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A study of Foraminifera in the core NP93-2 from the Prydz Bay, Antarctica*

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Abstract Analyses of Foraminiferal fauna in the core NP93-2 of the Prydz Bay, Antarctica shows that the sediments are rich in Foraminifera in which planktonic Foraminifera make up 26.3% of the total number of Foraminifera and the arenaceous agglutinated benthic Foraminiferal assemblages are prevailing with 57.9% of total number of benthic Foraminifera. The typical benthic Foraminiferal assemblage of *Miliammina arenacea* represents an assemblage of deep-water arenaceous agglutinated. Variations of content of warm and cold species of planktonic Foraminifera reflect the paleoclimatic changes and also reveal the paleo-environmental changes in this region and its relationship with the global changes. Other paleoceanographic and paleoclimatological questions, such as water depth, carbonate dissolution are also discussed.
Key words Prydz Bay, Antarctica, Foraminifera, arenaceous agglutinated, paleoenvironment.

1 Introduction

The core NP93-2 was collected from the middle of the Prydz Bay, Antarctica (67° 59′S, 73°08′E), with water depth 550 m and core length 78～80 cm, where northward is upslop of Southern Ocean, southward is Amery Ice Shelf, and Sosdar glacier is to the southeast. To the west, the water is deep 400～200 m, and deepens gradually to the northwest. Foraminifera in Antarctica are intensely studied over a century, particularly more detailed studies are carried out in Antarctic Peninsula and King George Island. Most foraminiferal studies are experienced in Marvanas Islands, South Shetland Islands, Maxwell Bay and adjacent areas, focused on modern Forminifera, only little reports about foraminiferal studies near Zhongshan Station can be referenced. In this paper, the authors have studied the downcore Forminifera of core NP93-2 from the Prydz Bay, northwest to Zhongshan Station. New obtained foraminiferal data and a comparision with reported results are used for understanding the Quaternary environmental changes from eastern and western Antarctica, also providing reliable data for global changes studies.

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2 Sampling and treatment

Samples for foraminiferal studies are from core NP93-2, continuously collected from the top to the bottom at an interval of 10 cm, except samples No. 1 and No. 2 at an interval of 3 cm, every sample covered a slice of 2 cm thickness, 9 samples are obtained in total. All samples are treated according to traditional method for foraminiferal studies. Prepared samples are laid to a stereoscopic microscope for identifying the species and data statistics.

3 Chronology and stratigraphy

The lithological character of core NP93-2 is clayey silt, containing fine sands. The core is divided into three layers, which are determined by the method of ^{14}C dating (made in ^{14}C Laboratory, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences) to be (5390±800) a B. P. at depth 30 cm, (8303±800) a B. P. at depth 58 cm and (10315±800) a B. P. at depth of 70 cm respectively. If the sedimentation rate is calculated between at depths 58～70 cm, the base of the core at depth 78 cm is (11657±800) a B. P..

Consequently, the layer Ⅱ at depths 0～58 cm is Holocene, and the layer Ⅰ (at depths 58～78 cm) is the upper part of upper Pleistocene.

4 Foraminiferal distribution

4. 1 General situation of foraminiferal distribution

All of 9 samples of core NP93-2 contain foraminiferal shells(Table 1). After calculation, the Foraminifera in every 50 g dry sample are much abundant at depths 1～3 cm and 66 cm to the core base(>100 foraminiferal shells), the other samples contain less than 50. The ratio of planktonic Foraminifera to total Foraminifera is consistent with the abundance of Foraminifera. But the planktonic Foraminifera are disagreeable in diversity with benthic ones, more diversities are found at layer 1～3 cm, but less downward in the core, especially at the lower section of core, they are high in abundance and low in diversity. In all samples of core NP93-2, the benthic Foraminifera are less than 100 shells in abundance, of them the arenaceous agglutinated Foraminifera are high in proportion, but with the minimum 31. 5% at depth 1～3 cm of the core. The other samples are all above 60% in abundance, or even most of them are larger than 70%, with the maximum value at depth 56～58 cm, and all benthic Foraminifera are composed of arenaceous agglutinated ones(Table 1). From the viewpoint of diversity of benthic Foraminifera, the layer at depth 1～3 cm contains less arenaceous agglutinated Foraminifera, but more species of benthic Foraminifera. Vice versa, the samples which contain less species of Foraminifera, contain more arenaceous agglutinated. Between the depth of 6 cm and 8 cm, the maximum number of species of arenaceous agglutinated Foraminifera (6 species) is determined, the depth of others, the number of arenaceous agglutinated species is only 1～2.

The sample at depth of 1～3 cm, contains low content of arenaceous agglutinated shells, and more content of calcareous Foraminifera shells, but it is the most in abundance of Foraminifera and the largest in diversities, or contains most abundant planktonic Foraminifera. The characteristics of sample's non-species parameters well demonstrate the nature and difference of sedimentary environment.

Table 1. The non-species parameter of downcore Foraminifera from the Prydz Bay, Antarctica

No.	Depth (cm)	Dry samples (g)	Abundance (50g)	Planktonic (%)	SNP	SNB	AG (%)	SNA	Lithological nature
1	1～3	29	158	44.6	11	22	31.5	2	shoal yellow gravel-mid-sand
2	6～8	54	53	28.7	8	13	71.7	6	same
3	16～18	42	36	20.1	4	4	87.4	1	same
4	26～28	57	36	29.7	9	9	61.7	2	same
5	36～38	60	46	28.3	9	8	77.7	2	same
6	46～48	45	59	22.6	5	6	82.5	2	same
7	56～58	55	30	15.0	4	2	100.0	2	shoal gray, coarse-mid-sand-gravel
8	66～68	43	150	39.5	9	17	64.0	2	shoal yellow mid-coarse sand
9	76～78	59	147	39.9	1	9	67.3	2	shoal gray, mid-coarse sand-gravel

SNP: Species number of planktonic; SNB: Species number of benthonic; AG: Arenaceous-agglutinated; SNA: Species number of arenaceous-agglutinated.

4.2 *Composition of foraminiferal species*

Eighty species of Foraminifera are found in core NP93-2, 21 species are planktonic Foraminifera and 59 species are benthic. Samples all have considerable difference in species and abundance. Frequency of each species are tabulated at Table 2, details about species of planktonic and benthic Foraminifera are illustrated in the following.

Table 2. Distribution of downcore Foraminifera from the Prydz Bay, Antarctica (number/50g)

Depth	1～3 cm	6～8 cm	16～18 cm	26～28 cm	36～38 cm	46～48 cm	56～58 cm	66～68 cm	76～78 cm	Total number	Content (%)
Globigerina aequilateralis	3.4	1.0								4.4	1.7
Globigerina bulloides								1.2		1.2	0.5
Globigerina digitata	5.2							3.2		8.4	3.4
Globigerina pachyderma(R)	1.7		1.2							2.9	1.1
Globigerina pachyderma(L)		1.0	3.6	1.8	2.5	8.9	1.8	25.6	58.5	103.7	41.1
Globigerina rubescens	3.4		1.2	1.8			0.9			7.3	2.9
Globigerina sp.							0.9			0.9	0.4
Globigerinita glutinata	3.4	1.9			0.8	1.1		1.2		8.4	3.3
Globigerinoides ruber	25.9	2.8		0.9	3.3	1.1	0.9	14.0		48.9	19.4
Globigerinoides sacculifer	10.0	1.9	1.2	1.9	3.3	1.1		8.1		27.5	11.0
Globigerinoides tenellus					0.8					0.8	0.3
Globigerinoides conglobata				0.9						0.9	0.4
Globoquadrina conglomera				0.9	0.8			2.3		4.0	1.6
Globoquadrina dutertrei	3.4	0.9			1.1			1.2		6.6	2.6
Globorotalia crassaformis				0.9	0.9			2.3		4.1	1.6

Depth	1～3 cm	6～8 cm	16～18 cm	26～28 cm	36～38 cm	46～48 cm	56～58 cm	66～68 cm	76～78 cm	Total number	Content (%)
Globorotalia menardii	5.2	1.0								6.2	2.5
Globorotalia truncatulinoides					0.8					0.8	0.3
Hastigerina siphonifera		4.6								4.6	1.8
Pulleniatina obliquiloculata	6.9	1.0		0.9	0.8			2.3		11.9	4.7
Sphaeroidinella dehiscens	1.7									1.7	0.7
Ammonia beccarii		2.8								2.8	0.6
Ammonia cf. *pauciloculata*	1.7									1.7	0.4
Ammonia confertitesta		1.0								1.0	0.2
Ammonia katienziensis				3.5						3.5	0.8
Ammonia sp.	3.4	2.8			0.8			4.7		11.7	2.5
Amphicoryna sublineata								1.2		1.2	0.3
Angulogerina angulosa			1.2		2.5	5.6			42.2	51.5	11.2
Astrononion gallowayi	1.7									1.7	0.4
Biloculinella labiata	1.7									1.7	0.4
Bulimina marginata				1.8	1.7			3.5		7.0	1.5
Bulimina sp.	5.2									5.2	1.1
Cassidulina parkeriana									0.8	0.8	0.2
Chilostomella oolina	1.0									1.0	0.2
Cibicides cf. *wuellerstofi*	1.7									1.7	0.4
Cibicides pseudoungeriana								1.2		1.2	0.3
Cibicides subhaidingeri	10.3	1.0		0.9	0.8			1.2	3.4	17.6	6.8
Eggerella bradyi		1.0								1.0	0.2
Glandulina echinata	1.7									1.7	0.4
Globocassidulina subglobosa								3.5	5.1	8.6	1.9
Hanzawaia compressa								2.3		2.3	0.5
Haplophragmoides cancriensis		2.8				1.1				3.9	0.8
Lagena substriata				0.9						0.9	0.2
Melonis affimis									3.4	3.4	0.7
Melonis sp.								1.2		1.2	0.3
Miliammina arenacea	24.1	21.3	25.0	14.9	25.0	35.6	24.6	57.0	22.9	250.3	54.3
Miliolinella circularis				0.9						0.9	0.2
Nonion sp.	1.7									1.7	0.4
Pseudoeponides japonica			1.2							1.2	0.3
Pulsiphonina elegans								1.2		1.2	0.3
Pyrgo depressa	1.7									1.7	0.4
Pyrgoella tenuiaperta				0.9						0.9	0.2
Quinqueloculina bicostata								1.2		1.2	0.3
Quinqueloculina lamarckiana	4.4	1.0	1.2			1.1		1.2		7.9	1.7
Quinqueloculina parkeri	1.7									1.7	0.4
Quinqueloculina seminula	5.2	1.9								7.1	1.5
Quinqueloculina sp.								2.3		2.3	0.5
Rectobolivina virgulata								1.2		1.2	0.3
Reophax fusiformis							3.5			3.5	0.7
Reophax scorpiurum		2.6								2.6	0.5
Reophax spiculifer	1.0									1.0	0.2
Reussella sp.				0.9	0.8					1.7	0.4
Robulus calcar	1.7				0.8					2.5	0.5
Sphaeroidina bulloides	1.7									1.7	0.4
Spiroloculina communis	3.4									3.4	0.7
Spirorutilis pseudocarinata								1.2		1.2	0.2
Tretomphalus milletti		1.0								1.0	0.2
Trifarina carinata	3.4							9.4	10.2	23.0	4.5
Ttiloculina tricarinata	1.7									1.7	0.4
Trochammina grisea		1.0							0.8	1.8	0.4
Uvigerina asperula						1.1			4.2	5.3	1.1
Uvigerina cf. *aculeata*						1.1				1.1	0.2
Uvigerina interrupta	1.7									1.7	0.4
Uvigerina schwageri	5.2					1.1				6.3	1.4
Valvulineria rugosa					0.8					0.8	0.2

4.2.1 *Planktonic foraminiferal assemblages*

All samples through the core NP93-2 contain planktonic Foraminifera, with the exception of minimum content(15.0%) at depth 56～58 cm, others are larger than 20% in content(Fig. 1). 21 species of planktonic Foraminifera are identified, of them, the highest abundance is *Globigerina pachyderma*, which occupies 41.1% of planktonic Foraminifera. All samples except at depth 1～3 cm contain this species, but frequency of

appearance increased as the depth increased. Lower appearance frequency of *Globigerinoides ruber* in samples are found with the maximum abundance at depth 1～3 cm. Samples at depths 36～38 cm and 66～68 cm contain it, only less than samples at depth 1～3 cm. *Globigerinoides sacculifer* are performed similarly as *Globigerinoides ruber*, only less in abundance. Other species are distinguishably less than 5% even 2% in abundance, and most of them can be found in less than 1/2 of total samples. Warm water species of planktonic Foraminifera occupied a certain ratio, and variations of content and abundance provided important evidence of paleoclimatic changes downcoreward.

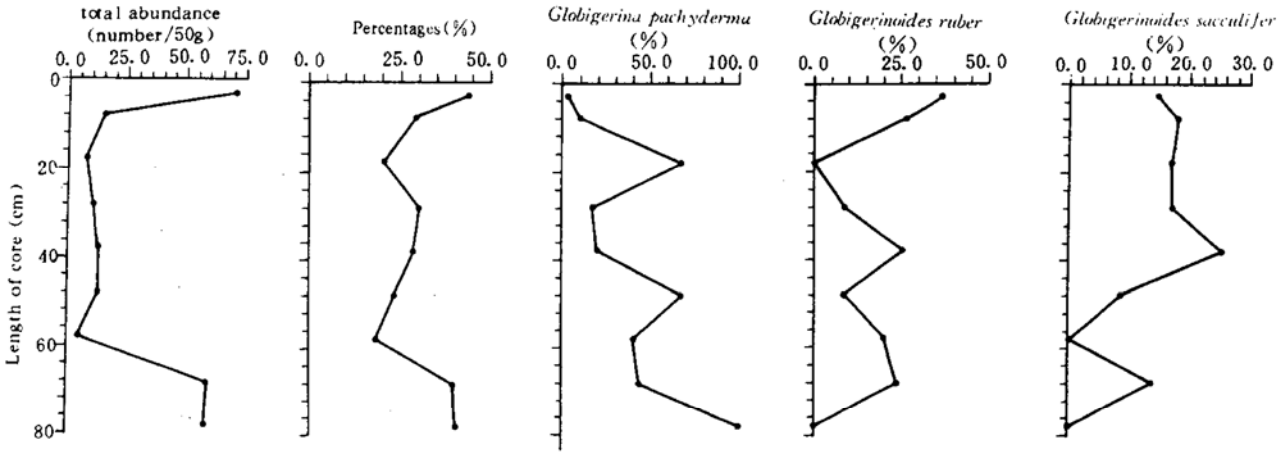

Fig. 1. Distribution of telative abundance and content of planktonic Foraminifera.

4. 2. 2 Benthic foraminiferal assemblages

The number of benthic foraminiferal shells is less than 100 shells per 50 g dry sample. Abundance of sample at the depth 1～3 cm and below the depth 66 cm are relatively high, ranging from 87 to 91 shells per sample, the others have less than 50 shells, particularly with the minimum abundance of 26 shells at depths 26～28 cm and 56～58 cm. The diversities are high and 57 species are determined in the core, 6 species are determined at generic level due to broken shells, so 51 species are determined in fact. Eleven species or 57. 9% of benthic Foraminifera are of arenaceous agglutinated type, indicating the prevailing of arenaceous agglutinated assemblages, but the diversity is less than calcareous type. It reflected that the benthic foraminiferal distributions are directly controlled and influenced by Antarctic environment. In addition, calcareous imperforate forms occupied 6. 7% of benthic Foraminifera. These forms were the lowest content among the three types of benthic Foraminifera, calcareous perforate forms be referred to as sub-dominant, occupied 35. 4% of the benthic Foraminifera(Fig. 2).

Among 57 species of benthic Foraminifera, most frequency of occurrence of species are *Miliammina arenacea*, then *Angulogerina angulosa*, *Cibicides subhaidingeri*, *Ammonia* sp. , *Trifarina carinata*, *Globocassidulina subglobosa*, *Quinqueloculina lamarckiana*, *Q. seminula*, *Bulimina marginaia*, *Uvigerina schwageri*, *U. asperula* etc. , most of them are deep-water species. Although shallow-water species are few, high abundance also can be

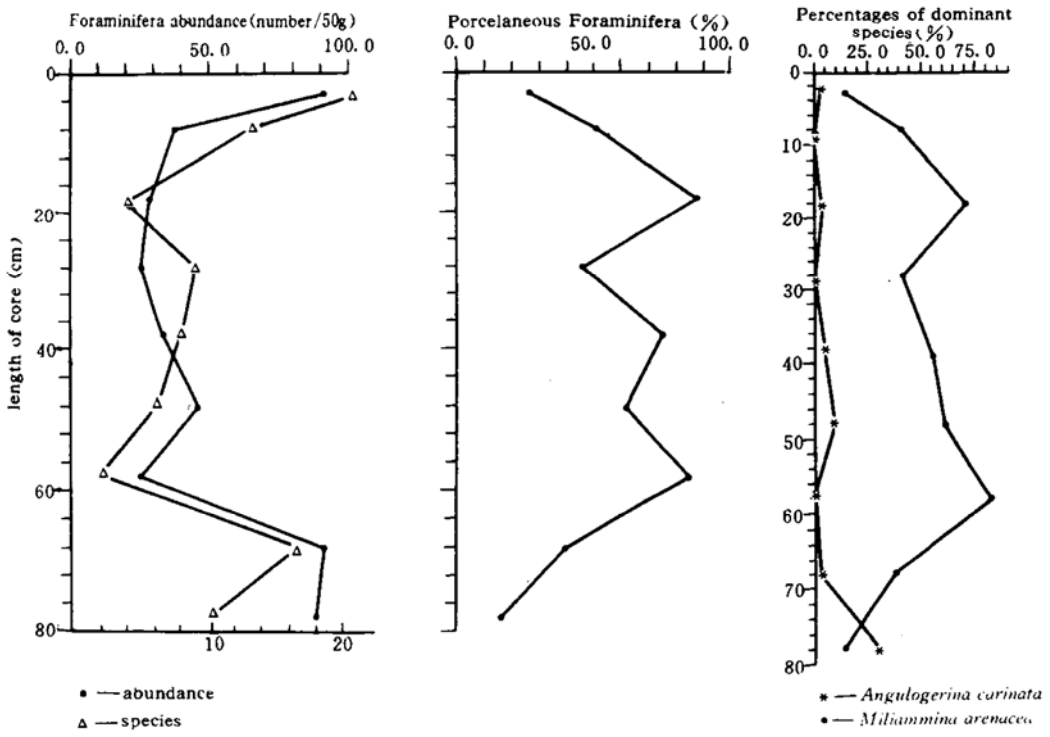

Fig. 2. Distribution of total numbers of benthic foraminifera from the Prydz Bay, Antarctic (number of specimens 5 grams of dry sediments).

found in some samples, their variations of abundance can be utilized to trace the water depth. Except for these species, another 40 species of benthic Foraminifera were discerned with total sum of less than 1%, and these species can only occurred in less than a half of samples. Some species can only occurred in one sample, with an abundance of less than 5 shells per sample. Though some species are occasionally contained with low abundance, they can be used for indicating the ecology and sedimentary environment.

According to distribution of the water depth of benthic Foraminifera in South China Sea (Zheng *et al.*, 1989), East China Sea (Wang *et al.*, 1988), Northern South China Sea (Zheng *et al.*, 1994), Pacific, Atlantic Ocean (Barker, 1960) and Antarctic sea area (Anderson, 1976), the distribution water depth of *Miliammina arenacea*, which is the main benthic foraminiferal species in core NP93-2, ranges from 100 m to 2000 m, *Angulogerina* cf. *carinata* ranges from 183 m to 274 m (Atlantic) and 2514 m (Pacific), *Cassidulinoides parkerianus* ranges from 82 m to 631 m (Eastern Pacific). The commom species *Cibicides subhaidingeri* ranges in 283 m (Pacific) and less than 200 m (South China Sea). *Chilostomella oolina* often can be found at water depth 173～1060 m (Pacific). The genus of *Ammonia* commonly occurred in a sea area shoal than 100 m, some species are best fitted to live in a semi-salty water, therefore it is characterized by eurysalinity of shallow sea and semi-salty waters, such as *Ammonia ketienziensis* and *Ammonia pauciloculata*, which commonly occur in a water depth of less than 50 m, and can be usually found at 50～150 m in South China Sea. In addition, water depth selection of benthic Foraminifera also varied with different shell-decorated species in a same genus, for in-

stance, *Uvigerina schwageri* is the main species of middle to outer shelf over the word, but *Uvigerina asperula* only can be found at a continental slope of water depth 500～2000 m. Although part of species are stated above, most of species are distributed at shelf to slope with water depth less than 1000 m. Downcore variations of abundance of varied species in samples suggest a variations of sedimentary environment.

4. 2. 3 Compositional characteristics of foraminiferal assemblages

Analytical and statistical results from NP93-2 suggest that the composition of benthic Foraminifera can be summarized to an foraminiferal assemblage with *Miliammina arenacea* mostly prevailing according to variation of foraminiferal composition and abundance. Absolutely dominant species in core NP93-2 is *Miliammina arenacea* (54. 7%), the next, *Angulogerina angulosa* (11. 2%), *Cibibides subhaidingeri* (3. 8%), *Ammonia* spp. (2. 5%), *Globocassidulina subglobosa* (1. 9%), *Quinqueloculina lamarckiana* (1. 7%). Most of these species belong to those in deep-water low-temperature environment, but are distributed in a large range of water depth. The planktonic Foraminifera are 20%～44. 6% in abundance, contain some warm water species with a certain abundance and variable content, such as *Globigerinoides sacculifer*, *G. ruber*, *Pulleniatina obliquiloculata*, *Globorotalia menardii*, cold water species *Globigerina pachyderma* mostly have negative relationship to the warm water species. According to the composition and non-species characteristics of downcore samples, three foraminiferal assamblages are again divided.

Assemblages I : *Cibibides subhaidingeri-Uvigerina schwageri* assemblage. Assemblages I is located at depth 0～3 cm, with high abundance of Foraminifera, 158 shells are contained in 50 g dry samples, 44. 6% are planktonic Foraminifera and warm water species are dominated, of which, the *Globigerinodes ruber* is prevailing, the next is *Globorotalia menardii*, *Globigerinoides sacculifer* and *Pulleniatina obliquiloculata*, the content of cold water and transition species (*Globigerina pachyderma* and *Globoquadrina dutertrei*) are less than it of warm water species. The abundance of benthic Foraminifera is 45. 5% with diversity of 21 species. Arenaceous agglutinated type occupies 31. 5% of total number of benthic Foraminifera, among which, *Miliammina arenacea* and *Cibibides subhaidingeri* are prevailing, the others species are less than 5 shells in abundance. *Quingueloculina seminula*, *Uvigerina schwageri*, *Bulimina* sp. (broken), *Angulogerina angulosa*, *Textularia foliacea*, *Quinqueloculina lamarckiana*, *Ammonia* sp. (broken), etc. are relatively abundant. Consequently, the benthic Foraminifera of sample from depth 1～3 cm are major outer shelf deep water species, also have shelf shallow water species, but the shallow water species are not dominant in foraminiferal assemblage. Therefore, sample at depth 1～3 cm are characterized by sub-deep foraminiferal assemblage.

Foraminiferal assemblage I a: *Ammonia ketienziensis-Haplophragmoides cancriensis* subassemblage. This sub-assemblage is located at depth of 3～58 cm, with a total foraminiferal abundance between 30～60 shells per 50 g dry sample. Evidently decrease on abundance of planktonic Foraminifera are detected, and usually 4～15 shells are contained, occupied 15. 0%～39. 5% of total abundance, with still high ratio of warm water planktonic Foraminifera and in the planktonic foraminiferal faunas. The numbers of

warm water species are generally decreasing with the changes of the depth, but differ form samples, opposite relationship of cold water species are also found. But, when summarized from absolute abundance, the frequency of occurrence of the warm water species was less, and the number of cold water species *Globigerina pachyderma* increased. Benthic Foraminifera are distributed with abundance of 25～46 shells and 2～13 species, and arenaceous agglutinated fauna occupied 61%～100%. Arenaceous agglutinated *Miliammina arenacea* is dominant occuping more than 50% of total benthic shells, in particular, it occupied 96.5% of benthic Foraminifera at depth of 56～58 cm. *Ammonia* sp., *Ammonia ketiziensis*, *Angulogerina angulosa* take the second dominance. *Bulimina marginata*, *Cibicides subhaidingeri* and *Globocassidulina subglobosa* also occupied a certain number. Shallow sea species, which emerged at assemblage I are less, but arenaceous agglutinated shells increased, such as *Reophax spiculifer*, *Trochammina grisea*, *Haplophragmoides cancriensis*, *Textularia porrecta*, *Eggerella bradyi*, *Reophax fusiformis*, Which emerged to some extent. The present foraminiferal assemblage is characterized by the dominance of deep-water arenaceous agglutinated Foraminifers assemblage.

Foraminiferal assemblage Ⅱb: *Angulogerina angulosa-Globocassidulina subglobosa* subassemblage. This sub-assemblage is located at depth 76 cm of core NP93-2, with the abundance of Foraminifera being 147 shells, in which, planktonic Foraminifera occupied 40% of total number and only one species *Globigerina pachyderma* was detected. Benthic Foraminifera are dominated with 67.3% of arenacous agglutinated and 10 species, in which *Angulogerina angulosa* is absolutely prevailing, and *Miliammina arenacea* is the second. *Uvigerina asperula*, *Globocassidulina subglobosa* are also detected to some extent. *Cibicides subhaidingeri*, *Melonis affimis*, *Cassidulina parkeriana* also occurred occasionally. The foraminiferal assemblage reflects a deep water assemblage which is dominated by arenaceous agglutinated Foraminifera.

Foraminiferal assemblage Ⅲ: *Bulimina marginata-Ammonia* sp. assemblage is located at depth 66～68 cm, with high abundance of Foraminifera (150 shells per 50 g dry sample), planktonic Foraminifera occupied 39.5%. Although warm water species *Globigerinoides ruber*, *G. sacculifer* are frequently found, the planktonic foraminiferal assemblage is dominated by cold water species *Globigerina pachyderma*, which occupied about a half of total planktonic Foraminifera. In addition, *Globigerina bulloides* occurred in the assemblage though only 1 shell of it appeared in the core. 91 shells of benthic Foraminifera are distinguished with diversity of 16, among which, arenaceous agglutinated type occupied 64% of benthic Foraminifera, but only 2 species are identified (*Miliammina arenacea* and *Textularia paraglutinans*), *Miliammina arenacea* is a dominant benthic foraminifer with abundance of 62.6%, but, only one shell of *Textularia paraglutinans* is found. The benthic foraminiferal assemblage is composed of common species distributed from shelf to slope. Species of relatively high abundance are *Ammonia* sp. *Augulogerina angulosa*, *Bulimina marginata*, *Globocassidulina subglobosa*, etc., shell-shallow sea species such as *Cibicides pseudoungeriana*, *Hanzawaia compressa*, *Rectobolivina virgulata* and *Spirorutilis pseudocarinata* are very low in abundance, or seldom occurred in other samples. This assemblage is characterized by shallow water arenaceous-calcareous benthic Foraminifera with the arenaceous agglutinated species prevailing.

5 Sedimentary environment analyses

The ecology of marine micropaleontology is directly controlled and influenced by the environment. Therefore, we can analysis the variation of paleoenvironment with assistance of data from micropaleontological tests buried in the geologic time. For instance, planktonic foraminiferal fossil contributed to estimate the paleotemperature, water depth and topography of ocean floor. Benthic Foraminifera is also used for reconstructing some geographic factors, such as the water depth, temperature, salinity and current conditions. According to the distribution and characters of foraminiferal assemblages of core NP93-2, the authors try to take a primary study to paleo-sedimentary environment.

5.1 Water depth

The foraminiferal distribution has a relationship with the water depth, in general, numbers and species reflected the water depth to some extent. Data from South China Sea, East China Sea and oceans over the world accordingly illustrate that for a certain water depth, the numbers and species of Foraminifera increased with the water depth, opposite relationship on slope and deep sea area are found. We regard the diversity as an index of various biological groups, which reflects sedimentary environment. The high diversity is corresponding to a sedimentary environment which is favorable for the distribution, deposition and preservation of Foraminifera.

High abundance and diversities of benthic Foraminifera are determined at depths 0～3 cm and 66～68 cm, opposite situations are found at depth 10～50 cm(Fig. 2). Abundance and diversities of benthic Foraminifera in core NP93-2 implied that the sedimentary environment at depths 0～10 cm and 68 cm to the base are beneficial to foraminiferal distribution and preservation. Anomalous of foraminiferal abundance and diversity at depth 16～38 cm is probably caused by the appearance of rare species and environmental changes. General water depth, recorded in core NP93-2, ranges within the depth of continental slope, with a little deeper at 10～58 cm and below 66 cm, and the minimum water depth is at 0～3 cm, intermediate depth is at 56～58 cm.

5.2 Paleotemperature

Samples from core NP93-2 contain definite abundance of planktonic Foraminifera, which can be divided into two great groups, the one is mainly composed of warm water species *Globigerinoides sacculifer*, *G. ruber* and another is represented by cold water species *Globigerina pachyderma*. From the downcore content of these species(Table 3), it can be described that samples above the depth 40 cm are rich in warm water species and cold water species are dominant at depth 40 cm to corebase.

According to the results of water mass studies of South China Sea , the surface water is as shallower water bed at the depth 75 m from northern South China Sea to Nansha area (Chou, 1982; Huang and Qiu, 1991), shallow water species of planktonic Foraminifera are best fitted to it and can really reflect the temperature of surface water. The variations of planktonic Foraminifera *Globigerinoides sacculifer* and *G. ruber* suggest

a warm period at depth 0～40 cm, the two species occupy more than 50% of planktonic Foraminifera at depths 0～3 cm and 36～38 cm, otherwise, little can be found at depth below 40 cm. It indicates the surface water at depth 0～40 cm is warmer than that below the depth 40 cm.

Table 3. Distribution of relative content of the main species of planktonic Foraminifera(%)

Deepth (cm)	0～3	5～8	16～18	26～28	36～38	46～48	56～58	66～68	76～78
Globigerinoides sacculifer	14.6	17.9	16.7	17.6	25.2	8.3	-	13.6	
G. ruber	36.5	26.4	-	8.3	25.2	8.3	20.0	23.6	-
Globorotalia menardii	7.4	9.4	-	-	-	-	-	-	-
Pulleniatina obliquiloculata	9.8	9.4	-	8.3	6.6	-	-	4.0	-
Globigerina pachyderma	2.4	9.9	66.7	17.0	19.0	66.1	40.0	43.0	100.0
Globigerina bulloides	-	-	-	-	-	-	-	2.0	-
Warm water species(%)	68.3	63.1	16.7	34.2	57.0	16.6	20.0	41.2	-
Gold water species(%)	7.2	9.9	66.7	25.3	19.0	66.1	40.0	45.0	100.0
Globigerinoides sacculier (%)+*G. ruber*(%)	51.1	44.3	16.7	25.9	50.4	16.6	20.0	37.2	-

The ecological characterisrics of planktonic Foraminifera implied the above two species are distributed at transition to tropic oceans, fitted to the temperature of 15℃～30℃ (*Globigerinoides sacculifer*) and 14℃～30℃ (*G. ruber*) (Rogl and Bolli, 1973). The temperatures reflected by these species, even if the minimum fit temperatures are discordant with the conditions of Antarctica. Therefore, authors thought that these species are devived from low latitude sea area, and also can be used for reconstructing the paleotemperature qualitatively. These species are brought to Antarctica due to the water current of subtropical water mass and Antarctic water mass, and the foraminiferal shells are drifting via water current, and deposited at a high latitude sea area as the water temperature is decreasing. According to the studies of water mass of Weddell Sea of Antarctica (Anderaws, 1976), the warm deep water mass, one of the four water masses of Antarctica (+0.20℃～－0.36℃ and salinity 3.45%～3.469%), enters the Weddell Sea at a longitude of 15°～20°E, and drifts along the continental slope to 28°W、74°S. It will influence the Prydz Bay when it extends eastward and decreases in temperature at low latitude water. Distributions of the water mass can be utilized to infer the resources of original water mass, also the relative abundance is a proxy of paleo-water temperature and used to estimate the global changes. More warm water species can be brought due to warm climate, and the variations of content imply the climate changes. It's very defficult to estimate the changes because poor physics oceanography conditions are understand and lack of observatory data, also further research is needed.

5.3 *Carbonate dissolution*

Carbonate is one of the important dissolution salt of oceans, the saturation of dissolved carbonate varies with the content of carbonate ion in water and the value of carbonate saturation increases with the water depth, also opposite related between carbonate saturation and water depth. Consequently unsaturation of carbonate ion except at the top-

most water suggests that the dissolution of carbonate was strengthened as water depth increased. Various conditions make different CCD depth, for instance, in Pacific Ocean, Indean Ocean and Atlantic Ocean, the CCD depth are 4500 m, 5000 m and 5300 m respectively. According to the studies in the middle South China Sea, the CCD sustains a depth of 3000～3500 m(Tu , 1984). But in various sea area CCD are found evidently different even if at neighboring sea area, for example, in Sulaweisi Sea, Bandung Sea and Marlugo Sea, the CCD are <3000 m,3500～4000 m and 7500 m, respectively(Kliannova,1959).

Analyses of core NP93-2 show different ratio of arenaceous Foraminifera alters with samples, for instance, Foraminifera of sample from the depth 0～3 cm are mainly composed of calcareous benthic Foraminifera, at depth 6～58 cm species of arenaceous agglutinated are absolutely dominated. Samples from depth 66 cm to 78 cm demonstrate arenaceous agglutinated species are the main forms, but calcareous Foraminifera species increased, it implies a variation of water depth and carbonate dissolute conditions. In order to trace the carbonate dissolution situations, we choose species of tropical to subtropical with different anti-dissolution of carbonate as a proxy. The variation of *Globigerinoides ruber* and *Pulleniatina obliquiloculata* are obviously corresponding, the former sustains the maximum content at depth 0～3 cm and decreased as the depth increased, the performance of the latter species is little poor. Carbonate dissolution coditions and the abundance of arenaceous agglutinated Foraminifera are varied consistently, with weak carbonate dissolution at depth 0～3 cm and content of *Globigerina pachyderma* varies negatively with depth, especially at corebase, it's the only planktonic foraminiferal species with larger abundance than other samples, indicating a strong carbonate dissolution and suggesting a typical polar deep water foraminiferal assemblage. All benthic Foraminifera are arenaceous agglutinated at depth 56～58 cm. In addition, the planktonic Foraminifera only have several shells existing and cold water species relatively are concentrated, still showing a polar assemblage after strong dissolution.

Ishman and Domack (1994) have studied distribution of the benthic Foraminifera in Bellingshausen margin of Antarctic Peninsula, and discovered that the abundance of calcareous benthic Foraminifera strongly decreased as the water depth increased. A sudden reduction of abundance of benthic Foraminifera is found at water depth >900 m in the Bransfield Strait, the same reduction of calcareous Foraminifera was discovered at 550 m in Rose Sea(Kennott,1966), suggesting a strong different of CCD in Antarctica. In core NP93-2, with water depth 550 m, all samples contain calcareous Foraminifera. Benthic Foraminifera are composed of arenaceous shells except several planktonic Foraminifera with low abundance at depth 56～58 cm, which implies that the depth does not reach, but is close to CCD. Also, in sample at depth 76～78 cm, foraminiferal assemblage is absolutely dominated by arenaceous agglutinated type with only one species of planktonic Foraminifera, *Globigerina pachyderma* slightly increasing, which indicates the depth of this layer is near the CCD. Therefore, the CCD of the Prydz Bay is similar to that of the Bransfield Strait, or corresponding with CCD of Rose Sea.

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Plate I

1～4	*Miliammina arenacea*(Chapman)	1×100;2×56;3×89;4×85	1～78cm
5	*Miliammina* cf. *arenacea*	×73	59～60cm
6～7	*Quinqueloculina lamarckiana* d'Orbigny	6×105;7×69	1 ～ 18cm; 46 ～ 48cm;66～68cm
8～9	*Uvigerina schwageri* Brady	8×61;9×80;	1～3cm;46～48cm
10～12	*Angulogerina angulosq*(Williamson)	10×73;11×69;12×105	16 ～ 18cm; 36 ～ 38cm;76～78cm
13	*Angulogerina angulosa* var.	×65	76～78cm
14～15	*Uvigerina asperula* Czjek	14×61;15×77	46 ～ 48cm; 76 ～ 78cm
16～17	*Cibicides subhaidingeri* Parr	16×16;17×77	1 ～ 8cm; 26 ～ 38cm;66～78cm
18	*Ammonia beccarii*(Linnaeus)	×114	6～8cm
19	*Uvigerina* cf. *aculeata* d'Orbigny	×80	36～38cm

Plate II

1～6	*Globigerina pachyderma*(Ehrenberg)	1×114;2×118;3×133;4×133;5×89;6×118	6～78cm
7	*Globigerinita glutinata*(Egger)	×143	1 ～ 8cm; 36 ～ 48cm;66～68cm
8	*Pulleniatina obliquiloculata*(Parker and Jones)	×80	1 ～ 8cm; 26 ～ 38cm;66～68cm
9	*Globoguadrina dutertrei* (d'Orbigny)	×93	1 ～ 3cm; 26 ～ 28cm; 46 ～ 48cm; 66～68cm
10	*Globorotalia menardii* d'Orbigny	×40	1～8cm
11	*Globigerinoides sacculifer* (d'Orbigny)	×61	1 ～ 48cm; 66 × 68cm
12	*Globigerinoides ruber* (d'Orbigny)	×89	1 ～ 8cm; 26 ～ 68cm
13	*Pulsiphonina elegans* Brotzen	×89	66～68cm
14	*Textularia foliacea* Heron-Allen and Earland	×65	1～3cm
15	*Reophax scorpiurus* Montfort	×202	6～8cm
16	*Eggerella bradyi*(Cushman)	×73	6～8cm

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Plate I

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