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Late Quaternary glacial-marine sedimentation in the Bransfield Strait off northeast Antarctic Peninsula*

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Abstract Systematical analyses of lithology, grain size, mineral composition, microbiological thanatocoenoses and other geological proxies from the sediments of piston core Pc10, drilled in the central part of the Bransfield Strait, have been carried out. Based on the above data, together with the shipboard investigation, the 753 cm long core sediments reveal the last 112.5 ka deposits of the study area under the glacial-marine environment. The sediments includes biogenic silica deposit, volcanic debris deposit and turbidity current deposit. Among them, the biogenic silica deposit is dominative not only in the highstand water/interglacial stage, but also in the lowstand water/glacial stage. The difference of sedimentation between the two stages was that the terrigenous debris content and the sedimentation rate were lower in the lowstand water/glacial stage.
Key words Bransfield Strait, Late Pleistocene, glacial-marine sedimentation.

1 Introduction

During the seventh Chinese National Antarctic Research Expedition in the austral summer of 1990～1991, on RV "Haiyang Ⅳ" of Ministry of Geology and Mineral Resources, investigation of geology and geophysics in the Bransfield Strait off northwest Antarctica was made and samples were taken from 43 sites including surface and shallow sediments by grab or gravity cores. Columnar piston core Pc10, taken from the central part of the strait in the water depth of 2000 m, is 753 cm long, the longest one of all the Chinese expeditions to Antarctica since 1980's (Fig. 1).

The Bransfield Strait stretches in NE-SW direction with the maximum water depth of 2759 m. The strait is about 400 km long with the maximum width of 100 km (from the Maxwell Bay to Trinity Peninsula). Sea bottom topography of the strait is rather asymmetric. It is steep in the north and gentle in the south, but higher in the west and lower in the east.

Tectonically, the Bransfield Strait is an actively-spreading back-arc basin, that was formed about four million years ago, corresponding to the cessation of subduction of

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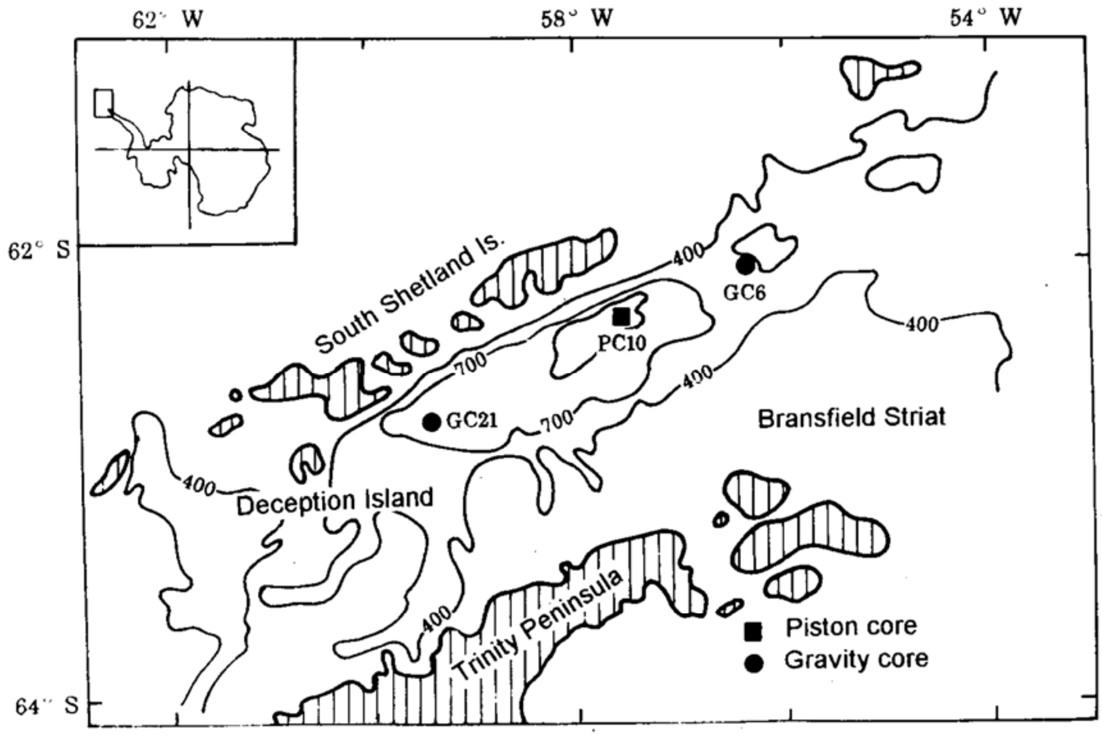


Fig. 1. Location of studied cores.

Drake plate to the South Shetland Trench (Anderson, 1989). The latest subaquatic volcanic eruption occurred in 1969～1970 (Smellie, 1988).

The present paper, chiefly based upon the analysis of Pc10 core made in lab, is to reveal and discuss the features of the glacial-marine sedimentation in the study area since Late Pleistocene.

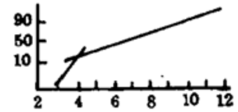
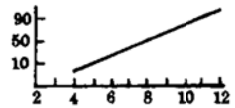
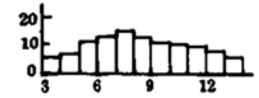
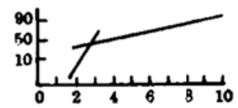
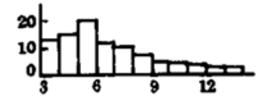
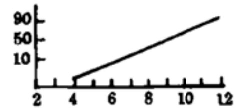
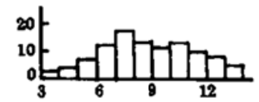
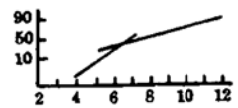
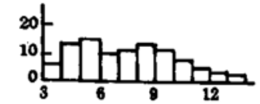
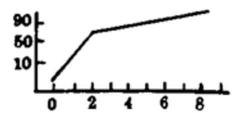
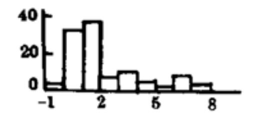
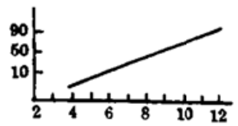
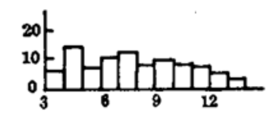
2 Features of sediments

2. 1 Lithology and particle diameter

The columnar Pc10 core is dominantly composed of fine grain sediment with its diameter less than 0. 063 mm. Its lithology was essentially grey yellow-yellow gray siliceous ooze and siliceous muddy silt, and 6% of the columnar core is sandy sediment including dark coarse-fine sand and light colour silt.

Analysis of the columnar sediments showed that the size of median grain (M_i) was 6. 37～9. 39 ϕ, and the frequency curve showed almost all multispike to round-like types, except 100～120 cm and 490～520 cm intervals. The sediments also had a very high divergency, and the standard deviations(σ_i) were all above 2. 0 ϕ, between 2. 23 and 3. 84 ϕ, very few could be 4. 6 ϕ. All these suggest that the whole columnar sediments had a poorly or an extremely poorly sorting (Friedman and Sanders, 1978). The normal probability plots generally showed two straight-line segments, or rarely three straight-line segments, which revealed that the transport patterns were mainly of suspen-

Table 1. Lithological characteristics and grain-size parameters of Pc10 core

Interval (cm)	Lithology	Composition (%)			Grain-size parameter			Probability curve	Frequency curve
		sand	silt	mud	Mi	σi	SKi		
I 0～10.5	S-M-S	10.6	45	43	7.79	3.29	0.21		
II 10.5～100	S-S-O	1.0～4.5	38.5～40	55～57	8.59～8.9	3.04～3.8	0.11～0.13		
III 100～120	S-S	13～36	40～57	22～29	5.9～6.93	2.29～3.06	0.11～0.42		
IV 120～380	S-S-O	0.7～4.6	31～45	52～67	8.70～9.39	2.5～3.18	0.08～0.13		
V 380～490	S-M-S	0.4～6.2	45～54	39～51	7.12～8.7	2.30～3.43	0.14～0.37		
VI 490～520	S	40～86	4～40	8～19	1.96～5.58	2.23～2.83	0.71～0.73		
VII 520～753.5	S-M-S S-S-O	1.2～32	29～43	38～61	6.37～9.0	2.8～4.6	0.02～0.25		

S-M-S: siliceous muddy silt; S-S: sandy silt; S-S-O: silty siliceous ooze; S: sand.

sion, amounting to more than 80% of the whole volumn. In view of sedimentary structures, there commonly were horizontal lamination and parallel (or wavy) lamination in the fine sediments, evidently gradational lamination could be seen at 490 to 520 cm and the domichnia structure occurred at 690 to 720 cm in the lower part of the Pc10 core. In addition, there occurred some white sandy pellets with a diameter of about 0. 2 cm, which mostly consist of diatom genus *Rhizosolenia*. The kind of sediments could be found in 70～80 cm and 160～170 cm intervals of the Core GC6 and 99～103 cm interval of the Core GC21 respectively. Based on the analyses of smear slides and grain size, the sediments of Pc10 core could be classified from top to bottom into seven intervals, their lithology and grain- size parameters are shown in Table 1.

2. 2 Mineral assemblage

2. 2. 1 Clastic mineral

The size of clastic minerals under study were mainly 0. 063～0. 25 mm. Totally more than 10 clastic minerals were observed in the sediments of the central strait. The commonest and more abundant heavy minerals were magnetite, olivine, pyroxene, horb-

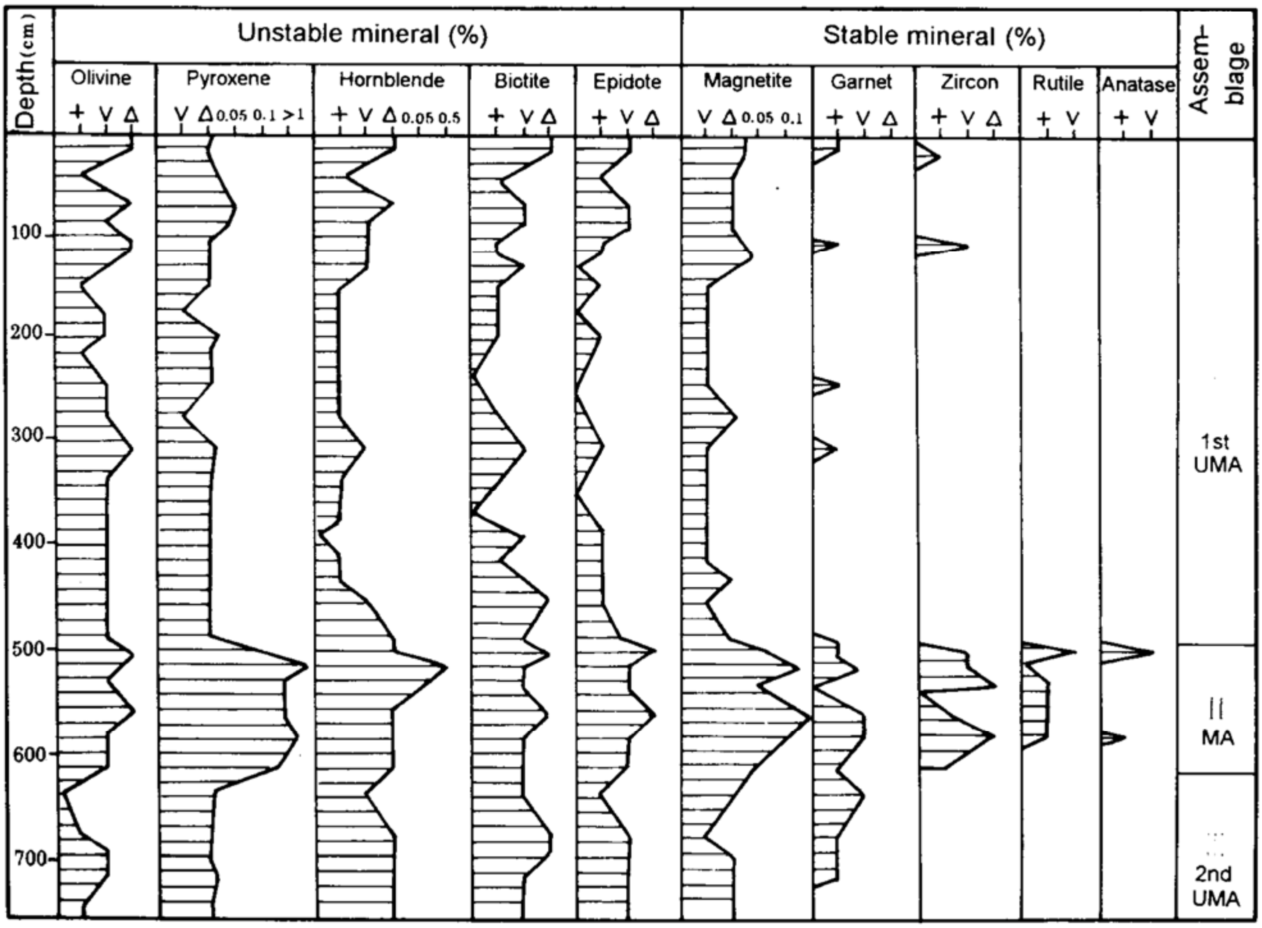


Fig. 2. Vertical distribution of heavy mineral contents in Pc10 core. +: 1～10 grains; V: 10～100 grains; △: >100 grains, <0. 001 mg.

lande, chlorite and epodosite. Garnet, pyrite and zircon were commonly seen but less in number. Besides, rutile, anatase, muscovite and apatite occurred occasionally.

The light minerals were mainly feldspar, quartz and volcanic glass, while carbonate minerals occurred occasionally. Fig. 2 and Fig. 3 show the clastic mineral composition of Pc10 core and the vertical distribution of their contents. The heavy minerals could be divided into:

0～490 cm first unstable mineral assemblage (1st UMA)
490～620 cm unstable and stable mineral mixed assemblage (MA)
620～753 cm second unstable mineral assemblage (2nd UMA)

According to the vertical changes of light minerals, the first unstable mineral assemblage could be subdivided into 0～120 cm rich quartz and debris assemblage (RQD), 120～460 cm poor quartz and poor debris assemblage (PQ-PD), 460～ 620 cm rich quartz and debris assemblage (RQD). Among them, the RQD could further be classified into two subassemblages: rich feldspar subassemblage at 460～516 cm and poor feldspar subassemblage at 516～620 cm.

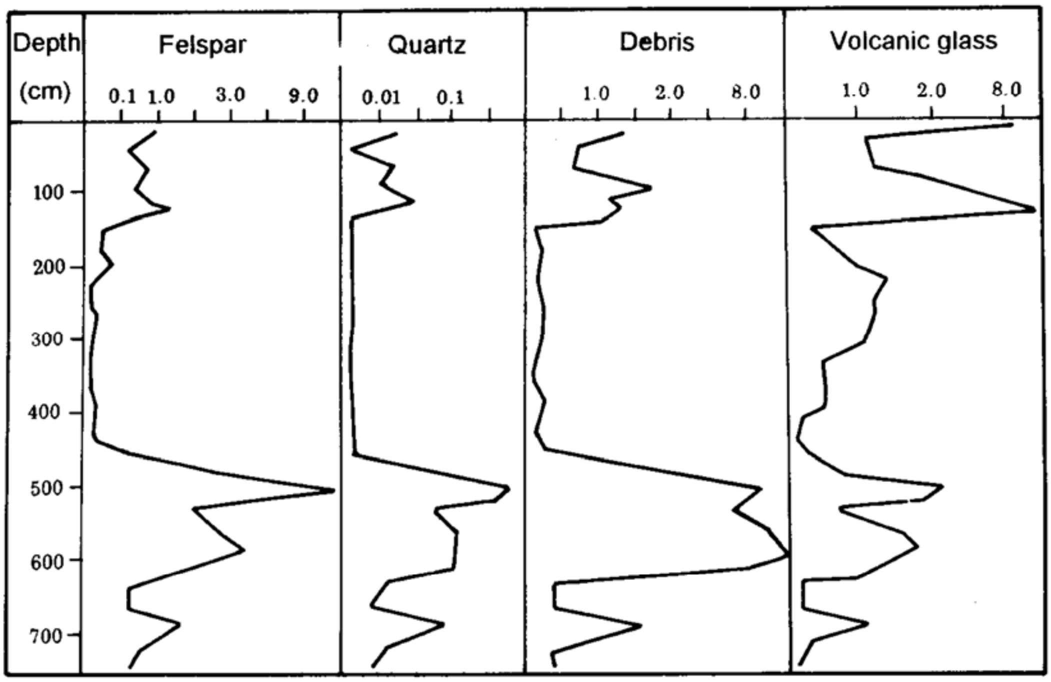


Fig. 3. Vertical distribution of light mineral contents in Pc10 core.

In this area, the clastic minerals were few in type and simple in assemblage consisting mainly of pyroxene and olivine, which suggested that the sediments were low in maturity, resulting not only from the material resource nearby but also from the climatic changes.

Quartz sand observed on the surface texture by scanning electron microscope (SEM) demonstrated that most of quartz grains were moderately angular in shape with more conchoidal fractures and V-shaped impact depressions. In addition, the solution and siliceous precipitation (layer or ball) could be seen commonly on the surface of quartz grain, in particular in the interval of 120～490 cm.

2. 2. 2 debris

Rock debris were mainly composed of basic volcanic rocks (basalt and andesite basalt) which were irregular in shape, brown or black-brown in colour and with more vesicular. Besides, there were medium-acid rock, metamorphic rock and sedimentary rock debris, all of which were of fragment-like or pellet-like shape. Also there were little clay lump. From Fig. 3, we could find the debris so change vertically and regularly just like such light minerals as feldspar and quartz, that their contents were higher and the compositions were very complicated. Besides basic debris, the others also could be seen.

2. 2. 3 Clay mineral

Clay minerals amount to 45%～65% of the columnar core Pc10 in the central strait sediments which are chiefly smectite with the contents varying about 45%～75%. The

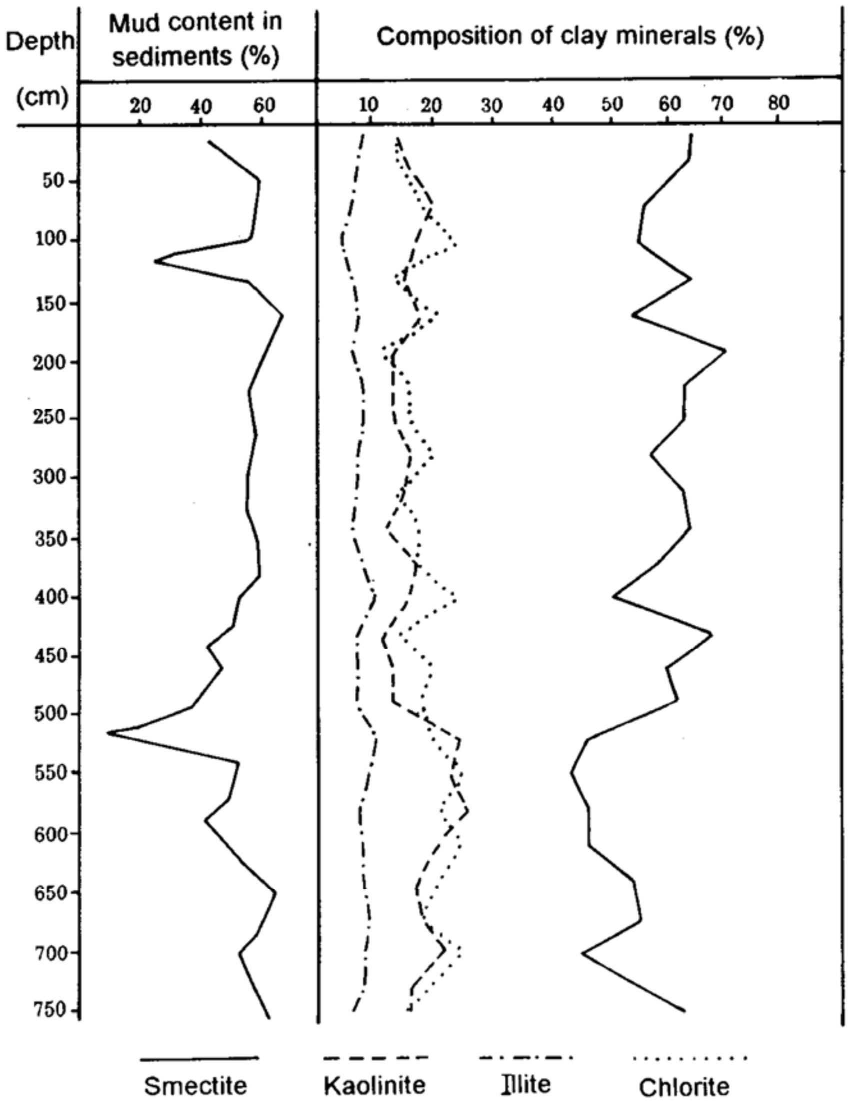


Fig. 4. Vertical change of clay mineral contents in Pc10 core.

others were illite and chlorite, their contents were 12%～35%. Besides, there were few kaolinites which occupy less than 10%. The mixed layer of clay minerals could be seen rarely. Fig. 4 reveals the growth and decline of smectite and illite in the sedimentary section.

(1) In 120～490 cm interval smectite is higher in content, usually being more than 60%, or at least being only 40%～45%.

(2) The contents of illite were just on the contrary, and in 120～490 cm interval, they were always less than 20%, evidently lower than those in the above interval or below the interval. In 490～750 cm interval, the contents of illite were all more than 20%, or 30% individually.

According to the vertical changes of the contents, the clay minerals of Pc10 core could be classified into two assemblages: smectite-illite-chlorite assmblage and smectite-chlorite-illite assemblage, the former occurred in 0～120 cm and 490～730 cm intervals in Pc10 core, while the latter in 120～490 cm interval.

2. 3 Sedimentary geochemistry

Contents of organic carbon were often less than 1%, the average content in 40 samples was 0. 7%, comparatively more than siliceous or calcarecous sediments in deep-sea. Especially in silty ooze of this area, the average content of organic carbon could be four times more than that of the siliceous ooze in deep-sea. Contents of $CaCO_3$ in sediments were extremely low, varying from 0% to 5. 17%, and being not clear vertically in distribution, incomparable with the dillution cycles of the Atlantic type, nor with the solution cycle of the Pacific type. The chemical elements in the sediments were characterized by their contents partly approaching those of similar sediments in deep-sea, for example, Mg, Ca, K, etc. In vertical direction, contents of SiO_2 in 520～753 cm interval were a bit greater than those in above intervals while the contents of Fe_2O_3 and TiO_2 increased in 100～520 cm interval. Fig. 5 shows the vertical change of some trace elements in Pc10 core.

(1) Higher Sr contents were found in the intervals below 480～490 cm, in some samples they could be 370 μg/g, which were in direct proportion to the changes of $CaCO_3$.

(2) The contents of B, Ba, Cu and Cr were comparatively higher in the two intervals of 0～90 cm and 490～753 cm, while a bit lower in the middle. On the contrary, the contents of V and Pb were higher within the interval of 90～490 cm than those in overlying and underlying sediments.

Concerning the distribution features of trace elements in the sediments of the Bransfield Strait, the contents of B, Ba, Cu and Cr, especially Cu, increased in pace with the deepening of water depth. Its content in central trough of the strait was commonly higher than 200 μg/g, the highest one could be 400 μg/g. Similarly, the content of B varied from <20 μg/g in the northern insular shelf-insular slope to ≥40～60 μg/g in the deepwater of central trough of the strait.

Besides the material supply, the changes of trace elements were also influenced by

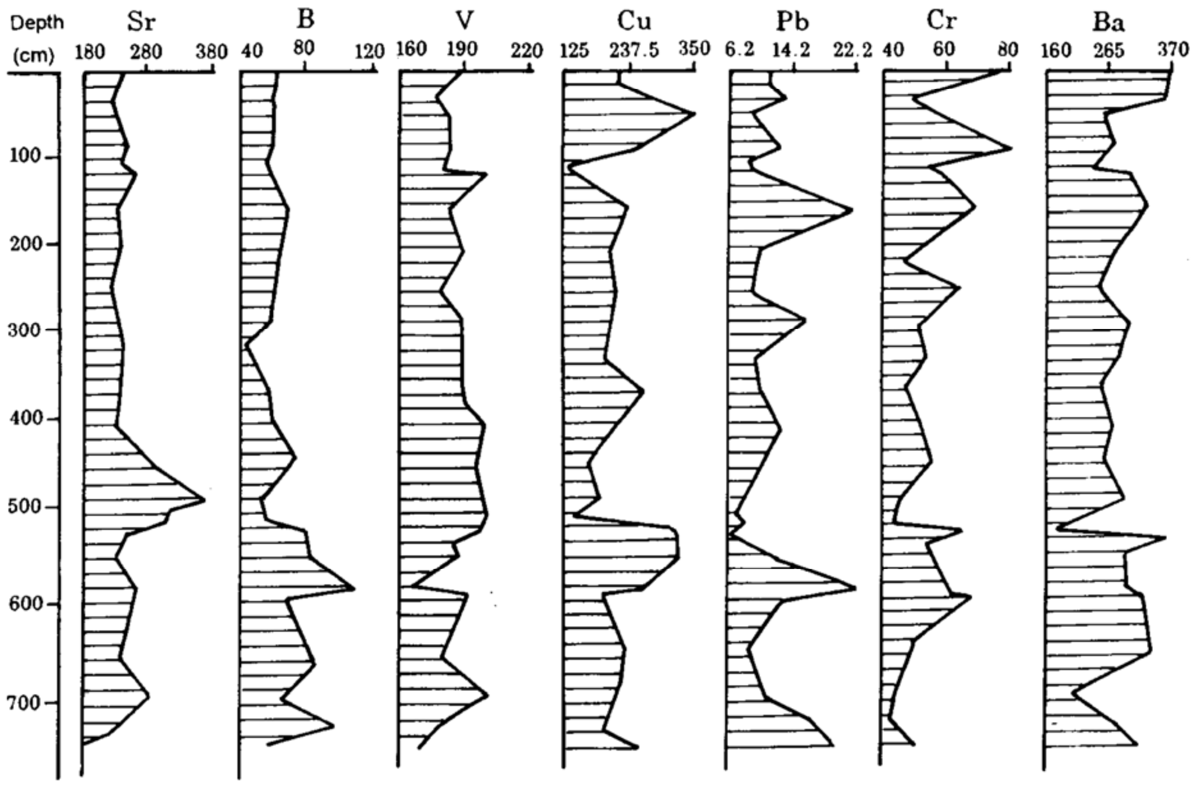


Fig. 5. Profile of chemical elements in sediments of Pc10 core.

the change of sedimentary environment. For example, cupreous fine colloids were deposited much easier in the central trough with weaker water dymanics than those in insular shelf-insular slope of stronger water dymanics.

2. 4 Microbiological thanatocoenoses

Microfauna and microflora including diatom, radiolaria, foraminifera and spores-pollen have been identified systematically from the columnar Pc10 core and several gravity cores. Siliceous microfossil within the sediments occupied the dominant position. Generally, the content of diatom in the Pc10 core sediments could reach as high as hundreds of thousands per gram sediment, with the maximum of 1. 5 million per gram sample. Radiolaria were rarely found in the sediments, only several tens could be seen per gram and vertically they were distributed uncontinuously. Foraminifera in the Pc10 core were dominated by siliceous benthic ones with the abundance of several hundreds per gram sample. On the contrary, the calcareous forminifera could be examined occasionally and they existed vertically only in restricted beds with several tens per gram sediment. The interval between 100/110 cm and 490 cm of Pc10 core was essentially barren with foraminifera. Composition of spore-pollen was rather simple, among them the pre-Quaternary reworks were often observed. The abundance of spore-pollen was extremely low, each slide only had several tens of spore-pollen grains.

Based on the vertical change of various kind of microfossils from Pc10 core, the distribution features can be drawn as follows:

(1) The whole section of Pc10 core could be divided into three parts, with two sand layers of 90/100 cm and 490/520 cm as boundary markers.

(2) Interval between 0 and 90/100 cm contains relatively abundant microfossils, such as diatom, radiolaria and siliceous foraminifera. Interval from 90/100 cm to 490/520 cm was characterized by yielding relatively more diatoms, rare radiolaria and no foraminifera. Siliceous microfossils within interval between 490/520 cm and 753 cm were more developing than those in the overlying bed, especially a few planktonic forminifera like *Neogloboquadrina pachyderma* can be observed within the interval. Besides those of pre-Quaternary reworks are more in number.

(3) The content of calcareous forminifera in the layer of 490/520 cm is as high as 60% of total amount, showing a feature quite different from that in the overlying or underlying sediments.

2.5 *Chronostratigraphic classification*

Age of surface sediments in the Bransfield Strait, with exception of some sites, were in the range of 2100～7200 years (Lin and Zheng, 1989), which indicated that the erosion action by recent bottom current in the area was not too strong. On the basis of columnar lithological observation, no distinctive sedimentary gap existed within the Pc10 core, while the sedimentary continuity showed well. Furthermore, the study of palaeomagnetism revealed that whole section of Pc10 core belonged to the Brunhes normal epoch (0～0.73 Ma), and was even younger than Emperor event occurring in 0.47～0.48 Ma.

Based on the vertical changes of sediment composition, and by using thermoluminescent (TL) and uranium series dating, the following chronostratigraphical classification for Pc10 core can be worked out (Table 2).

Table 2. Dating samples of Pc10 core by using different methods

Sample depth (cm)	Lithology	Testing results (ka)		Remarks
		TL[1]	U-seris[2]	
48.5～60	silty siliceous ooze		7.7	testing materials
107～118	sandy silt	13.2±1.0		by using TL and
220～230	silty siliceous ooze		33.7	U-seris method
400～410	siliceous ooze		61.0	are bulk-rock
512～516	medium-coarse sand	76.0±5.4		sample
520～530	silty siliceous ooze		79.2	
577～586	sandy clay	83.76±6.7		
600～610	silty siliceous ooze		91.3	
700～710	silty siliceous ooze		106.4	
740～750	silty siliceous ooze		112.5	

[1] Guangzhou Institute of Geochemistry, Academia Sinica; [2] South China Sea Institute of Oceanology, Academia Sinica.

(1) The columnar sample of Pc10 core, 753 cm long, represented the last 112.5 ka sediments in the Bransfield Strait. It means that the whole sequence is assigned to late Pleistocene to Holocene.

(2) In ascending order the lower part of the first sand layer (516.5~490 cm) was about 76.0±5.4 ka in age. It is inferred that it was deposited approximately during the late warm stage of last interglacial period (Cooke and Hays, 1982).

(3) The second sand layer (118~107 cm) was about 13.2±1.0 ka in age, being roughly the same deposits during the deglacial stage.

(4) Based on the vertical changes of diatoms and forminiferal thanatocoenoses together with the longtitudinal distribution of clay minerals and trace elements, the boundary between Pleistocene and Holocene is drawn in 90 cm depth, where the sedimentary age is thought to be about 9.0~10 ka (Yang, 1987).

3 Classification of sediments

Since late Pleistocene the sediments in the central part of the Bransfield Strait was dominated by fine-grained components with the diameter of less than 0.063 mm, they were mostly silty siliceous ooze and siliceous muddy silt. Columnar sediments with a length of 753 cm were composed of microbiologic remains, clay minerals, detrital minerals and volcanic clastics. Microbiologic remains were mainly diatom, seldom with dinoflagellate, siliceous foraminifera, spicule and radiolaria. Clay mineral contains abundant smectites. The detrital mineral includes unstable heavy mineral assemblage essentially consisting of pyroxene, hornblende and olivine, etc. and light mineral primarily felspars. Besides, there are more volcanic glasses and basaltic fragments with less medium-acid rock fragments and metamorphic minerals.

On the basis of sedimentogensis (Shen and Guo, 1993), the whole columnar sediments could be classified as three major types:

3.1 Biosiliceous sediment

It consists of siliceous biologic remains dominated by diatoms, and clay mineral composed mainly of smectite. Usually, its terrigenous detrital content was less than 20%. The silty siliceous ooze might be deposited in the environment where sea current was weak and water dynamics was low. It means that the depositional environment for siliceous ooze belonged to relatively quiet condition, most likely with single current. For example, some of the siliceous oozes from the interval between 120 cm and 380 cm of Pc10 core were probably deposited beneath the ice shelves on the ground of lacking of microfossil and having restricted mineralogy (Herron and Anderson, 1990). Sedimentary material of siliceous ooze mainly came from siliceous organisms in open sea and shallower sea. Among them the dominant ones were various kinds of diatoms living in different ecotype, such as thermophilous species *Nitzschia kerguelensis*, Subantarctic species *Coscinodiscus lentiginosus* and cryophilic form *Eucampia balaustium* (Zhan, 1989). The maximum content of diatom in the internal of 690~720 cm was up to 1.2~1.5 million per gram, nearly occupying 60%~75% of total sediments, which assumed "diatom blooming" phenomenon. The existence of varicolored beds and domichnia within the interval between 690 cm and 720 cm suggested that the water depth might be shallower and the depositional environment more active during that period. Comparing with other sediments in the same core, the siliceous ooze of this interval was characterized by relatively higher content of biologic remains (40%~75%) and lower content of detrital minerals (13%~18 %).

3. 2 Volcanic detritus

It derives directly from subaerial and submarine eruptions, for examples, interval between 100 cm and 120 cm of Pc10 core and interval from 170 to 192 cm of GC21 core. The content of volcanic detritus with the size of silt to coarse sand would be more than 50%, forming volcanic ash layer. The components of volcanic detritus include pumice fragments, dense shards, crystals and dense rock debris. Among them, volcanic shards were dominant, commonly in light colour (milky or colourless), secondly in brown and dark brown colour. They showed bunchy, fibrous, rip-up, massive and pumiceous in shape, fresh and bright in colour. The crystals often seen were pyroxene, being green in colour and granular, blocky or sharply angular in shape. Olivine was colourless or olive green in colour and granular or blocky in shape. Feldspar was colourless and transparent, irregularly granular and lath in shape, sometimes it was hardly distinguished from quartz. Most of crystals were clean with higher transparency. The dominant debris were basaltic, others and weathering minerals were extremely rare. Considering that the graded texture occurred in the volcanic detrital sediments, that most volcanic components were sharply angular in shape and fresh in colour and that weathering minerals were seldom seen, it is referred that the typical volcanic detrital sediments of this area originated from the nearby supply, but essentially, from the submarine eruption.

3. 3 Turbidity sediment

As a representative of this kind of sediments, the sample was taken from interval 490~520 cm of Pc10 core, its features are as follows:

(1) Grain size coarsened obviously with the contents of silt-coarse grade occupying over 50%.

(2) Graded bedding is well developed.

(3) Mineral and microfossil assemblages in this layer are apparently distinct from those in the overlying and underlying sediments. The terrigenous debrics increased more and more. The pyroxene were commonly green or seldom brown in colours, and automorphic or self-automorphic granular with rounded edges in shape. Also, the surface of pyroxene was unclean with low transparency. The abundence of calcareous foraminifera increased and so did the reworking foraminifera.

(4) The contents of debris increased. Besides basalt, they were gabbro, andesite, acid rocks and metamorphic rocks.

(5) Chemical solution and SiO_2 precipitation were developed on the surface of quartz grains(Xie, 1984).

As mentioned above, the sediments of 490～520 cm interval are evidently considered as turbidite. Similar sediments probably occurred at 570～590 cm of Pc10 core. The turbidity current deposit is thought to be closely related with warming weather at the end of last interglacial period, not at the beginning of last glacial period (Anderson, 1989; Cooke and Hays, 1982; Chen, 1989). The warming weather might cause deglaciation on a large scale, still resulting in the slumping of steep flank on the northern insular shelf and insular slope. So, the terrigenous province for turbidite mainly lay on the north of the Strait.

4 Sedimentation and sedimentary environment

The Pc10 core drilled in the Bransfield Strait lies in Subantarctica of high latitude zone, where the terrigenous detritus came from the South Shetland Island and Trinity Peninsula without any surface runoffs. Grain size analysis of 35 samples of Pc10 core reveals that the sediments were very poorly sorted and extremely poorly sorted because of scattering grain size, higher divergency and the standard deviation(σ_i) which was usually greater than 2.3 ϕ with the maximum of 4.6 ϕ (Fridman and Sanders, 1978). Quartz grains always were worse rounded or sub-rounded with conchoidal fractures and V-shaped depressions seen on the surface by means of SEM. Some surfaces of quartz show parallel striae and nailhead structure, or chemical solution pits and SiO_2 precipitation. Generally, the features of quartz grain surface texture reflected that the fine-grain sediments of Pc10 core deposited once in a relatively low-energy environment with weaker agent of sea current, namely, the lately superimposed reformation was not sufficient to change considerablely the original appearence of moraine deposits. According to Harland *et al.* (1966) and Anderson *et al.* (1980), the sediments of Pc10 core were roughly classified as compound paratills and residual paratills. Fig. 6 shows the sedimentary characteristics of the Pc10 core including physical properties, grain size, mineralogy, fossil content and others as proposed by Anderson(1989), Anderson *et al.* (1982), Powell(1987) and Herron and Anderson(1990).

It should be pointed out that the Pc10 core might contain sub-ice shelf sediments at the depth of 120 cm to 490 cm of the core, which were finer grained siliceous ooze than the rest of sediments in the core. Following characteristics are shown by these sediments:

(1) Content of debris and detrital mineral with the grain size of more than 0.063 mm range 1.37%～1.74% of total sediments, namely, ice-rafted material made up only a small amount of sediments.

(2) The components of debris and detrital mineral are homogeneous. The former is restricted to basalt fragments only, and the latter consists of the unstable heavy mineral assemblages and poor feldspar and quartz light mineral assemblage.

(3) The biogenic components appear to be relatively rare or absent.

The sedimentary features of glacial-marine deposits in this area since late Pleistocene

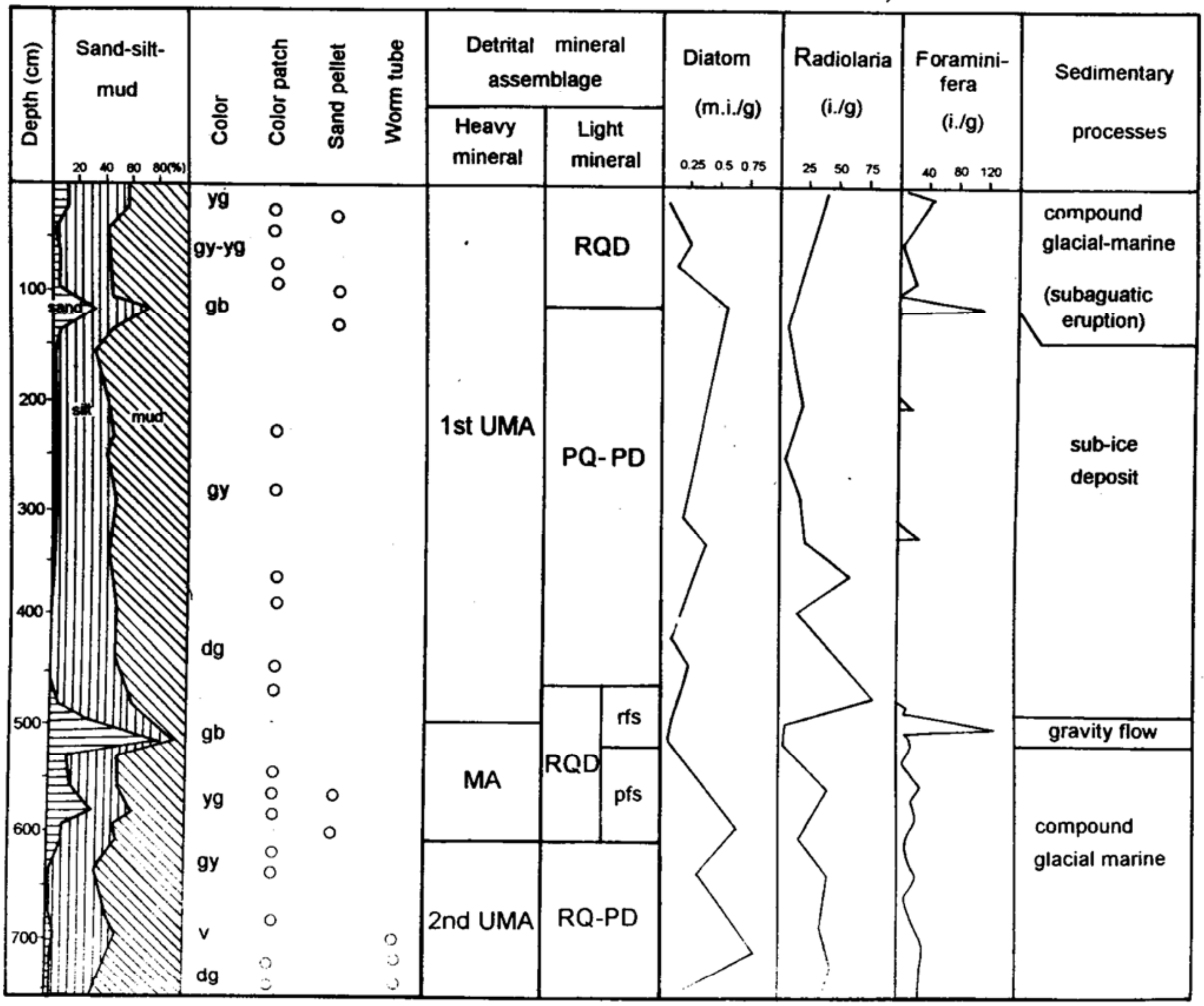


Fig. 6. Descriptive log of the core Pc10 from the central part of the Bransfield Strait. yg: yellow gray; gy: gray yellow; gb: gray black; dg: deep gray; v: variegated; UMA: unstable mineral assemblage; Ma: mixed assemblage; RQD: rich quartz and debris assemblage; PQ-PD: poor quartz and poor debris assemblage; rfs: rich feldspar subassemblage; pfs: poor feldspar subassemblage, m. i. /g: million individual per gram.

could be summarized as follow:

(1) Multiple material supply: It includes organic supply, mostly amorphous biogenic silica, volcanogenic supply, chiefly basic volcanics together with a large number of smectite, and terrigenous supply, primarily feldspar and quartz. For the sediments of Pc10 core, the organic supply played the leading role.

(2) Predominance of biogenic sedimentation: It is siliceous sediments that display predominance the whole columnar section. The contents of siliceous remains in the sediments varied 32%~75%, its average being 42% with exception of some intervals. The clay particle of siliceous ooze was mainly the siliceous organic remains, while the silt particle, besides the terrigenous finer grains, also was siliceous organic remains which occupied a certain proportion.

(3) Faster sedimentation rate: It was dated that the lowermost sediments of Pc10 core might be 112.5 ka in age. So the average sedimentation rate for 753 cm long core is about 6.54 cm/ka. The sedimentation rate of Holocene is about 9.0 cm/ka. These rates are very faster than those sediments from open sea or marginal sea on the earth, in particular in middle-low latitude areas. However, there are considerabely inagreement on the rate. By using ^{210}Pb method the Holocene diatomaceous sediments from the Bransfield Strait was measured 1 ~ 3 m/1000a (DeMaster and Harden, 1988), and also the Holocene sediments from Maxwell Bay is measured 0.75 m/1000a (Kim and Nam, 1991).

(4) Controlling on the sedimentation by the alternating highstand water/interglacial stage and lowstand water/glacial stage: Besides the tectonic movement, the alternation of interglacial and glacial stages had their strong influence on sedimentation. That was demonstrated essentially by the presence of turbidity current deposit and increasing of debris and detrital mineral in sediments during the highstand water/interglacial period. This might be caused by the warming weather, finally resulting in iceberg slumping and ice-rafted debris increasing. Similar phenomenon could be observed in the neibouring place, such as South Orkney Plateau (Herron and Anderson, 1990).

It was reported that in open Southern Ocean the siliceous ooze was the dominant sediment during the highstand water/interglacial period, while it was mostly silt during the lowstand water/glacial period (Burckle and Cirilli, 1987). In addition the sedimentation rate was also reported to be higher during the glacial period than that during the interglacial period. These sedimentary characteristics, however, are not so evident in the central part of the Bransfield Strait. The actual cause could be as follows. The Bransfield Strait is an asymmetrical depression with steep north and gentle south, higher west and lower east, belonging to pull-apart and back-arc basin. On the southwest of Deception Island, the sea-floor exhibits distinctively upwarping and become a gentle subaqutic uplift, where the sea-floor, at the water depth of 200~300 m, is restricted on its north, west and south (Huang *et al.*, 1989). According to Anderson (1989), the range of elevating and subsiding of sea level in Bransfield Strait during the highstand water/interglacial and lowstand water/glacial periods may reached to 200~250 m. Then, the central part of the strait (westward from the east termination of King George Islands) was probably a relatively closed-up and low-energy sedimentary area with water current hindered, which brought limited terrigenous supply by ice-rafted during the lowstand water/glacial period. Furthermore, the sediments were still finer-grained in size and the sedimentation rate was lower (or approached) during the glacial period than or approached to that during the interglacial period.

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References

Anderson, J. B. (1989): Antarctica's glacial setting. In: Glacial-Marine sedimentation(Short Course in Geology, 9), Ed. by Anderson, J. B. and Molnia, B. F., 28th Int. Geol. Congr. , Washington D. C. Am Geology. Union, Wanshington, 11—57.

Anderson, J. B. , Kurtz, D. D. , Domack, E. W. and Balshaw, K. M. (1980): Glacial and glacialmarine sediments of the Antarctic continental shelf. *Jour. Geol.* , 88(4), 399—414.

Anderson, J. B. , Kurtz, D. , Weaver, F. and Weaver, M. (1982): Sedimentation on the west Antarctic continental margin. In: Antarctic Geoscience. Univ. , Ed. by Craddock, C. , Wiscosin Press , Madison, 1003—1012.

Burckle, L. H. and Cirilli, J. (1987): Origin of diatom ooze belt in the Southern Ocean: implication for late Quaternary Paleoceanography. *Micropaleot.* 33(1), 82—86.

Chen Wenbin (1989): Radiolaria biostratigraphy of core S11 in the area northwest of Antarctic peninsula. Proceedings of China first symposium on southern ocean expedition, Shânghai Scientific and Technical Publishers, Shanghai, 313—318(in Chinese).

Cooke, D. W. and Hays, J. D. (1982) : Estimates of Antarctic Ocean seasonal sea-ice cover during glacial intervals. In: Antarctic Geoscience. Ed. by Graddeck, C. , Univ. of Wiscosin Press, Madison, 1017—1025.

Demaster, D. J. and Harden, S. L. (1988) : Rates of Holocene sedimentation on Western continental shelf of the Antarctic peninsula. *U. S. Antarctic Jour.* , 23(5), 94—96.

Fridman, G. M. and Sanders, J. E. (1978) : Principles of sedimentology. John Wiley & Sons Inc. , New York, 792.

Harland, W. B. , Herod, K. N. and Krinsley, D. H. (1966): The definition and identification of Tiles and Tiletes. *Earth Science*, 2, 225—256.

Herron, M. J. and Anderson, J. B. , (1990), Late Quaternary glacial history of South Qrkney plateau, Antarctica. *Quaternary Res.* , 33, 265—275.

Huang Huiyu, Wang Huizhong, Wu Bangyu, Wu Zhennan, Zheng Zhaoxiang and Ge Jianping (1989): Characteristics of marine glacial deposition surrounding the South Shetland Islands, Antarctica. Proceedings of China first symposium on southern ocean expedition. Shanghai Scientific and Technical Publishers, Shanghai, 366—375(in Chinese).

Kim Yeadong and Nam Sangheon (1991): High resolution seismic survey of Maxwell Bay, King George Island: Glacial marine sedimentation and tectonic. *Korea Jour. Polar. Res.* , 2(1), 79 —88.

Lin Chengqing and Zheng Lianfu (1989) : Sediment types and sedimentation of the northwestern sea area of the Antarctic peninsula. Proceeding of China first symposium on southern ocean expedition, Shanghai Scientific and Technical Publishers, Shanghai, 378—386(in Chinese).

Powell, R. D. (1987): Modern glacimarine environments. Epsodes (special issue), 10(1), 23—25.

Shen Xichang and Guo Buying (1993): Marine Geology. China University of Geoscience Press, Wuhan, 196 (in Chinese).

Smellie, J. L. (1988): Deception Island. In: Tectonic of the Scotia Arc, Antarctica (Field Trip Guidebook T180), 28th Int. Geol. Congr. , Ed. by Dalziel, I. W. D. , Washington D. C. , Am. Geophy. Union, Washington, 191.

Xie Youyu (1984): Atlas of quartz sand surface textural features of China micrographs. China Ocean Press, Beijing , 148. (in Chinese).

Yang Huairen (1987): Quaternary geology. High Education Press, Beijing, 428(in Chinese).

Zhan Yufen (1989) : Diatom distribution of core S11 and Paleoclimate variation in the northwestern sea area of the Antarctic peninsula. Proceeding of China first symposium on southern ocean expedition. Shanghai Scientific and Technical Publishers, Shanghai, 322—328(in Chinese).