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The concentration variation features of sea salt ions and non sea salt ions in a firn core recovered from Princess Elizabeth Land, East Antarctica

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Abstract A 51.85 m firn core drilled in Princess Elizabeth Land, Antarctica, during the 1996-1997 Chinese First Antarctic Inland Expedition, has been measured for $\delta^{18}O$ and major ions. Based on the high quality data of the seasonal variations of major ions, the firn core was dated with errors within ±3 years. The 51.85 m firn core record extends for 251 years (A. D. 1745-1996). The results of the glaciochemistry data of the firn core show that the mean concentrations of Cl^-, Na^+ and Mg^{2+} are similar to those reported from other coastal areas in East Antarctica. However, mean concentrations of Ca^{2+} are much higher than those reported from other regions, this anomaly phenomenon may be related to the strong local terrestrial sources. It is found that the variations of three kinds of sea salt ions (Cl^-, Na^+ and Mg^{2+}) in the past 150 years show very similarly rising trends, which may be the results the Southern Hemisphere warming in the past century.

Key words Antarctica, firn core, sea salt ion and non sea salt ion

1 Introduction

The study on the features of atmospheric environment by glaciochemistry is the major content of snow-ice and global change research. Antarctic ice sheet is far from the regions polluted by human activities, and surrounded by ocean, and the Antarctic Circumpolar Current is the wide sea water and atmosphere barrier between Antarctica and the outside world. All of the unique geographical features make the impurities in snow and ice in Antarctic ice sheet is simple. Therefore, it is significant to study the origins, transmission paths and depositional styles of major ions in the firn and ice recovered from Antarctic ice sheet for investigating the past atmospheric environment by ice core.

Generally speaking, the ions in Antarctic ice sheet can be divided as follows: 1) sea-salt ions (including Cl^-, Na^+, Mg^{2+} *et al.*), 2) non-sea-salt ions (including Ca^{2+}, Al^{3+} *et al.*), 3) SO_4^{2-} in Antarctic ice sheet can be divided into sea-salt (ss) SO_4^{2-} and non-

sea-salt (nss) SO_4^{2-}, of which the former comes from sea-salt aerosols and the latter mainly comes from marine organisms in the low and middle latitudes and volcanic eruptions; 4) NO_3^-, the origins of which is complicated. In this paper, the glaciochemical data of the 51.85-m firn core collected from site DT001 (71°51′S, 77°55′E; 270 km inland, 2325 m a.s.l., accumulation rate 127 kg·m^{-2}·a^{-1}, mean annual temperature −33.1℃) on Princess Elizabeth Land, East Antarctica, during 1996-97 Chinese First Antarctic Inland Expedition is studied, and the study is particularly on the variation features of sea-salt ions and non-sea-salt ions (not including Al^{3+}) in the firn core. The results of SO_4^{2-} and NO_3^- of the firn core are reported in (Zhang *et al.* 2002; Zhang *et al.* 2003). The ice core drilling, sampling, analysis and dating are discussed elsewhere in detail (Zhang *et al.* 2002; Li *et al.* 1999; Zhang *et al.* 1999).

2 easonal variations of sea salt ion concentrations

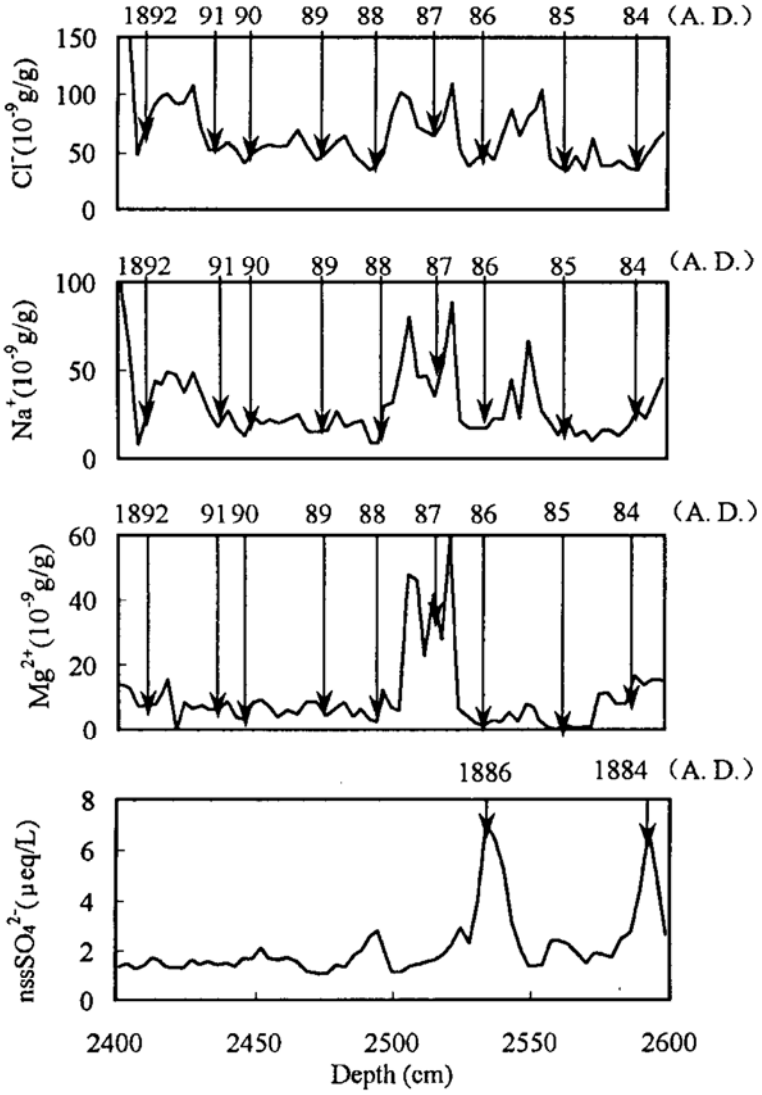

Fig 1 Seasonal variations of sea salt ion concentrations of the 51.85 m ice core from Princess Elizabeth Land, Antarctica covering depth 24-26 m.

The variations of the sea-salt ions recorded in the 51.85 m ice core recovered from Princess Elizabeth Land, East Antarctica show obvious seasonal variations and annual stratagraphy. The reason is that Princess Elizabeth Land locates in the East Coast of Antarctica

In winter, the cyclones from Sub-Antarctic Ocean bring sea-salt ions into the ice sheet when they invade south region and frequently enter the inland of Antarctica. Thus the concentrations of sea-salt ions is high in winter and low in summer, forming a clear seasonal cycle in the study region. Therefore the seasonal variations of sea-salt ions lay solid foundation for ice core dating.

3 The concentration variation features of major ions in the past 250 years

Mean concentrations of Cl^-, Na^+, Mg^{2+}, Ca^{2+} and the ratio of Cl^-/Na^+ are reported in Table 1. Table 1 show that the mean concentrations of Cl^-, Na+ and Mg^{2+} are similar to those reported from other areas in East Antarctica. However, mean concentrations of Ca^{2+} are much higher than those reported from other regions; this anomaly phenomenon may be related to the strong local terrestrial sources; for there are many bare mountains around Lambert Glacier Basin, the biggest basin in east Antarctica, where the local atmospheric circulation and wind field is complicated (Qin and Ren 2001). The mean ratio of Cl^-/Na^+ in the firn core is 1.9, consistent with the ratio in seawater, which shows that the marine airmass controls the region and the impurities in snow-ice mainly come from ocean. The study on the microparticle in surface snow samples along a 330km profile from Zhongshan Station to Inland of Antarctica shows that although the area is controlled by the polar easterly wind and katakatic wind, transportation and deposition of the microparticles in Princess Elizabeth Land are mainly influenced by marine airmass in coastal area (Wang *et al.* 2000), which consequently means that the sea salt ions in Princess Elizabeth Land come from the surrounded ocean.

Table 1. Mean concentrations of Cl^-, Na^+, Mg^{2+}, Ca^{2+} and $Cl^-/Na+$ for the 51.85m ice core from Princess Elizabeth Land, Antarctica

Site	Cl^- 10^{-9}g·g^{-1}	Na^+ 10^{-9}g·g^{-1}	Cl^-/Na^+	Mg^{2+} 10^{-9}g·g^{-1}	Ca^{2+} 10^{-9}g·g^{-1}
DT001 Core					
Mean	64	45	1.9	10	54
Std dev.	28.5	24.5		8.8	48.2
Min	5	1		0	1
Max	263	197		77	497
LGB10 pit (Qin and Ren 2001) 2.5m in depth	91	51		7.2	55
DML Core (Isaksson *et al.* 1992) 1865-1991	35.6	13.5	2.8	2	1.2
	34.1	11.1	2.9	2.8	4.2
South Pole Core (Whitlow *et al.* 1992) 1955-1988	69	22	3.9		
Dome C Core (Legrand and Delmas 1988) 1760-1980					

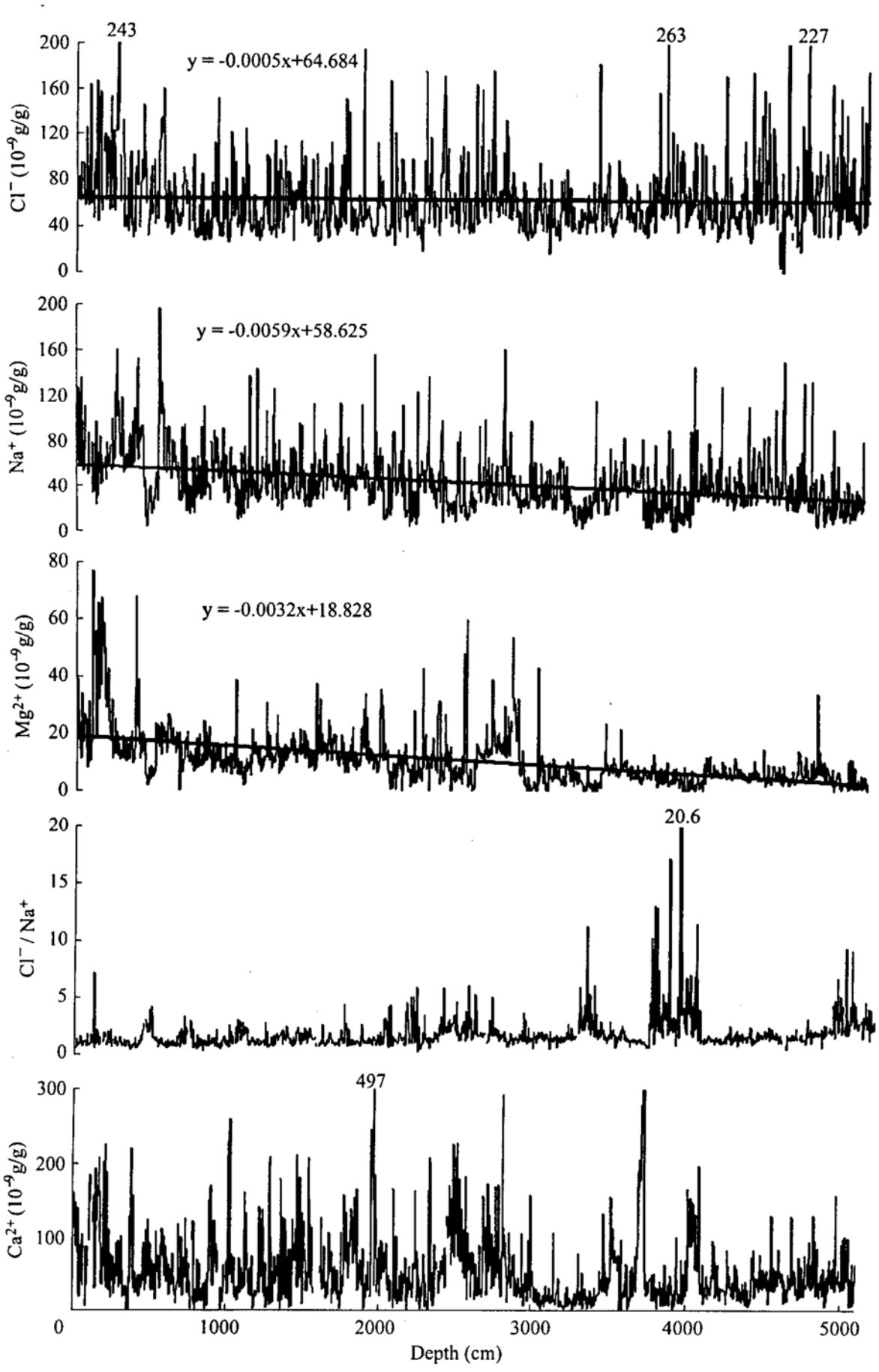

Fig 2 The ion concentration records of Cl^-, Na^+, Mg^{2+}, Ca^{2+} and $Cl^-/Na+$ in Princess Elizabeth Land, Antarctica for the past 250 years

Fig 2 shows that the variations of three kinds of sea salt ions (Cl^-, Na^+ and Mg^{2+})

in the past 250 years are rather smooth except for high concentrations in very few years and show very similarly slightly rising trends; rising is obvious in the past hundred years and the reason may be due to the Global, especially the South Hemispheric warming in the past hundred years(Jone *et al.* 1999). Studies show that on the background of the Global, especially the South Hemispheric warming in the past century, the area of the sea ice cover over the Antarctic ice sheet obviously decreased (Wu *et al.* 1999). As the sea salt ions in Princess Elizabeth Land, Antarctica mainly come from the surrounded ocean, therefore, the decreasing of the area coverd by the sea ice means the shortened distance between the source site and the depositional site, which make the sea salt ions can be more easily transmitted to Antarctic ice sheet, so the concentrations of three kinds of sea salt ions show increasing trend in the past hundred years. Fig. 2 shows that the variation of Cl^-/Na^+ in the past 250 years is rather smooth except for high concentrations during 1810-1825 ((correspond to about 40 meter in depth in the firn core), which may be due to the HCl increasing in the atmosphere(Isaksson *et al.* 2001). Previous studies show that HCl from the inside of globe can be transmitted to the snow and ice over Antarctic ice sheet during the volcanic eruptions (Qin 1995). Fortunately, many volcanic eruptions can be detected in the DT001 firn core during 1810-1825, especially the largest scale of volcanic event (Tambora) erupted in 1815. However, further work is necessary to investigate whether the increased ratio of Cl^-/Na^+ in the firn core resulted from the volcanic eruptions. The variation of Ca^{2+} is smoother than those of sea salt ions and shows slightly increasing trend. The reason may be as follows: the firn core was drilled at DT001 where is 270 km far from ocean, therefore, a portion of Ca^{2+} comes from ocean, so the variation of Ca^{2+} is similar to those of sea salt ions, but smoother variation may suggest that a considerable portion of Ca^{2+} comes from continent.

4 Conclusions

Princess Elizabeth Land located in the eastern side of Lambert Glacier Basin, the biggest basin in east Antarctica. There has been no ice core study in this region, so it is a virgin region for chemical records study. Therefore, further work is needed to study the origins, transmission paths and depositional styles of major ions in the firn and ice in order to investigate the past atmospheric environment by ice core. Fortunately, during 1997-1998, 1998-1999 and 1999-2000 Chinese National Antarctic Research Expedition, four firn cores were drilled in Princess Elizabeth Land. Most of the laboratory analyses of the cores are still in progress, and the expected results may be helpful to explain for the overall climate and atmospheric environment in this region.

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