Chinese Journal of Polar Science, Vol. 10, No. 1, 61 - 66, June 1999

The primary research on the environmental climatic records of the two snow pits recovered from Princess Elizabeth Land, Antarctica

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Received January 25, 1999

Abstract Snow samples collected from two snow pits (2.5 m and 3.5 m deep) along the route of the 1996/1997 Chinese Antarctic Inland Expedition in Princess Elizabeth Land, East Antarctica, have been analyzed for chemical composition and oxygen isotope ratio. Annul accumulation layers can be well-identified based on fluctuations of major anions (especially Cl^-) and $\delta^{18}O$. However, no obvious seasonal variations of cation concentrations were found in the profiles. The results provide a useful tool for dating the snow stratum in this region. High sulfate (SO_4^{2-}) concentrations found in the two snow-pit profiles for the periods of 1992 - 1995 may be due to the June 1991 Pinatubo (Philippines) volcanic eruption and August 1991 Cerro Hudson eruption in Chile.

Key words Princess Elizabeth Land, anion, cation, $\delta^{18}O$, volcanic eruption.

1 Introduction

Meticulous records of high-resolution, short-term time series environmental climatic variations can be obtained by analyzing and studying the content of major ions of the shallow snow pit. In theory, seasonal variations can be identified if the sample numbers are no less than 5 in one annual layer. This resolution, with the help of high precision and high sensitivity instruments of the 1990's, makes the research on the records of shallow snow pits outstanding among the various sediments. But there are also many problems, for example, to ascertain the time series of the shallow snow pit, or to date the ice core, is still a long disturbing difficult problem for the glaciologists. For another instance, the variation processes of anions and cations after being deposited in snow stratum is the research topic on modern environmental process, which has been little studied. Only to better solve these difficult problems, can we guarantee the truthfulness and reliability of the records in the snow pits and ice cores, strengthen the status of glaciochemistry in global change research and thus the research will become more meaningful (Qin 1995).

In recent years, there are plentiful glaciochemical data of the snow pits available but, as compared with the complicated natural geography conditions and vast area of Antarctica, the concerning data are too little. In the following, this paper will discuss on the glaciochemistry data of the two snow pits obtained from the route of the 1996/1997 Chinese Antarctic Inland Expedition in Princess Elizabeth Land, East Antarctica.

One of the authors, Prof. Li Zhongqin, participated the 1996/1997 Chinese Antarctic Inland Expedition that is an important step of Chinese ITASE program. The expedition covered the distance of 300 km from Zhongshan Station to Dome A (as shown in Fig. 1). Because of hard conditions, this region is not familiar for studying Antarctic ice sheet. Therefore, the glaciochemical data obtained from Princess Elizabeth Land are important for consummating the glaciochemical data of Antarctica.

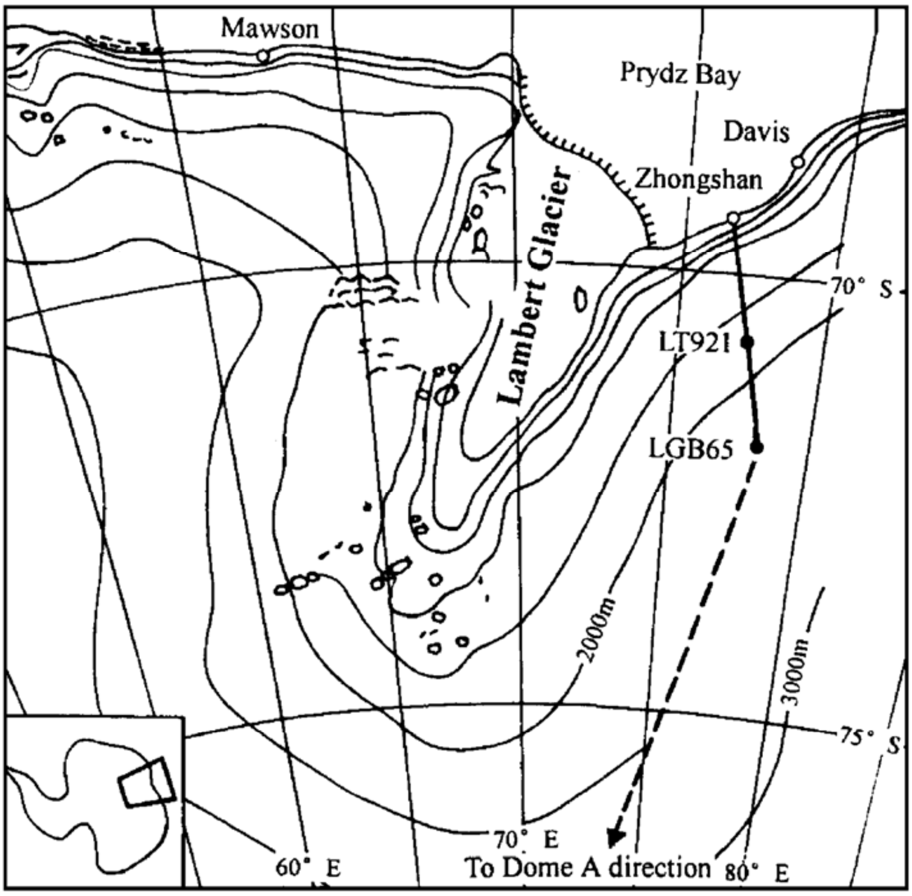

Fig. 1. Map showing the route of the First Chinese Antarctic Inland Expedition during 1996/1997. ● :the location of the two snowpits.

2 Sampling and analysis

Two snow pits (2. 5 m and 3. 5 m) were excavated at LT921 and LGB65, respectively (Fig. 1). Samples were collected at an interval between 3 cm and 4 cm. Before sampling, one of the snow pit walls was scraped with pre-cleaned stainless steel shovel. Then vertically continuous snow samples were taken from pit wall and sealed in the polyethylene (PE) sampling bottles that were pre-cleaned only by deionized water without the use of acid. Finally they were carried to the cold chamber (−15°C) in Lanzhou Institute of Glaciaology and Geocryology, Chinese Academic of Sciences.

The major anions and cations were analyzed in the Laboratory of Ice Core and Cold Regions Environment, Lanzhou Institute of Glaciaology and Geocryology, Chinese Academy of Sciences. All snow samples were melted at room temperature in the laboratory, the measurement was done under a super-cleaned environment. Deionized water (>18.3 MΩ) was used to clean the experiment utensils and to prepare in standard solution during the measurement process.

Cations were measured by Dionex300 ion chromatograph, anions were determined using Dionex100 ion chromatography, $\delta^{18}O$ values were analyzed using MAT-252 gas mass spectrograph. The detection limits for cation, anion and $\delta^{18}O$ were $1\times10^{-9}g\cdot g^{-1}$, $1\times10^{-9}g\cdot g^{-1}$, $\pm0.5‰$, respectively.

3 Results

From Fig. 2 we can see that: in the both snow pits, the seasonal variations of NO_3^- are partly in phase with the variations of $\delta^{18}O$, while the peaks of Cl^- correspond to the troughs of $\delta^{18}O$. Both variations of Cl^- and NO_3^-, like the variations of $\delta^{18}O$, form the seasonal variation stratum. Thus if we found time series based on stable isotope, the time series of Cl^- and NO_3^- are comparable to the time series of stable isotope. Therefore, when the data of stable isotope are incomplete or not available, the researchers can take Cl^- and NO_3^- as the important foundations to date ice cores and found time series. However, as regarding cations, only the peaks of Na^+ in one snow pit correspond to the troughs of $\delta^{18}O$, the variations of Na^+ in the other snow pit and the variations of Ca^{2+} in both snow pits don't show obvious seasonal variation stratum.

We can see from Fig. 3 that the concentrations of $nssSO_4^{2-}$ in both snow pits show high peaks during 1995/1994 and 1993/1992, that is to say, the variations of $nssSO_4^{2-}$ in the two snow pits are partly in phase.

4 Discussion

From the result revealed by Fig. 2, we can get such impressions: between the sea-salt ions and the non-sea-salt ions in Princess Elizabeth Land, East Antarctica, the sea-salt ions are apt to reveal the seasonal variations of climate. The reason is that Princess Elizabeth Land lies in the East Coast of Antarctica. In winter, the cyclone from Sub-Antarctic Ocean invades south region and frequently enters the interior of Antarctica, in the meanwhile, it brings all kinds of sea-salt ions into the ice sheet. Thus the concentrations of sea-salt ions show high peaks in winter and lower troughs in summer, that is forming a clear seasonal cycle in the Antarctic ice sheet. Therefore it makes the sea-salt ions become the foundation to date the ice core. We can also see from the above mentioned figure that: by making comparison between sea-salt anions and cations, the anions are apt to represent seasonal variations, it is probably related with the depositing processes of anions and cations and "post-deposition processes". Many documents indicate that the sea-salt, no matter they are anions or cations, can both show marked seasonal cycle (Whitlow *et al*. 1992; Legrand and Delmas 1988). So here we just exhibit our research result, as regards the correctness and causes of the conclusion, it needs further careful research on depositing and post-deposition processes of all kinds of ions in

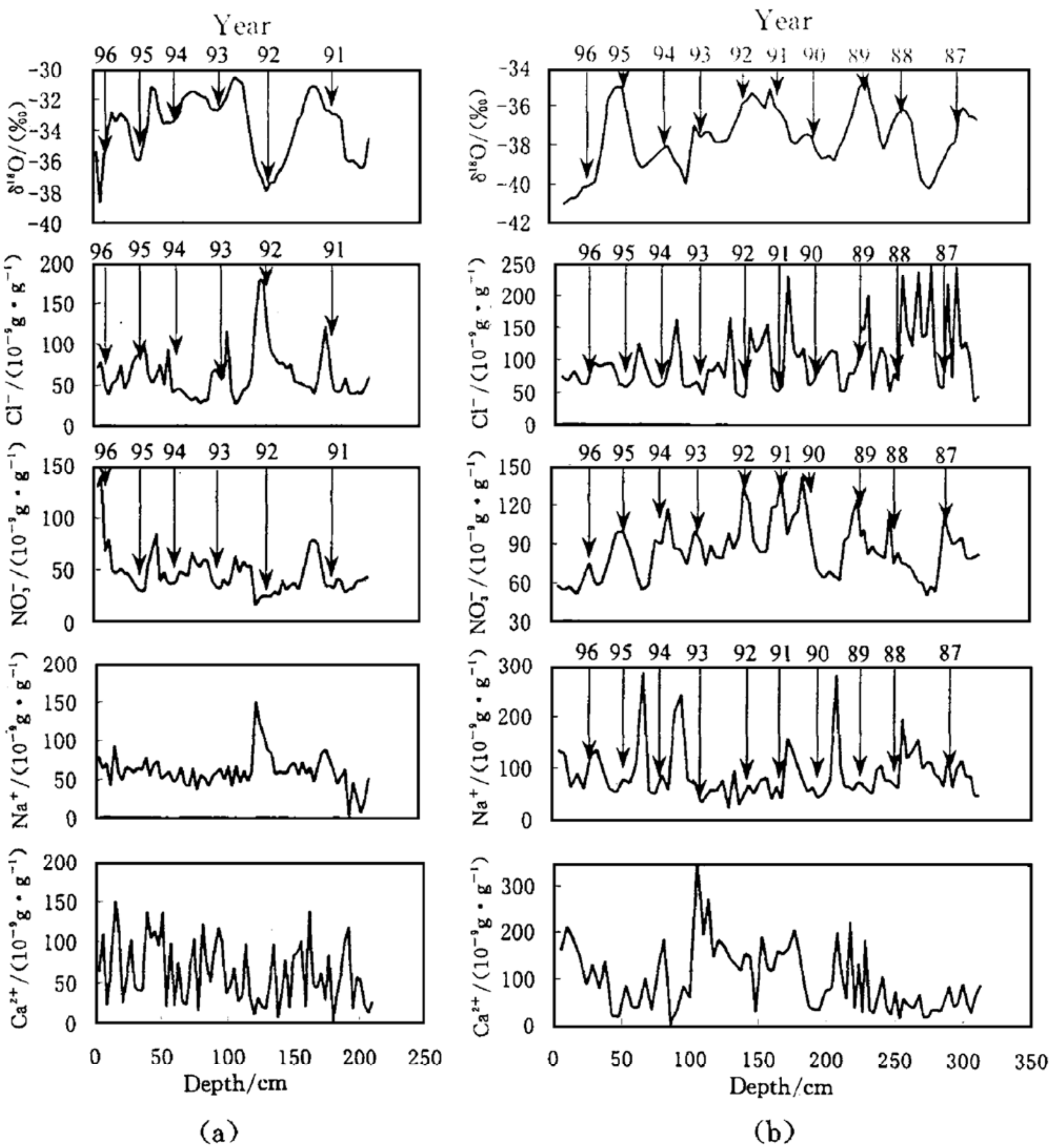

Fig. 2. (a) $\delta^{18}O$, Cl^-, NO_3^-, Na^+, and Ca^{2+} data from 2.5-m pit at LT921 during 1991 – 1996; (b) $\delta^{18}O$, Cl^-, NO_3^-, Na^+, and Ca^{2+} data from 3.5-m pit at LGB65 during 1987 – 1996.

the ice sheet.

At the same time, we unexpectedly find that the variations of NO_3^- are partly in phase with the variations of $\delta^{18}O$. The documents show that one of the important characteristics in the nitrate concentrations of Greenland and Antarctic snow is that there is a persistent nitrate summer peak (Andreas *et al*. 1994; Mulvaney and Volff 1993; Whitlow *et al*. 1992; Steffensen 1988; Neubauer and Heumann 1988; Mayewski *et al*. 1987, 1990; Legrand and Delmas 1986). Some researchers even found the persistent nitrate summer peak in the alpine snow (Davis *et al*. 1995). But we still have not perfect explanations to the variations of NO_3^- in accompanying with the variations of season. It is

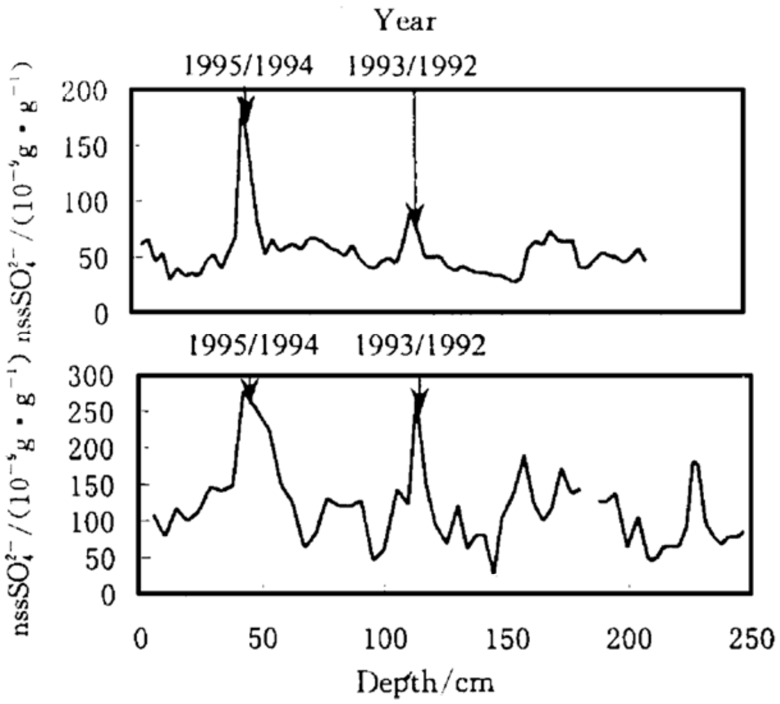

Fig. 3. Comparison of the variations of nssSO_4^{2-} concentrations from LT921 snowpit and LGB65 snowpit.

mainly because NO_3^- comes from a lot of sources, and it is difficult to ascertain which kind of source is the most important. However, the present results seem to indicate that among the many sources of NO_3^- in Princess Elizabeth Land, the source that could reflect the seasonal variations may occupy a dominant status.

In addition, as shown in Fig. 3, in the two snow pits, nssSO_4^{2-} show very high concentrations during 1995/1994 and 1993/1992. It may be ascribed to the volcanic eruption, which is reflected in the Antarctic ice sheet. Dai *et al*. (1997) also identified the June 1991 Pinatubo eruption in Philippines and the August 1991 Cerro Hudson eruption in Chile in analyzing nssSO_4^{2-} of the two snow pits at South Pole. The nssSO_4^{2-} phase of the two snow pits is similar to the phase shown in Fig. 3, so we consider that the increased nssSO_4^{2-} concentrations of Princess Elizabeth Land during 1995/1994 and 1993/1992 may be the result of the June 1991 Pinatubo eruption and the August 1991 Cerro Hudson eruption.

5 Conclusions

By analyzing the glaciochemical data of the two snow pits in Princess Elizabeth Land, East Antarctica, we not only detected the traces (the increased nssSO_4^{2-} concentrations) of the June 1991 Pinatubo eruption in Philippines and the August 1991 Cerro Hudson eruption in Chile, but also made a comparison of the variations of all kinds of ions and $\delta^{18}O$, we draw such conclusions: in the region of Princess Elizabeth Land, East Antarctica, sea-salt ions and NO_3^- are more apt to reveal the seasonal variations than non-sea-salt ions. Moreover, between the sea-salt anions and cations, anions are more capable to show seasonal cycle than cations, but with respect to that problem, we need further research and discussion.

Acknowledgements We greatly acknowledge Huang Cuilan for measurements of anions, Wang Xiaoxiang for cations and Sun Weizheng for measurements $\delta^{18}O$. The financial support for this research is provided by the National Natural Science Foundation of China (No. 49771022), Chinese Academy of Sciences (KZ 951-A1-205) and the Ministry of Science and Technology of China (98-927).

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