

CONCENTRATION CHARACTERISTICS OF SOLUBLE IMPURITIES IN THE SURFACE SNOW OF COLLINS ICE CAP, KING GEORGE ISLAND, ANTARCTICA

Han Jiankang¹(韩建康), Kang Jiancheng²(康建成), Wen Jiahong²(温家洪),
Paul A. Mayewski³ and Mark S. Twickler³

¹ Lanzhou Institute of Glaciology and Geocryology Academia Sinica, Lanzhou 730000

² Polar Research Institute of China, Shanghai 200129

³ Glacier Research Group, Institute for the Study of Earth Oceans and
Space(EOS), University of New Hampshire U. S. A. 03824-3525

Abstract Measurements carried out for the upper 10m firn/ice obtained at the main dome of Collins Ice Cap, King George Island, Antarctica revealed the direct relation of soluble impurities of snow mass to the composition of atmosphere aerosols. It was indicated that sea salt source dominates the atmosphere aerosol around Collins Ice Cap.

The simultaneous variation shown by the concentration profiles of Na^+ , K^+ , Mg^{2+} , Ca^{2+} , SO_4^{2-} , Cl^- , Br^- and very close EF values (≈ 1) suggested their common marine source and similar deposition process. Besides the possible surface contamination, NH_4^+ varied uniformly along deeper part of the core in concentration, which could be considered as background value of ammonium. A satisfactory explanation for NO_3^- concentration profile has not reached at present.

Key words Collins Ice Cap, concentration of soluble impurities, deposition process

Introduction

An important subject of polar glaciology through careful glaciochemical studies is to obtain information on global atmospheric chemistry for the past and at present. The initial principle for this purpose is based on that there exists a direct relationship between chemical properties of atmosphere aerosols and chemical constitute of precipitation in polar regions, which has been supported by the theoretical consideration (Junge, 1977).

Antarctic continent is far away from other ones. Previous studies suggested that a considerable part of aerosols in atmosphere inland of Antarctica was originated from other area. In order to find the substances initially taken into the atmosphere, an investigation to the chemical constitute of aerosols in littoral and sub-Antarctic area should be carried out first. When air or precipitation sampling was proceeded on sea level, however, the samples

were always dominated by sea droplet which brought some difficulties about interpreting the aerosols in the atmosphere. The ice masses with snow deposited thus become ideal site for providing such samples.

The summit of main dome with an elevation of 679m a. s. l. on Collins Ice Cap, King George Island, Antarctica at $61^{\circ}53' - 62^{\circ}16'S$, $57^{\circ}34' - 59^{\circ}03'W$ (see Fig. 1) was selected as the sampling site for present study. During 1991 field season, a few of firn/ice cores with length of 40–50m were recovered there. The ice cores were packed in polyethylene sleeves and transported in low temperature condition below $-10^{\circ}C$ to the Institute for the Study of Earth Oceans and Space (EOS), University of New Hampshire U. S. A in Feb. 1992. The concentration of some soluble impurities were determined then in the laboratory of Glacier Research Group. The data on main anions and cations will be presented and analyzed

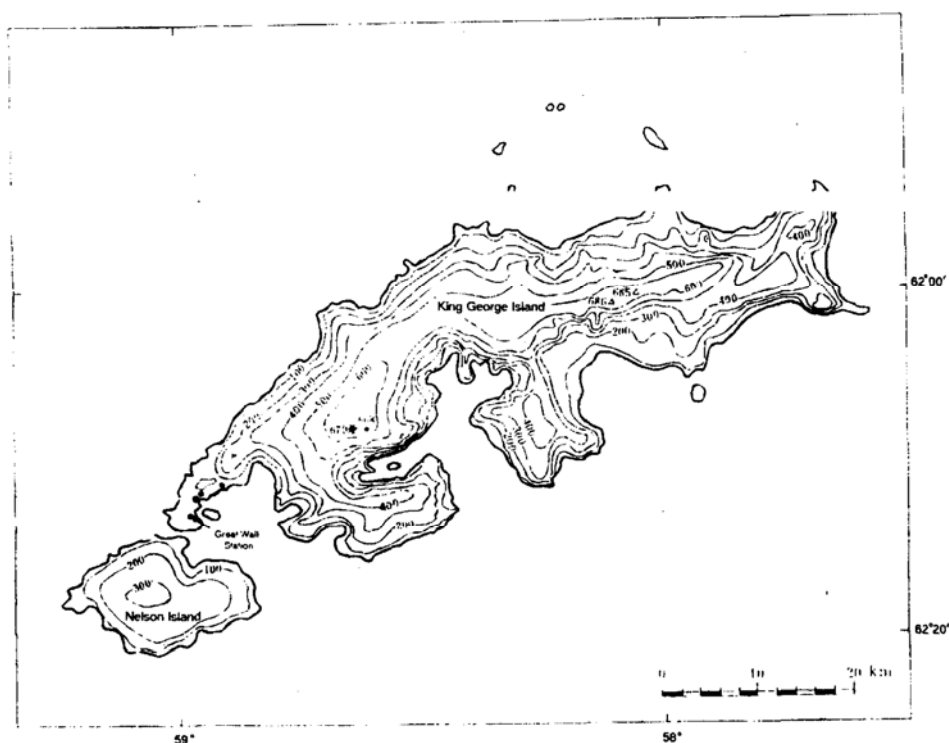


Fig. 1. Map showing the location of Collins Ice Cap and drilling site (denoted by *).

preliminarily in the present paper.

Sampling and Work Procedures

The concentration determination of soluble impurities in snow and ice of Collins Ice Cap was mainly carried out along a 45m core. The snow in surface 2.5m was too loose to be collected with complete cores, so it was sampled with snow block instead on the wall of a

snow pit. Considering the firn density increasing with depth and sample size for cross analyses, the sampling interval was chosen 20cm in thickness from 2.5 to 10m, 15cm from 10 to 20m, and about 10cm below 20m in depth. In this way more than 8 samples could be obtained generally for an annual layer. Measurements were conducted for anions of SO_4^{2-} , Cl^- , NO_3^- , Br^- and cations of K^+ , Na^+ , Ca^{2+} , Mg^{2+} , NH_4^+ by ion chromatography Dionex T^M Model 2010 (detailed working procedures refer to Mayewski *et al.*, 1986; Mayewski *et al.*, 1987). The variation of soluble impurity concentration against depth for the upper 10m of snow/firn was shown in Fig. 2.

Profile Features and Preliminary Analyses

The following features were shown on Fig. 2: 1) The concentration of Na^+ , Cl^- and SO_4^{2-} were very high, which were different in order of magnitude from others; 2) In spite of the above quantitative discrepancy, K^+ , Ca^{2+} , Mg^{2+} , Br^- concentration varied with exactly the same trend as that of Na^+ , Cl^- , SO_4^{2-} ; 3) NH_4^+ showed high values only at depths shallower than 2.5 m, below which it was fluctuated uniformly with lower concentration; 4) The NO_3^- concentration was rather low with maximum value less than 50ppb. Its general variation trend was in consistent with the seven ions even though some inconsistency existed, e. g. the slight shift of the highest peak around 8m in depth.

Na^+ , Cl^- and SO_4^{2-} are the main chemical constituents of sea water while K^+ , Ca^{2+} , Mg^{2+} important species of sea salt (O'Neill, 1985). The simultaneous variation in Fig. 2 indicated the consistency of their origination and similarity of deposit process. Of special interest is that the content of Br^- is too low to be detected usually in Antarctic snow and ice, but in our samples variation of Br^- was clear and definite, which suggested the contribution of sea salt (Br^- is also one of important ionic species of sea salt) to atmospheric aerosols. In order to demonstrate the sources of soluble impurities in snow of Collins Ice Cap further, the enrichment factor of each ion was calculated based on mean concentration for the 10m snow/firn and by taking Na^+ as reference element in association with sea water. The enrichment factor of element X was defined as:

$$EF(X) = (X/\text{Na})_{\text{snow and ice}} / (X/\text{Na})_{\text{sea water}}$$

Table 1. The calculation results (ppb) of $EF(X)$.

element(X)	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	Br^-
$(X/\text{Na})_{\text{snow and ice}}$	0.037	0.035	0.106	0.266	1.887	0.007
$(X/\text{Na})_{\text{sea water}}$	0.037	0.038	0.119	0.252	1.795	0.006
$EF(X)$	1	0.92	0.89	1.06	1.05	1.17

The sea water chemical constituents were quoted from Brewer (1975). The $EF(X)$ values listed in Tab. 1 were all approximated to 1, which suggested the atmospheric aerosols

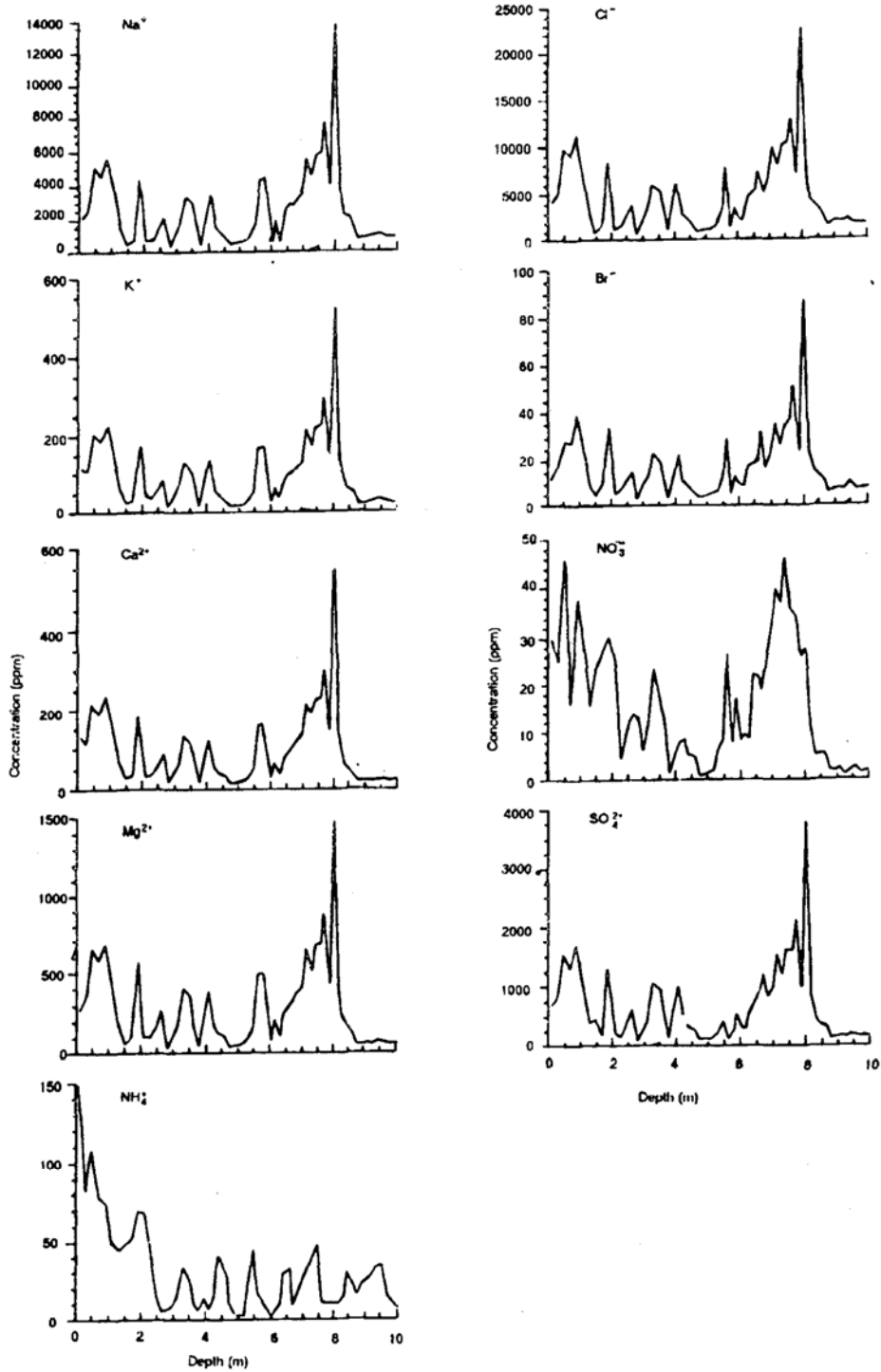


Fig. 2. The soluble impurity concentration against depth for the 10m snow/firn at the summit of main dome of Collins Ice Cap, King George Island, Antarctica.

over King George Island were mainly originated from sea salt. They went up to the sky, through a distance of transportation, and then incorporated into surface snow of the ice cap.

The variation shown on the NH_4^+ profile was associated with contamination of samples in the firn of upper 2.5m. As previously mentioned, the complete ice cores couldn't be obtained due to very loose surface snow, the block samples were collected in a snow pit. Although the samples were tightly sealed in the polyethylene plastic bags, they were still unavoidable to be contaminated by omnipresent gaseous ammonia in the process of several thousands kilometers of transportation by sea and by air. The similar phenomenon was also observed in the Byrd ice core (Palais and Legrand, 1985). Legrand *et al.* (1984) pointed out that it would increase the opportunities for chemical reactions between gaseous ammonia and enclosed impurities in ice as microfractures formed continuously along the ice core ultimately, resulting in the increase of ammonium concentration. The samples below 2.5m in depth of Collins Ice Cap core were collected through the procedure of regular sample preparation and measurement. Extra operation for decontamination were strictly obeyed (Mayewski *et al.*, 1986; Mayewski *et al.*, 1987). The contamination was decreased to the minimum and the NH_4^+ variation below 2.5m shown in Fig. 2, thereby, could be taken as the background ammonium concentration in the local atmospheric aerosols and reflected its deposition process in the surface snow of glacier.

Similar with NH_4^+ , the NO_3^- concentration variation on top 2.5m of the Collins core might be influenced greatly by the contact contamination of samples with nitric/nitrous oxide in the transportation. Throwing these data away, it was found that the NO_3^- concentration variation was well consistent with that of other seven ions as previously described. Some researchers thought that although nitrate was not an intrinsic production of marine, it could precipitated into the sea from sky, and incorporated into atmosphere aerosols through adhesion to the grains of sea salt (Gravenhorst *et al.*, 1979). This might be the reason causing similarity of its profile with others. But we also noticed that there did exist some difference. Herron (1982) proposed that the chemical reactions happened at the altitude between upper part of troposphere and lower part of stratosphere with NO_x ($\text{NO} + \text{NO}_2$), such as photochemical reactions in lightning, might consist the main source of NO_3^- . He drew a conclusion that the NO_3^- concentration maximum could occur in summer season in Antarctica. By comparison of NO_3^- concentration variation with the stratigraphic feature in our work, it was found that the peak values of NO_3^- concentration were not well corresponding to the melt phenomenon in summer layers, giving the evidence that the high values of NO_3^- must not be caused by summer lightning, but by the deposition of aerosols originated from sea salt. In addition, it was important to know that the lightning was seldom at high latitude. Even in mid-low latitude area where lightning frequently happened, the NO_3^- produced by photochemical reactions was scavenged out by comparing torrential rain usually and quickly. It was very difficult for it to be transported into polar regions (Qin *et*

al., 1992). According to an incomplete statistics there were more than 14 origins for NO_3^- production (Qin Dahe, personal communications), the lightning was only one of them. The similar features were also found in ice cores from James Ross Island near King George Island (Aristarain *et al.*, 1982). It showed clearly that the origin and deposition of NO_3^- in polar regions is really a far unsettled question (Huebert and Lazms, 1980).

Conclusion and Remarks

The measurements of soluble impurities in the surface 10m snow/firn of Collins Ice Cap revealed a direct relationship between snow chemical constituents and that of atmospheric aerosols. Although there are many nude rocks and weathering substances around the study area, the atmospheric aerosols are still dominantly originated from sea salt. The simultaneous variation in Na^+ , K^+ , Mg^{2+} , Ca^{2+} , SO_4^{2-} , Cl^- and Br^- concentration and very close EF value (≈ 1) suggested a common marine source of them and a similar deposition process before they incorporated into snow. Besides the possible surface contamination, NH_4^+ varied uniformly along the deeper part of the core in concentration, which could be considered as background value of ammonium. However, A satisfactory explanation for NO_3^- concentration variation could not be reached yet.

In summary, the atmospheric aerosol around King George Island, Antarctica were preliminary marine origin. They have not undergone significant chemical reactions before incorporated into snow.

Acknowledgements We thank prof. Zhu Guocai, Mr. Gao Xingsheng and Jing Xiaoping for their assistance during drilling operations and sample collections. The great support was provided by the Great Wall Station of China and Artigas Station of Uruguay in 1991/1992 field season. We are also indebted to Prof. Qin Dahe for valuable discussions, to Prof. Huang Maohuan for going over a manuscript and to Ms. Li Yufang for assisting in drawing. Mr. Zhang Wanchang made the translation of present paper.

References

- Aristarain, A. J., Delmas, R. J. and Briat, M. (1982): Snow chemistry on James Ross Island (Antarctica Peninsula). *Journal of Geophysical Research*, Vol. 87, No. C13, 11004–11012.
- Brewer, P. (1975): In: Riley and Skirrow (ed), *Chemical oceanography*, Vol. I.
- Gravenhorst, G., Muller, K. P. and Frauken, H. (1979): Inorganic nitrogen in marine aerosols, *Ges. Aerosol forschung*, 7, 182–187.
- Herron, M. M. (1982): Impurity sources of F, Cl^- , NO_3^- and SO_4^{2-} in Greenland and Antarctic precipitation. *J. Geophys. Res.*, Vol. 87, No. C4, 3052–3060.
- Huebert, B. J. and Lazms, A. L. (1980): Tropospheric gas-phase and particulate nitrate measurements. *J. Geophys. Res.* Vol. 85, No. C12, 7322–7328.
- Junge, C. E. (1977): Processes responsible for the trace content in precipitation, In: *Proceedings of the*

- Symposium "Isotopes and Impurities in Snow and Ice", UGGI, Grenoble, IAHS—AISH publ. ,118, 63—77.
- Legrand, M. , Angelis, M. de and Delmas, R. J. (1984): Ion Chromatographic determination of common ions at ultratrace levels in Antarctic snow and ice. *Annual chem. Anta.* ,54,1336—1339.
- Mayewski, P. A. *et al.* (1986): Sulfate and nitrate concentrations from a South Greenland ice core. *Science*, 233, 975—977.
- Mayewski, P. A. *et al.* (1987): Seasonal and spacial trend in South Geenland snow chemistry. *Atmos. Environ.* ,21 (4) 863—869.
- O'Neill, Peter (1985): Environmental chemistry, George Ailen and Unwin, 87—125.
- Palais, J. M. and Legrand, M. (1985): Soluble impurities in the Byrd Station ice core, Antarctica; their origin and sources. *Journal of Geophysical Research*, Vol. 90, No. C1, 1143—1154.
- Qin Dahe, Zeller, E. J. and Dreschhoff, G. A. M. (1992): The distribution of nitrate content in the surface snow of the Antarctic Ice Sheet along the route of 1990 International Trans-Antarctica Expedition, *Journal of Geophysical Research*, Vol. 97, No. A5, 6277—6284.