Piston core PC10 was drilled by R/V "Haiyang Ⅳ" during the 1990/1991 cruise of the 7th Chinese National Antarctic Research Expedition. The core site is located in the central Trough of the Bransfield Strait with water depth 2000 m. The 753 cm long columnar sediments of PC10 consist of the siliceous ooze and mud silt. Generally the diatom frustules number hundreds of thousands per gram in dry sample, the maximum amounts to 1.5×10^6 (Duan *et al*. 1996), commonly they are: *Chacotia actinohilus*, *Cocconcis fossilata*, *Coscinodiscus lentiginnosus*, *Eucampia balaustium*, *Nitzchia kerguelensus*, *N*. spp., *Thalassiora arctica*, *T*. spp.. 51 samples using in oxygen isotope analysis are dry diatom samples extracted from sediments. Commonly, sampling interval is 10 cm besides a few of 20 cm or 40 cm. Owing to more impurity and crystal water in diatom, the pretreatment of sample or, in other word, purifying chemistry method could directly influence the quality of the analysis data. Basing on former experiments (Labeyrie and Juillet 1982; Wang and Yeh 1984b; Juillet and labeyrie 1987), the sample treatment method used in this paper are: taking about 1 mg diatom sample which has already been treated by H_2O_2 and HCl, then washing again with supersonic and mechanical sorting with 240 mesh sieve, and removing various impurities (feldspar, quartz, organic material and ferri-oxide). The cleaning samples need to be dehydrated at 1100 ℃ under high vacuum according to Wang and Yeh (1984a).

After purification and hydration, diatom will be changed into CO_2 gas, using to mass spectrographic analysis by BrF_5 and testing the oxygen isotope composition ($^{18}O/^{16}O$) by using MAT-251 mass spectrograph. At last changing the $\delta^{18}O$ value into correspondent SMOW within testing precision 0.2‰.

3 Results and evaluation

3.1 Analytical results

Among 51 samples, 2 samples from 390 – 400 cm and 490 – 500 cm intervals respectively have rare diatoms to analysis, the other 49 samples' analytical results are 24.30‰ – 35.32‰ (Table 1), eight of which were tested respectively by the MAT-251 of Institute of Exploration and Development of Sichuan Petroleum Administration and mass spectroscopy of State Laboratory of Environment, Guiyang Institute of Geochemistry, CAS, and the results are very similar ($\sigma_x < 0.4$).

3.2 Evaluation

As compared with known data, the oxygen isotopic values of diatom in core PC10 are systematically lower. At DSDP core of Guaymas basin in California, the $\delta^{18}O$ values of diatom are 36.5‰ – 43.1‰ (Wang and Yeh 1985). To find out the cause leads to lower oxygen isotope value of PC10 core, we pick up 11 diatom samples having lower or higher oxygen isotopic value to X-ray diffraction analysis. The results are showed in Table 2, from which you can find the amorphous content are only 75% – 86%. So we infer that the oxygen isotope value should not fully stand for the oxygen isotope value of diatom.

Table 1. The oxygen isotopic compositions of core PC10

Sample number	Depth/cm	$\delta^{18}O$ (‰) vs. SMOW	n/σ_x	Sample number	Depth/cm	$\delta^{18}O$ (‰) vs. SMOW	n/σ_x
PC10 – 1	0 – 10	29.66		PC10 – 38	370 – 380	25.40	
– 5	40 – 50	24.69		– 40	390 – 400		
– 9	80 – 90	32.67		– 42	410 – 420	32.32	2/0.07
– 10	90 – 100	31.20		– 43	420 – 430	25.49	
– 11	100 – 110	24.68		– 44	430 – 440	28.83	
– 12	110 – 120	27.14		– 45	440 – 450	33.59	2/0.39
– 13	120 – 130	33.31		– 46	450 – 460	35.19	
– 14	130 – 140	34.51		– 47	460 – 470	28.54	
– 15	140 – 150	31.33		– 49	480 – 490	28.54	
– 17	160 – 170	34.54		– 50	490 – 500		
– 19	180 – 190	30.54	2/0.29	– 51	500 – 510	31.92	2/0.20
– 21	200 – 210	25.00		– 52	510 – 520	30.83	
– 22	210 – 220	31.80	2/0.05	– 54	530 – 540	29.58	
– 24	230 – 240	30.04		– 56	550 – 560	33.10	
– 25	240 – 250	29.31		– 58	570 – 580	27.54	
– 26	250 – 260	27.72	2/?	– 60	590 – 600	34.81	
– 27	260 – 270	33.39		– 62	610 – 620	31.67	
– 28	270 – 280	30.50		– 64	630 – 640	30.56	
– 29	280 – 290	25.93		– 65	640 – 650	31.79	
– 30	290 – 300	32.30	2/0.3	– 66	650 – 660	30.28	
– 32	310 – 320	29.97		– 68	670 – 680	31.69	2/0.22
– 33	320 – 330	24.30		– 70	690 – 700	31.65	
– 34	330 – 340	30.97		– 72	710 – 720	31.29	
– 35	340 – 350	26.98		– 74	730 – 740	30.31	
– 36	350 – 360	31.92		– 75	740 – 750	35.32	
– 37	360 – 370	28.43					

Table 2. X-ray powder diffraction records of core PC10(%)*

Sample	Depth /cm	Amorphous	Smectite	Kaolinit	Illite	Stellerite	Analcite	Cristobalite	Quartz	Albite	Calcite	Total	$\delta^{18}O$(‰) vs. SMOW
PC10-5	40 – 50	81.0		1.0		6.4			3.4	6.0	1.1	98.9	24.69
9	80 – 90	76.0		1.2		8.4		1.6	4.4	6.9		98.5	32.67
10a	90 – 100	78.0		2.5		13.5			1.5	3.7	1.1	100.3	31.20
10b	90 – 100*	85.0				5.6			1.7	5.7	1.7	99.7	
14	130 – 140	76.0		1.0		7.9	0.6	2.0	4.8	7.0		99.3	34.51
21	200 – 210	79.0		1.0		3.8	0.8	5.6	3.2	5.4		98.8	25.00
26	250 – 260	84.0	2.2	2.5		4.8			1.8	3.1		98.4	27.72
29	280 – 290	79.0				10.0			2.6	4.9	2.0	98.5	30.50
34	330 – 340	75.0						20.0	3.0			98.0	30.97
46	450 – 460	80.0	1.8	1.4		5.9		2.5	2.6	4.9		99.1	35.19
75	740 – 750	86.0		1.3	2.7	1.7			3.0	3.8		98.5	35.22

* sample sieved by 32 μm siever.

According to the X-ray diffraction results, the impurity could be divided into:

(1)clay mineral: montmorillonite+kaolinite+illite, and slightly positive correlation to the $\delta^{18}O$ value (Fig. 1b);

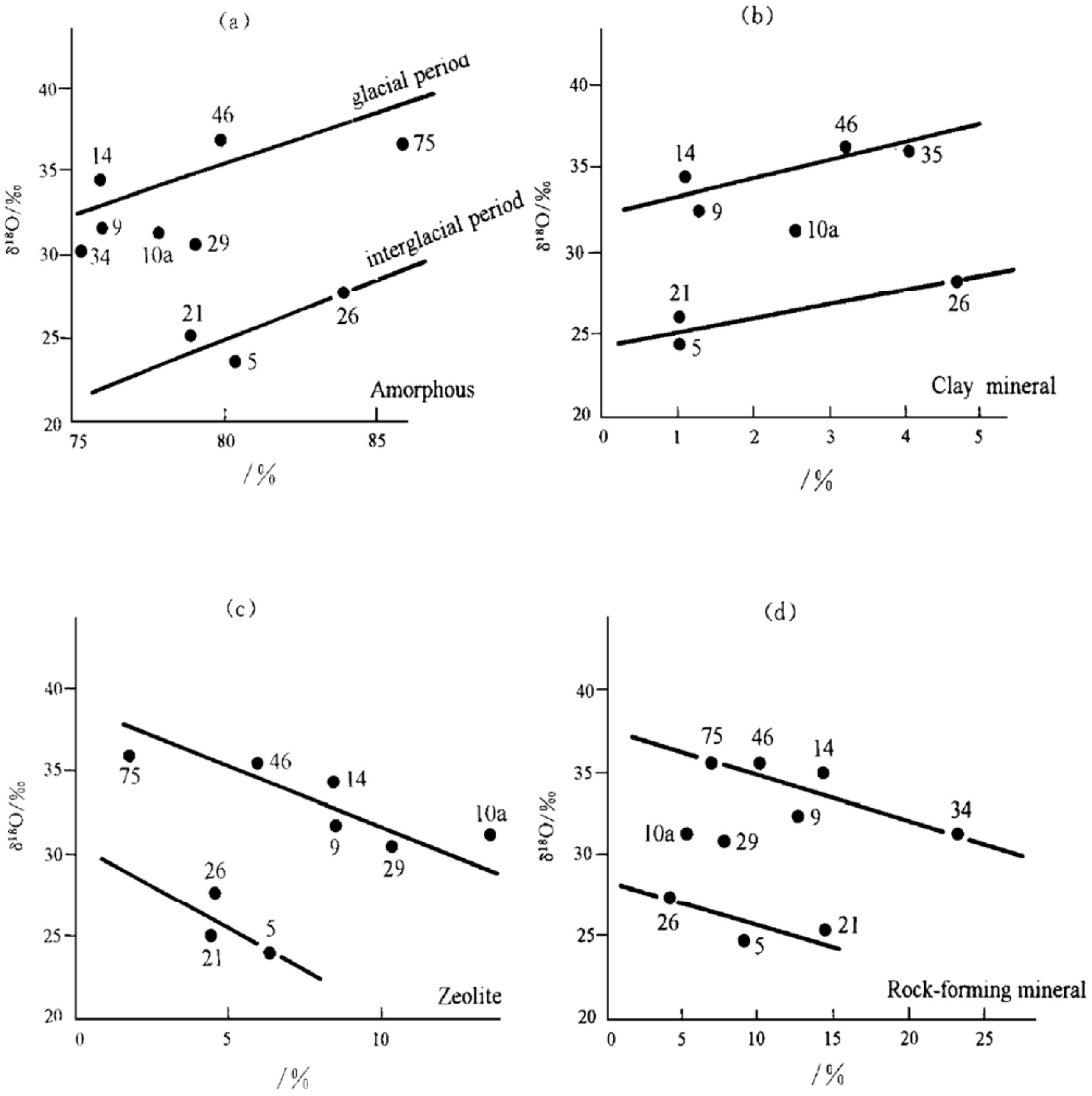

Fig. 1. Plots of $\delta^{18}O$ versus contents of amorphous substance and impurities within diatom samples.

(2)Zeolite: stellerite+analcite, and negative correlation to $\delta^{18}O$ value (Fig. 1c);

(3)Rock-forming mineral: cristobalite + quartz + albite, and negative correlation to $\delta^{18}O$ value (Fig. 1d);

(4)Calcite: Few data so that the regularity is unclear.

The oxygen isotope values of impurity are far less than the ones of diatom, for example the $\delta^{18}O$ value of quartz is about 10‰, while that of feldspar <10‰. For zeolite it's very complicated, most of it are 20‰ – 25‰, but analite is 13.4‰ (Feng and Savin 1991). In Fig. 1a, it is showed that $\delta^{18}O$ value is evidently interrelated to the diatom content. On the basis of sedimentary features, we found that the higher $\delta^{18}O$ values of glacial stages are obviously different from the lower value samples of interglacial stages. Impurity has no essential influence on environment information reflected by $\delta^{18}O$ value.

3.3 *Oxygen isotopic stratigraphy*

Fig. 2 shows the oxygen isotopic curve of diatom along with the depth change. In order to provide the comparative time scale, samples of core PC10 were used for dating analysis. Chronology of oxygen isotope events based on the foraminifera data have been widely used for division and correlation of high-resolution late Quaternary stratigraphy. In this paper we mainly adopted what Martinson *et al.* had proposed in 1987 to distinguish the oxygen isotopic stages, the time data are listed in Table 3.

Overall, five intervals with relatively high peak and low valley of oxygen isotopic recoreds of core PC10 diatom are observed as given in Fig. 2.

Table 3. Sedimentary rate at core PC10

$\delta^{18}O$ stage	Stage boundary	Duration /ka B. P.	Boundary age* /ka B. P.	Sedimentary thinkness/cm	Sedimentation rate /cm
1		12		118	9.83
	1/2		12.05±3.41		
2		12		77	6.41
	2/3		24.11±4.91		
3		35		220	5.71
	3/4		58.96±5.56		
4		25		65	2.70
	4/5		73.91±2.59		
5	5.4	38.5	110.79±6.28	293	7.61

*: Martinson *et al.* (1987).

1) 0 – 118 cm interval: with lower $\delta^{18}O$ value and ranging from 24.67‰ – 32.67‰, the results are (13.2±1) ka B. P. at the sample of 105 – 120 cm by thermoluminescent dating, and 7.7 ka B. P. at the sample 48.5 – 60 cm by Uranium series method. Therefore this interval 0 – 118 is thought to be equivalent to the post-glacial period, and to be equivalent to the oxygen isotope stage 1. The age at depth 118 cm is about 12 ka B. P., approximately being the lower boundary of post-glacial period.

2) 118 – 195 cm interval: showing higher $\delta^{18}O$ value with 2 peaks, ranging from 27.14‰ – 34.54‰, the limitation age of this interval is less than 33.7 ka B. P. on the basis of dating result. So the high $\delta^{18}O$ peaks could be representative of the later phase of the last glacial period, corresponding to oxygen istope stage 2. The higher $\delta^{18}O$ peak at the interval 120 – 140 cm might be matching to oxygen isotopic event 2.2 at the acme of the last glacial period.

3) 195 – 390 cm interval: comparatively lower $\delta^{18}O$, and ranging from 24.05‰ – 33.39‰, peaks alternating with valley, the lowest valley approaches the oxygen isotope stage 1, and this interval stands for comparatively warmer environment, being equivalent to oxygen isotope stage 3.

4) 390 – 460 cm interval: $\delta^{18}O$ curve shows one valley with two peaks, total values being higher, ranging from 28.83‰ – 35.1‰, peak value slightly greater than that in the 2nd interval. Data-testing of 400 – 410 cm interval is 610 ka B. P, ap-

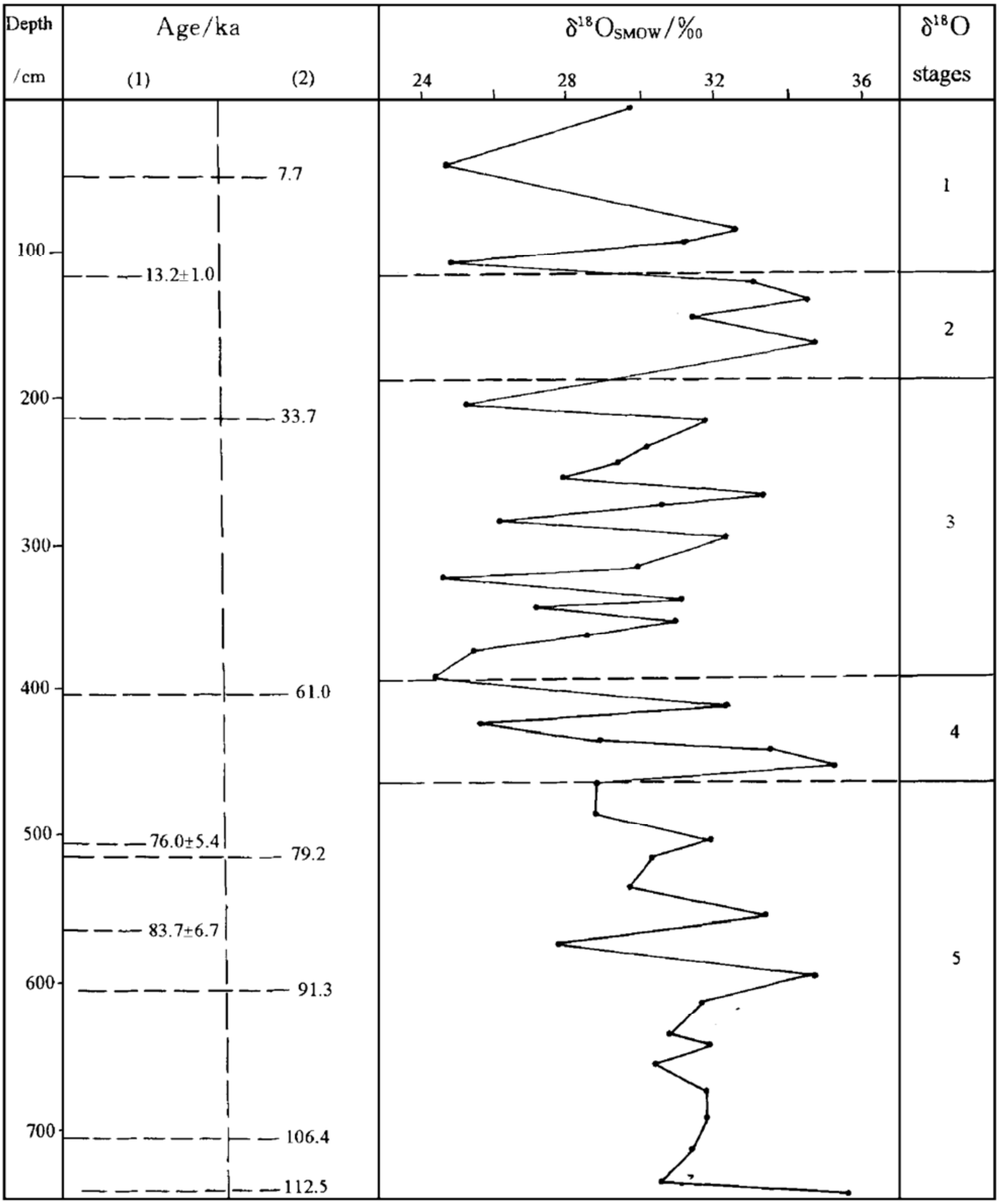

Fig. 2. Diatome oxygen isotope stages with chronologic date from core PC10. (1) TL method (whole rock) measured by Guangzhou Institute of Geochemistry, CAS; (2) U-series method (whole rock) measured by South China Sea Institute of Oceanology, CAS.

proaching the 3/4 stage boundary age of oxygen isotope by Martinson *et al*. (1987). It reveals a colder climate, being equivalent to oxygen isotope isotope event 4.2.

5) 460 – 735 cm interval: $\delta^{18}O$ value being relatively lower, ranging from 27.54‰ – 33.10‰, representing a warmer climate. Five data-testing samples are

used, from which we may infer that its top and bottom interface ages are (76.0±5.4) ka B.P. and 112.5 ka B.P.. Therefore it is equivalent to oxygen isotope stage 5, among which 740 – 750 cm interval obviously shows a half-peak feature and probably stands for oxygen isotope event 5.4.

3.4 Sedimentation rate

The sediments of PC10 core mainly consist of fine-grain components, with the grain size of less than 0.063 mm, among which content of the siliceous organism is 32% – 75%, averagely 42%. The sediments are mainly siliceous mud-silt. Biosedimentation plays a dominant role and no surface runoff replenishes. Based on oxygen isotopic stratigraphy of diatom and age data of each interval, sedimentation rate of core PC10 are calculated and listed in Table 3.

As compared with those in the mid-low latitude areas, the main difference is in that the sedimentation rate of the present area is much faster, besides the higher contents of detrital minerals within the warmer periods (oxygen isotope stages 1 and 5) than those within the colder periods. For the reason, in addition to the more terrigenous supply, it is most likely that the dissolving of ice-cap, growing of ice-rafting materials and the developing of sea-current are closely related due to the climate changing warmly.

4 Summary

(1)Columnar sediments of core PC10 include oxygen isotope stages 1 – 5 (incomplete in its lower part), representing a post-glacial period and incomplete glacial/interglacial cycle, and recording the sendimentary history of about 112.5 ka B.P..

(2)Sedimentation rate of core PC10 during the interglacial and post-glacial periods is slightly higher than that during last glacial period, resulting from the plentiful ice-rafting materials and stronger sea current of warmer period. The features differ from those in mid-low latitude areas.

(3)Climatic phases of last interglacial, last glacial and post glacial could be distinguished from each other since 112.5 ka B.P.. Generally the tendency of the climate turned warmly.

Acknowledgements We thank prof. Yu Jinsheng, Guangzhou Institute of Geochemistry, CAS for his constant help; prof. Wang Chungho, Institute of Earth Sciences, Taipei for his helpful discussion in sample preparation; also prof. Wang Guanxin of Guangzhou Institute of Geochemistry, CAS for his assistance with X-ray diffractometer.

References

Anderson JB (1989): Antartica's glacial setting. In: Anderson JB and Molnnia BF, ed. Glacial-Marine Sedimentation (Short Couse in Geology, 9), 28th Int. Geol. Congr., Washington D.C.: Am. Geol. Union, 11 – 57.

Department of Marine Geology, Tongji Uniersity (1989): Introduction to Paleoceanography. Shanghai: Tongji University Press, 316(in chinese).

Duan WW, Zhong HX, Li Y(1996): Late Quaternary glacial-marine sedimentation in the Bransfield Strait off northwest Antarctic Peninsula. Antarctic Research, 7(1): 19 - 33.

Feng XH, Savin SM(1991): Oxygen isotope studies of zeolites stiebite, analcime, heulandite and Clinoptilolite - I. Analytical technique. In: Tayler HP Jr *et al.*, ed. Stable isotope Geochemistry: A tribute to Sanuil Epstein, The Geochemistry society, special publication No 3, San Antonio (U. S. A.): Lancaster press, 271 - 283.

Juillet A, Labeyrie LD (1987): Temperature dependence of the oxygen isotopic fractionation between diatom silica and water. Earth Plant. Sci. Tett., 84: 67 - 74.

Labeyrie LD, Juillet A (1982): Oxygen isotopic exchangeability of diatom value silica, interpretation and consequences for palaeoclimatis studies. Geochimica et Cosmichimica Acta, 46: 967 - 975.

Martison DG, Pisias WG, Hays JD *et al.* (1987): Age dating and orbital theory of the ice age: development of a high resolution 0 to 300000 years chronostratigraphy. Quaternary Research, 27: 1 - 29.

Mikkelsen N, Labrie L Jr, Berger WH(1978): Silica oxygen istopic in diatoms: a 20000ys record in deep-sea sediments. Nature, 271: 536 - 538.

Wang CH, Yeh HW(1984a): Oxygen isotopic analysis of marine diatoms. Bulletin of the Institute of Earth Sciences, Academica Sinica, 4: 131 - 140.

Wang CH, Yeh HW(1984b): Water in biogenic silica and its effects on oxygen isotope values. Bulletin of the Institute of Earth Sciences, Academia Sinica, 4: 141 - 147.

Wang CH, Yeh HW (1985): Oxygen isotopic compositions of DSDP site 480 diatoms: Implications and applications. Geochimica et Cosmochimica Acta, 49: 1469 - 1478.