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A preliminary study on the element strata and palaeoenvironment of core NP95-1 from the Prydz Bay, Antarctica

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Abstract This paper deals with the characteristics of element geochemistry of the core NP95-1 from the Prydz Bay, Antarctica and its palaeoenvironment implication. The results show that the sediments in this area were greatly affected by dissipation of ice cover, gushing of freshwater and terrigenous materials in the process of deposition, and the elements such as SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, P, S and C_{org} in sediments have well recorded the changes of material source resulting from palaeoclimate change and the distribution patterns of these elements correspond to the palaeosedimentary environment of ocean and the variations of palaeoclimate. Climatically five periods can be roughly divided, such as warm, cold, hot, turning cold and turning warm since the late pleistocene. The turning points of temperature , which indicate the changes of climate, lie at 145 cm, 85 cm and 25 cm of the core NP95-1, and the sudden change of element content occurs at 85 cm of the core NP95-1, this layer indicating that an abnormal event happened and marking the beginning of Holocene.

Key words sediments, element strata, palaeoenvironment, Prydz Bay, Antarctica.

1 Introduction

Any ancient or mordern sediments, formed in a specific geological setting, have recorded the geochemical information involving in their formation and evolution (Wen and Diao 1987). It is an important part of palaeoenvironment research as well as an important geochemical method to discuss palaeoenvironment according to distribution of elements in strata because the riching and dispersing of elements could reflect the changes of sedimentary environment to a great extent. This paper deals with the palaeoenvironmental evolution from the late pleistocene on the basis of detailed studies on element strata of core NP95-1 from the Prydz Bay, Antarctica.

2 Geological and geographical setting

The studying area is located at the Prydz Bay, Antarctica. It is adjacent to the Larsemann Hills, a part of the ancient crystalline shield of East Antarctica. Its basement has experienced polyphase strong migmatic metamorphism (Li 1993). The main metamorphic events, fraction melting and migmatization occurred in about 500 Ma (Zhao *et al.* 1992; Zhou and Hensen 1992). Rock layers outcropping in the Larsemann Hills mainly consist of migmatized pelite, arenaceous rock and halleflintgneiss.

Lenticular and stripped mafic granulite and ultramafic granulite, gneissic granite, pegmatite (Wang *et al.* 1994) and vein quartz are also found. The Larsemann Hills is characterized by rugged landform and numerous lakes, showing tyical topographic features of glacial abrasion. The lake-bottom sediments consist of large quantities of sand (99.67%) and a small quantity of gravel (0.33%) (Burgess *et al.* 1988). Moreover, wind-erosion holes and wind-erosion cliffs can be seen everywhere. Two abrasion terraces go along the coast-line, and the low-lying land is covered with sand layer of different thickness (Li 1993).

3 Materials and methods

The core NP95-1 with water depth 1960 m and core length 170 cm was collected from the outer continental slope of the Prydz Bay, Antarctica (66°45.555′S, 74°50.070′E) in 1994/1995 by the 11th Chinese National Antarctic Research Expedition (Fig. 1). According to changes of the size of sediments, the core can be divided 10 sections as follows:

(1) 0 – 19 cm, yellowish-brown silt clay;
(2) 19 – 37 cm, greyish-green silt clay;
(3) 37 – 73 cm, dark grey silt clay with gravel;
(4) 73 – 79 cm, dark grey medium fine sand with gravel;

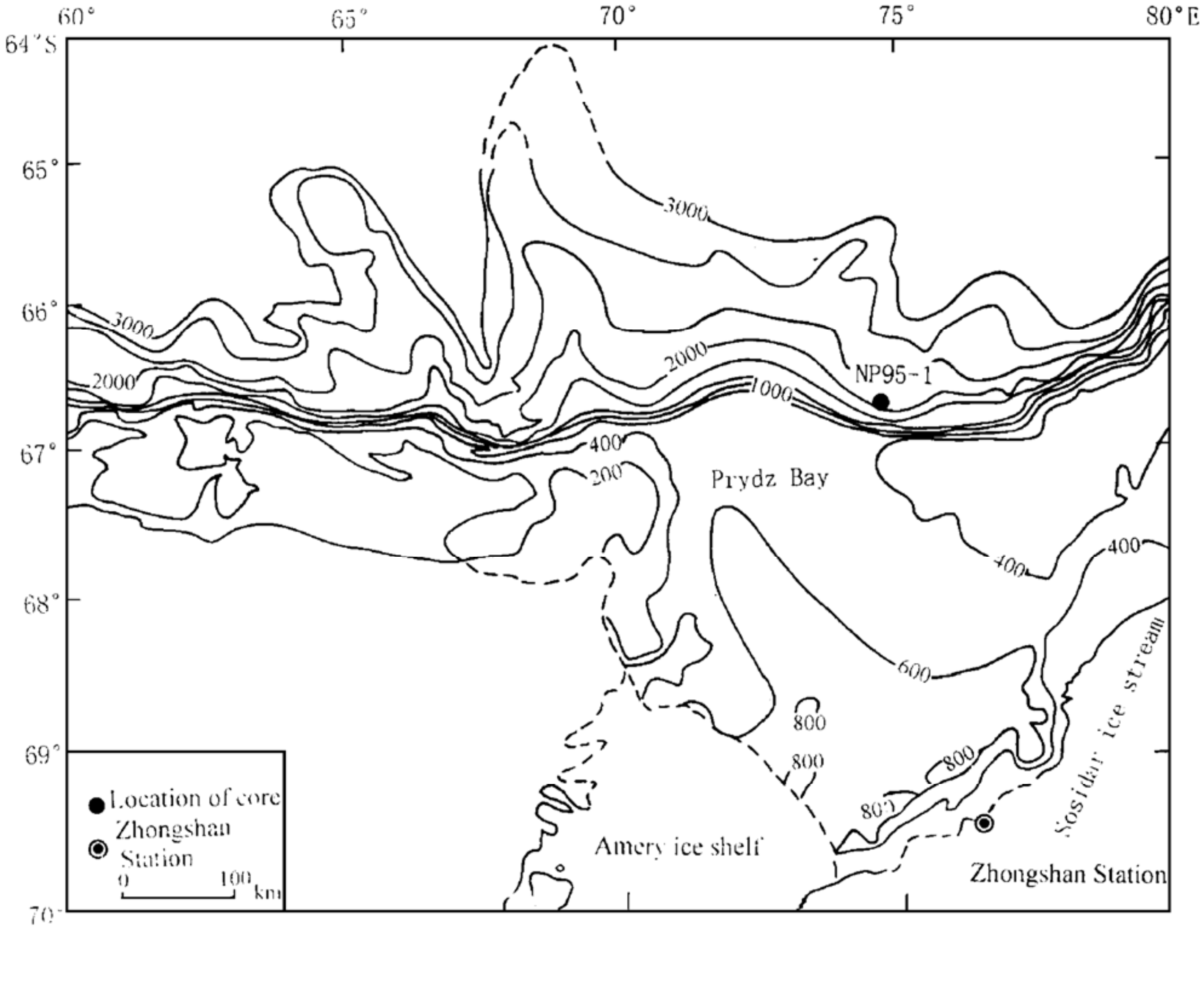

Fig. 1. Location of the core NP95-1.

(5)79 – 89 cm, grey coarse medium sand;
(6)89 – 123 cm, greyish green sandy clay;
(7)123 – 136 cm, yellowish-brown fine clay;
(8)136 – 143 cm, grey medium coarse sand with gravel;
(9)143 – 156 cm, light yellow muddy silt;
(10)156 – 170 cm, greyish-green silt clay.

Thirty-four samples for geochemical analysis was taken from the core NP95-1 with an interval of 5 cm. SiO_2 was analysed by weight method and the organic materials by capacity method. The content of CaO, MgO, Fe_2O_3, Al_2O_3, S and P was determined by ICP after dissolving in HNO_3, $HClO_4$ and HF. The results are listed in Table 1.

Table 1. Element content and element ratio of core NP95-1 from the Prydz Bay, Antarctica

Length of core /cm	Layer	SiO_2 /%	Organic material /%	CaO /%	MgO /%	Fe_2O_3 /%	S /($\times 10^{-6}$)	P /($\times 10^{-6}$)	($100 \times$ MgO) /Al_2O_3
4. 25	1	64. 91	0. 82	2. 08	2. 282	6. 569	466	585	16. 82
9. 25	2	63. 15	0. 88	1. 663	3. 116	7. 416	1083	826	24. 65
14. 25	3	65. 06	1. 23	1. 521	2. 690	6. 354	1201	615	24. 63
19. 25	4	64. 29	1. 47	1. 956	2. 991	6. 173	773	556	24. 31
24. 25	5	67. 23	1. 27	1. 935	2. 482	5. 415	1745	783	21. 49
29. 25	6	64. 09	1. 12	2. 288	3. 009	5. 974	535	514	22. 13
34. 25	7	61. 44	0. 95	2. 239	3. 134	6. 948	846	917	21. 42
39. 25	8	55. 80	0. 85	2. 270	3. 777	13. 935	931	1373	25. 99
44. 25	9	57. 50	1. 02	2. 121	4. 454	9. 330	1140	988	26. 34
49. 25	10	57. 30	1. 51	2. 241	3. 648	9. 325	646	707	22. 19
54. 25	11	58. 00	1. 07	2. 396	3. 880	9. 504	1076	1029	23. 83
59. 25	12	58. 37	0. 99	2. 405	3. 864	8. 781	482	688	22. 88
64. 25	13	56. 58	1. 08	2. 241	4. 203	9. 771	501	739	24. 52
69. 25	14	59. 94	0. 98	2. 587	3. 184	8. 550	440	720	18. 95
74. 25	15	67. 31	1. 18	2. 407	2. 165	5. 169	275	600	13. 95
79. 25	16	71. 14	0. 42	2. 036	1. 947	5. 649	413	488	15. 84
84. 25	17	80. 96	0. 12	1. 771	0. 711	2. 075	156	212	6. 64
89. 25	18	64. 56	0. 64	2. 190	2. 771	6. 184	653	824	20. 24
94. 25	19	58. 85	0. 71	2. 303	3. 878	8. 133	859	1050	24. 13
99. 25	20	60. 25	0. 69	2. 162	3. 203	6. 993	793	817	21. 86
104. 25	21	61. 81	0. 81	2. 098	3. 114	7. 202	752	808	19. 87
109. 25	22	63. 71	0. 64	2. 355	2. 921	6. 154	819	854	20. 96
114. 25	23	63. 61	0. 59	2. 695	3. 184	6. 293	451	496	22. 10
119. 25	24	65. 65	0. 54	2. 641	2. 886	6. 208	435	574	19. 84
124. 25	25	69. 58	0. 42	2. 264	2. 217	4. 977	379	431	17. 71
129. 25	26	69. 98	0. 51	1. 097	2. 052	4. 793	751	514	17. 59
134. 25	27	73. 30	0. 46	1. 844	1. 695	4. 125	777	604	15. 58
139. 25	28	78. 14	0. 32	1. 775	1. 262	4. 112	363	428	13. 30
144. 25	29	78. 63	0. 25	1. 974	1. 023	2. 969	210	350	9. 55
149. 25	30	76. 19	0. 21	2. 159	1. 285	3. 987	226	459	11. 34
154. 25	31	74. 13	0. 21	2. 201	1. 453	4. 368	413	691	11. 40
159. 25	32	73. 21	0. 25	2. 451	1. 647	4. 542	274	599	13. 13
164. 25	33	74. 25	0. 26	2. 137	1. 233	3. 548	371	574	10. 68
169. 25	34	65. 94	0. 69	2. 114	2. 540	6. 231	437	558	B. 57

4 Distribution of elements in strata

The content of elements in core NP95-1 can be divided into 5 layers, referring to the ratio of MgO to Al_2O_3 (Fig. 2).

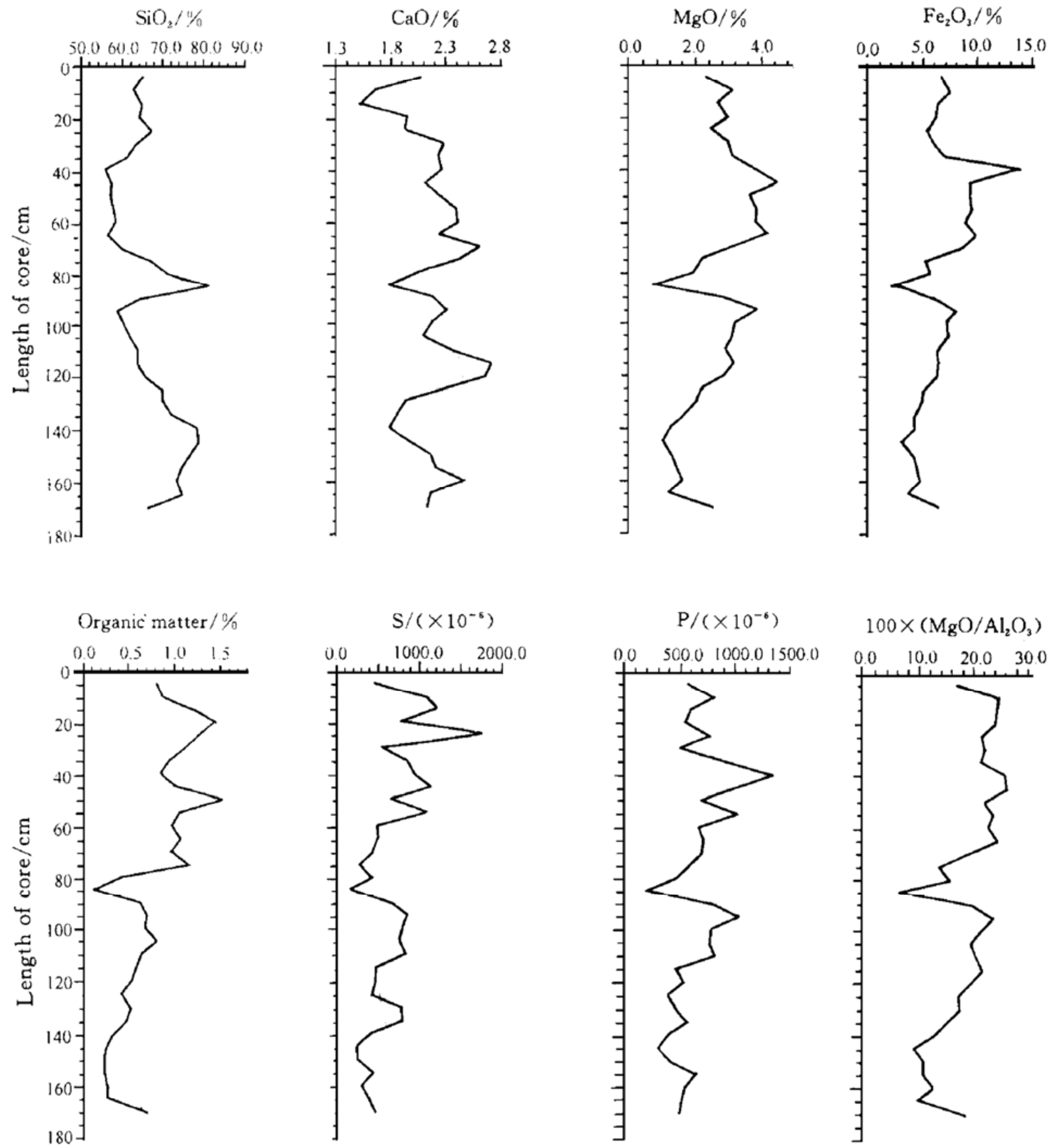

Fig. 2. Element content and element ratio of the core NP95-1 from the Prydz Bay, Antarctica.

(1)0 – 35 cm, with fluctuating content of CaO, S and organic materials. CaO occurs at the lowest value, S at the highest value and organic materials at the secondly highest value. The content of other elements is medium.

(2)35 – 73 cm, with low content of SiO_2 and medium to high content of other elements. SiO_2 occurs at the lowest and at secondly lowest values, and other elements at the highest or secondly highest values.

(3)73 – 89 cm, with medium to high content of SiO_2 and medium to low content of other elements. SiO_2 occurs at the highest value and other elements at the lowest or secondly lowest value in the middle of this layer. There is a sudden change of content at about 85 cm for all the elements.

(4)89 – 136 cm, with low to medium content of SiO_2 and medium to high content of other elements. CaO occurs at the highest value and MgO and P at the secondly highest value.

(5)136 – 170 cm, with medium to high content of SiO_2 and medium to low content of other elements. SiO_2 occurs at secondly highest value and other elements at secondly lowest values at about 145 cm.

5 Stratigraphical implication of elements

The distribution pattern of elements in strata is directly controlled by the geochemical properties of elements themselves and the size of sediments. The distribution law of elements in strata is similar to that of modern sediments. This is the important basis for dividing strata and studying changes of paleo-oceanic environment (Yan *et al*. 1991).

5.1 Distribution of elements in strata is controlled by the geochemical properties of elements themselves

The elements can be divided into two groups according to their distribution patterns in core NP95-1.

(1) SiO_2: SiO_2 in core NP95-1 shows a clear variation of medium — low — high — medium — high content from the top to bottom of the core, and reaches the highest value at about 85 cm and the secondly highest value at about 145 cm. Silicon is a typical lithophile element and often appears in the form of quartz. It is rich in rocks and minerals of the upper crust and tends to be dissolved in alkaline medium (Liu *et al*. 1984). So the content change of SiO_2 can reflect the change of sedimentary environment.

(2) CaO, MgO, Fe_2O_3, S, P and organic materials: The distribution patterns of elements in this group, which are exactly contrary to that of SiO_2, are on the whole the same, and reach the lowest or secondly lowest values at about 85 cm and 145 cm. There are still some differences among these elements even though they have the same tendency of changing (Fig. 2).

Ca and Mg are of strong ability to migration in sea, and their content in residual sediments is very low. The content of Fe increases gradually from continental crust to transitional crust, then to oceanic crust. Fe tends to migrate in reduction environment and acidic medium and to precipitate in alkaline medium. Most of the phosphorus, which is released from minerals under the action of weathering, is brought into ocean by river water, and a little by atmosphere (Liu *et al*. 1984). The sulphur, an important mark of biogeochemical action in sedimentary process, has the similar nature to phosphorus. Most of the sulphur is also leached to river and then migrated to ocean. The quantity of organic materials generally represents the productive forces, and mainly represents the productive forces of marine life in Antarctica. Content variation of the organic materials can also reflect the climate change. This element group is often rich in marine environment.

5.2 The element content is controlled by the size of sediments

There is obvious relation between element content and the size of sediments in core NP95-1. The core can be roughly divided five sections according to the size change of sediments:

(1)0 – 35 cm, silty clay, medium content for most of the two group elements, which shows a relatively calm environment of sedimentation;

(2)35 – 73 cm, silty clay with gravel, medium to low content for SiO_2 and medium to high content for other elements, which also geneally shows a relatively calm environment of sedimentation;

(3)73 – 89 cm, sand with gravel, medium to high content for SiO_2 and medium to low content for other elements, which shows intermittent addition of great deal of terrigenous materials and a turbulent environment of sedimentation;

(4)89 – 136 cm, sandy clay, low to medium content for SiO_2 and medium to high content for other elements, which shows a relatively calm environment of sedimentation accompanying slight turbulence;

(5)136 – 170 cm, medium-coarse sand with gravel, muddy silt and silty clay, medium to high content for SiO_2 and medium to low content for other elements, which shows a turbulent environment of sedimentation.

6 Palaeoenvironmental implication of the distribution of elements in strata

It can be seen clearly from the changing curves of geochemical parameters, such as MgO/Al_2O_3, that palaeoclimate changed at 25 cm, 85 cm and 145 cm of the cor e NP95-1. The ratio of MgO to Al_2O_3 can reflect the variation tendency of water salinity in the sedimentary process of core NP95-1. The fact that the ratio of MgO to Al_2O_3 reached the minimum at 85 cm of the core (10.3 ka B. P.) indicates that this area was in a transitional sedimentary environment from continental facies to marine facies in that time (Zhang 1988). In the meantime, the fact that the content of SiO_2 reached the maximum, MgO, Fe_2O_3, S, P the minimum and CaO nearly the minimum at 85 cm of the core shows the addition of freshwater (Lin and Cai 1988). The sudden change of element content at 85 cm of the core, which corresponds to the Gothenburg geomagnetic excursion, indicated occurrence of extreme event, in which the global climate warmed suddenly, the ice cover dissipated, the freshwater gushed into the sea, a great deal of terrigenous materials was carried into the sea, and thus sediments with much sand and gravel were deposited. This marks the beginning of Holocene in Antarctica after 10.3 ka B. P.. The layer of 145 cm of the core (14.4 ka B. P.), in which the ratio of MgO to Al_2O_3 is less than 10, content of SiO_2 is high and of other elements is low, and the sediments mainly consist of sand and gravel, is similar to that of 85 cm, so this layer can also be considered as a turning point of warm climate. Morever, it can be inferred that the layer of 25 cm of the core (6.3 ka B. P.) is another minor turning point of warm climate according to the changing law of SiO_2 content in core NP95-1.

Organic materials, S and P are the marks of climate change. The content of these elements suddenly dropped to low value during sedimentation of the preceding two stages because the ice cover dissipated, a great deal of freshwater and terrigenous materials were carried into the sea, and the sampling location is near the coast and was greatly affected(Zhao 1991).

Studies on the palaeoclimate recorded by magnetic parameters (S ratio and SIRM/K) of core NP95-1 show that the palaeoclimate changed at 19 cm, 90 cm and 130 cm of the core (Hou *et al.* 1997). This is in line with the result from this paper on the whole. We may attribute the little difference between them to the different sensitivity of each proxy to climate. The three palaeoclimatic events revealed from element content can also be seen clearly from the lithologic change of the core. This further shows the authenticity of the three palaeoclimatic events.

With regard to the distribution of sediment types and their element content, the palaeoclimate recorded in core NP95-1 can be divided into five stages from the top to bottom as follows:

(1) 0 – 35 cm: Period turning to warm. Temperature changed from cold to warm;

(2)35 – 73 cm: Period turning to cold. Temperature dropped obviously;

(3)73 – 89 cm: Period of high temperature. A period of suddenly turning warm after little glacial period, showing temperature changes from low to medium to high;

(4) 89 – 136 cm: Cold period. The little glacial period, showing temperature changes from medium to low;

(5)136 – 170 cm: Warm period. The interglacial period, temperature fluctuated in medium — high — low.

7 Conclusions

(1)Sediments of the Prydz Bay, Antarctica were greatly affected by the dissipation of ice cover, gushing of freshwater and terrigenous materials in the process of sedimentation. It was well recorded by chemical elements of sediments of the core NP95-1.

(2)Distribution of the main chemical elements in the core can be used for dividing strata and reconstructing environment of palaeo-ocean. The variations of element content have well reflected the evolution history of environment of Antarctica. The climate of this area can be divided into five periods, such as warm period, cold period, hot period, turning-cold period and turning-warm period since late Pleistocene. The turning points of temperature, which indicated the changes of climate , occurred at 145 cm, 85 cm and 25 cm of the core.

(3) The sudden change of element content at 85 cm of the core, which corresponds to the Gothenburg geomagnetic excursion, indicates occurrence of extreme event and marks the beginning of Holocene in Antarctica after 10.3 ka B.P..

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References

Burgess J *et al*. (1988): On the thermal stratification of freshwater alkes in the Snowy Mountains, Australia and the Larsemann Hills. Antarctic Research, 19: 147 - 149.

Hou HM, Wang BG, Tang XZ(1997): Environmental magnetism of marine sediments from Antarctica since 15 Ka B. P.. Chinese Journal of Polar Research, 9(1): 35 - 43.

Li SK(1993): The geomorphical features at Stornes Peninsula, Larsemann Hills, East Antarctica. Antarctic Research (Chinese Edition), 5(1): 16 - 23.

Lin ZQ, Cai HY(1988): Discussion on marine and continental facies change of well drilling in East Sea by geochemical indications. Report of Mineralogy, Petrology and Geochemistry, (1): 40 - 42.

Liu YJ, Cao LM, Li ZL (1984): Elemental geochemistry. Beijing: Science Press, 19 - 27, 88 - 93, 444 - 470.

Wang YB, Zhao Y, Ren LD *et al*. (1994): Geochemical characteristics and medium pressure granulite facies metamophism of mafic granulite rocks from the Larsemann Hills, East Antarctica. Antarctic Research (Chinese Edition), 6(3): 1 - 11.

Wen QZ, Diao GY (1987): Some advance on sedimentary geochemistry of Quaternary. Report of Mineralogy, Petrology and Geochemistry, (4): 196 - 199.

Yan J, He LJ, Xue SJ(1991): Studies on element strata and its implications to palaeoceanology of the Marginal Sea of West Pacific. Marine Geology and Quaternary Geology, 11(2): 57 - 66.

Zhang SS(1988): Studies on the ratio of Mg to Al and its application. Report of Mineralogy, Petrology and Geochemistry, (2): 112 - 113.

Zhao JL(1991): Characteristics of modern environmental geochemistry and evolution of natural environment in Great Wall Station, Antarctica. Beijing: Science Press, 58 - 60.

Zhao Y, Song B, Wang Y *et al*. (1992): Geochronology of the granite in the Larsemann Hills, East Antarctica, In: Yoshida Y *et al*., ed. Recent Progress in Antarctic Earth Science, 155 - 161.

Zhou B, Hensen BJ(1992): Sm/Nd isotopic analysis of garnet: constraints on the metamorphic histories of the Prydz Bay and northern Prince Charles Mountains granulite terranes, Antarctica. in abstracts, The application of geochronology to field related problems, Geological Society of Australia SGGMP Workship, Australia: Alice Springs.