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Post-depositional modification of magnesium in the S25 core, near the coast in East Antarctica

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Abstract

Chemical data in an ice core obtained at site S25 (S25 core), near the coastal region on the Mizuho Plateau, East Antarctica, have been analyzed. Post-depositional migration of Mg^{2+} seemed to be detected below about 15m. There was found to be a high correlation between the Mg^{2+} and Na^+ concentrations at shallow depths, whereas there was a weaker correlation at greater depths.

1. Introduction

Ice core studies provide valuable information allowing investigators to reconstruct past atmospheric conditions, because polar snow and ice samples contain traces of atmospheric gases and aerosol constituents from the past. However, post-depositional changes of chemical constituents in snow complicate the interpretation (Wolff, 1995; 1996; Kreutz *et al.*, 1998; Mulvaney *et al.*, 1998). Several studies have discussed NO_3^- movement in snow. Nakamura *et al.* (2000) presents the mechanism of post-depositional loss of NO_3^- in snow samples from Dome Fuji. Recently, post-depositional movement of relatively stable chemical species has also been reported (Wolff, 1996).

In the present paper, we report seasonal variations of sea-salt and post-depositional modification of Mg^{2+} mainly derived from sea-salt in an ice core taken from a coastal site (a heavy snow-accumulation site) on the Mizuho Plateau, East Antarctica.

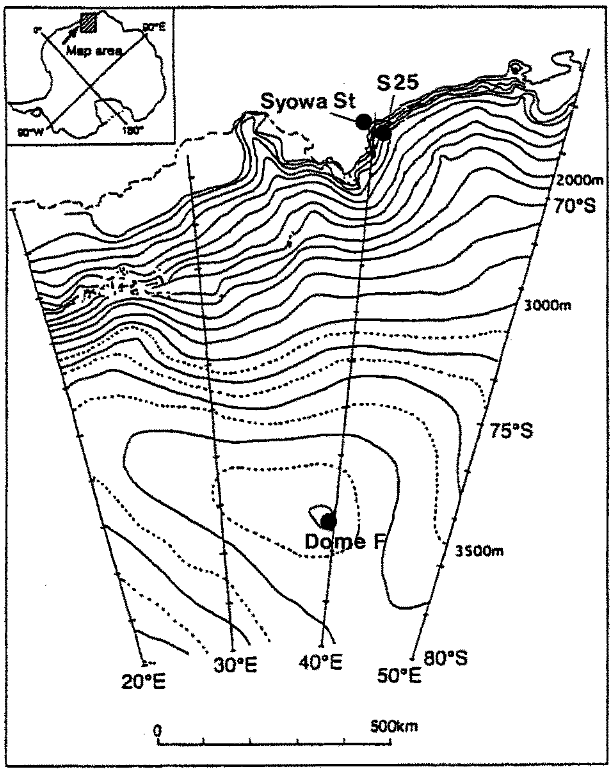

Fig. 1. Location of site S25.

2. Methods

The ice core was taken at site S25, located near the coast on the Mizuho Plateau (near Syowa Station), East Antarctica (69°01′58″S, 40°28′07″E, altitude 868m) (Fig. 1), by the 26 th Japanese Antarctic Research Expedition (JARE-26) in January 1986. The mean annual temperature is 257 K at site S25 and the annual accumulation rate is estimated to be near 30 cm a^{-1} water equivalent (Watanabe *et al.*, 2000). The S25 core has been stored in the low-temperature room (−20°C) of the National Institute of Polar Research (NIPR).

The ice core was cut in the low-temperature room, with the sampling interval being about 5cm. About 1cm of the ice core surface was removed in order to eliminate contaminants. After melting the cut ice, the concentrations of major ions in the resulting water samples were measured by means of an ion chromatograph (Dionex 2000i), equipped with a separate AS4A column, preceded by an AG4A guard column to quantify Cl^-, NO_3^- and SO_4^{2-}. In addition, the chromatograph had a separate CS2 column preceded by a CG2 guard column to quantify Na^+ and K^+, and had a CS3 column preceded by a CG3 guard column to quantify Mg^{2+} and Ca^{2+}. The eluent used was 2mM Na_2CO_3/1mM $NaHCO_3$ for Cl^-, NO_3^- and SO_4^{2-}, 20mM HCl for Na^+ and K^+, and 48mM HCl/8mM DAP for Mg^{2+} and Ca^{2+}, as described in detail by Fujii *et al.* (1989). The mean analytical error was within 5%. The methods of the S25 core analysis were also reported in Watanabe *et al.* (1998, 1999 and 2000).

3. Results and discussion

The concentrations of non-sea-salt SO_4^{2-} in the S25 core present strong seasonal variations (Watanabe *et al.*, 1999), as has been reported for many ice cores (Mosley-Thompson *et al.*, 1991; Langway *et al.*, 1994). Vertical profiles of the concentrations of Na^+ and $nssSO_4^{2-}$ from 20 m to 25 m depth are shown in Fig. 2. Seasonal variations of Na^+ in the S25 core show peaks both in the summer (high $nssSO_4^{2-}$) and winter (low $nssSO_4^{2-}$) in many layers. There is only one Na^+ peak (in winter) per year, for example, in the region from 22m to 23m depth and 24m to 25m depth, therefore, the Na^+ concentration profile does not appear to be an dating tool in the case of the S25 core. Peaks of sea-salt concentrations seem to occur during the winter months in Antarctic snow, especially inland regions (Legrand and Delmas, 1984). However, more than one peak of Na^+ per year is also observed (Kreutz *et al.*, 1999). Double peaks of Na^+ in snowdrift samples obtained on the Mizuho Plateau have been reported (Osada, 1994). Kanamori *et al.* (1997) performed measurements of chemical constituents in atmospheric aerosols at Syowa Station, and detected Na^+ peaks not only in the winter but also in the summer.

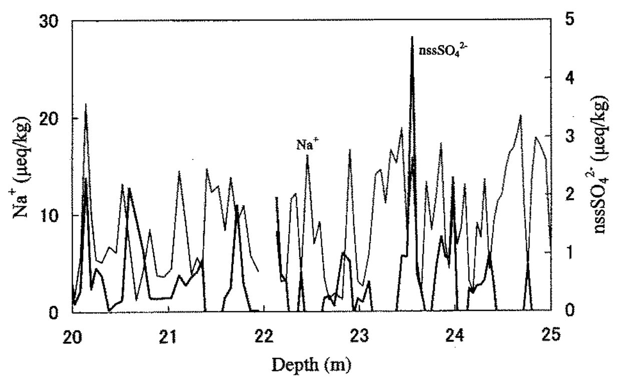

Fig. 2. Vertical profiles of the concentrations of Na^+ and $nssSO_4^{2-}$ from 20m to 25m depth in the S25 core.

Figure 3 shows vertical profiles of the Na^+ and Mg^{2+} concentrations in the S25 core. Na^+ and Mg^{2+} are well correlated, suggesting that Mg^{2+} at site S25 may be mainly derived from sea-salt aerosols. The mean ratio of Mg^{2+}/Na^+ in the core is 0.23, similar to the ratio in the case of seawater (Wilson, 1975; Keen *et al.*, 1986). Sea-salt cations such as Na^+ and Mg^{2+} are considered to be very highly conserved species, for example, reaction is impossible, and diffusion is considered to be very slow. However, Mg^{2+} migration relative to Na^+ seems to be found below 15 m depth (Fig. 3). The relationship between Na^+ concentrations and Mg^{2+} concentrations in the top 15m (left panel) and that below 15m (right panel) are shown in Fig. 4. There was found to be a high correlation between the Mg^{2+} and Na^+ concentrations at shallow depths (left panel of Fig. 4), whereas there was a weaker correlation at greater depths (right panel of Fig. 4). Origins of Mg^{2+} in polar snow are not only sea-salt but also continental dust (Slater *et al.*, 2001). Vertical profiles of the concentrations of Mg^{2+} and non-sea-salt Ca^{2+} ($nssCa^{2+}$), a good indicator of continental origin, are shown in Fig. 5. The peaks of $nssCa^{2+}$ hardly coincided with Mg^{2+} peaks below 15m depth. The result shows that the Mg^{2+} in the layers where Na^+ peaks are not found, may not be derived from continental dust, and supports Mg^{2+} migration.

Post-depositional migration of Mg^{2+} has also been reported in the case of the Dolleman Island core and the Siple Dome core (Wolff, 1996; Kreutz *et al.*, 1998). Wolff (1996) reported that Mg^{2+} forms two peaks on either side of a trough that coincides with a Na^+ peak below about 10m in the Dolleman Island core. The two peaks forming occurs at near 20m depth in the S25 core, whereas Mg^{2+} smoothing is seen below 20m in the S25 core (Fig. 3). According to Kreutz *et al.* (1998), there was no apparent reduction in Mg^{2+} peak amplitude and the peaks retained a sharp character throughout all 24m of the snow and ice samples in the case of the Siple Dome core. Iizuka *et al.* (2000) analyzed snowpack samples from the dome of Austfonna ice cap, Svalbard, and reported that the ions were flushed out from the snowpack during the thaw. The ratio of Mg^{2+}/Na^+ in melting-experienced snowpack was much lower than that in non-melted snowpack. Mg^{2+} may be relatively easy to be flushed out. Although there are ice crust layers in the S25 core, no significant melting layers were observed above 30m depth (about 1cm melting layer was only detected at 10m depth). The migration of Mg^{2+} may not be due to the thaw.

Wolff (1996) suggested the hypothesis that there is a limited number of sites for cations, either within the grain or at the boundaries, and that as the grain grows and the surface area decreases, the number of sites may decrease. As sea-salt particles which initially present as discrete particles, slowly dissolve, Na^+ may preferentially occupy the external sites, whereas Mg^{2+} is driven away from the regions with high Na^+ or Cl^- concentrations towards the edges. The migration of Mg^{2+} evident near 20m depth in the S25 core (formation of two peaks) may be due to this mechanism, however, that below 20m depth may be caused by other processes.

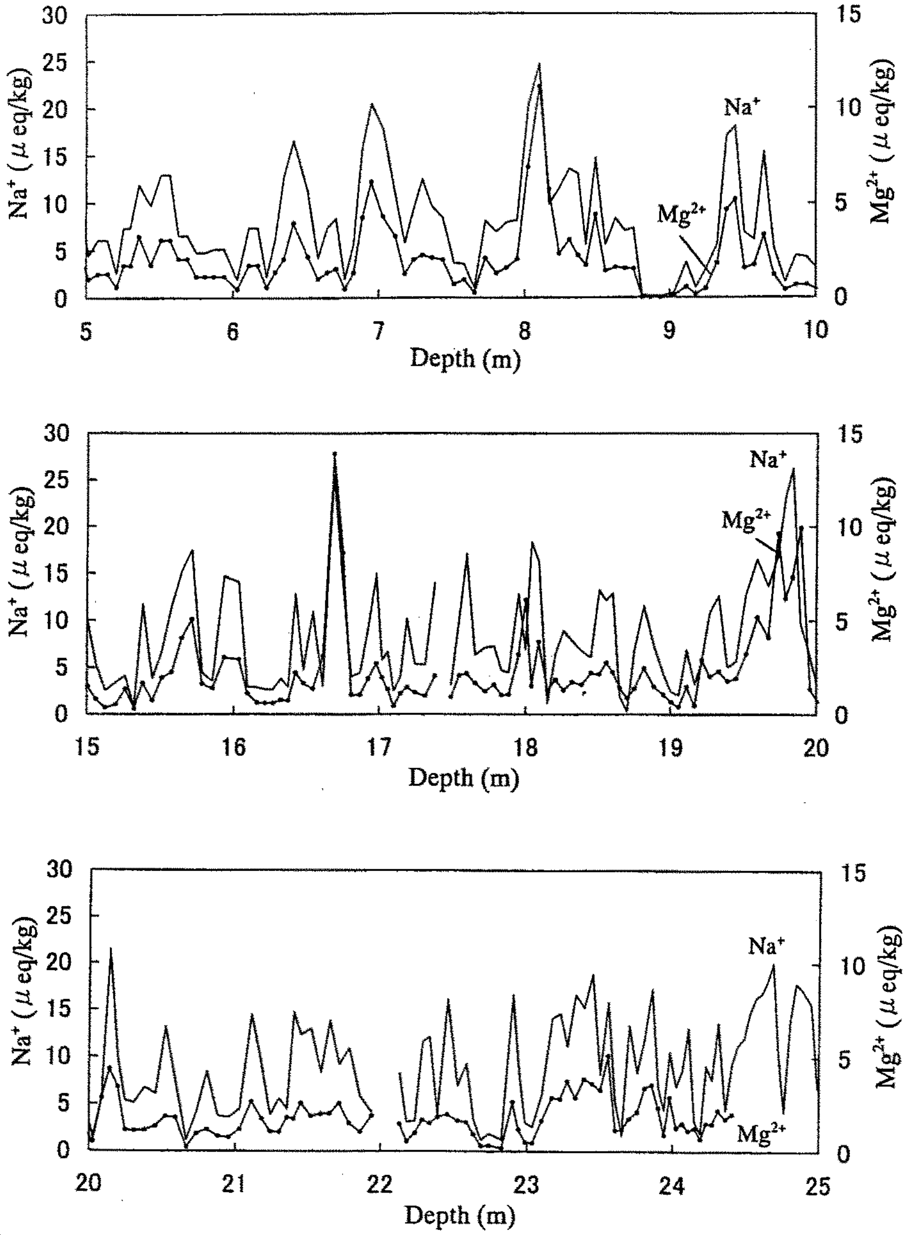

Fig. 3. Vertical profiles of the concentrations of Na^+ and Mg^{2+} from 5m to 10m depth (upper panel), 15m to 20m depth (middle panel) and 20m to 25m depth (lower panel) in the S25 core.

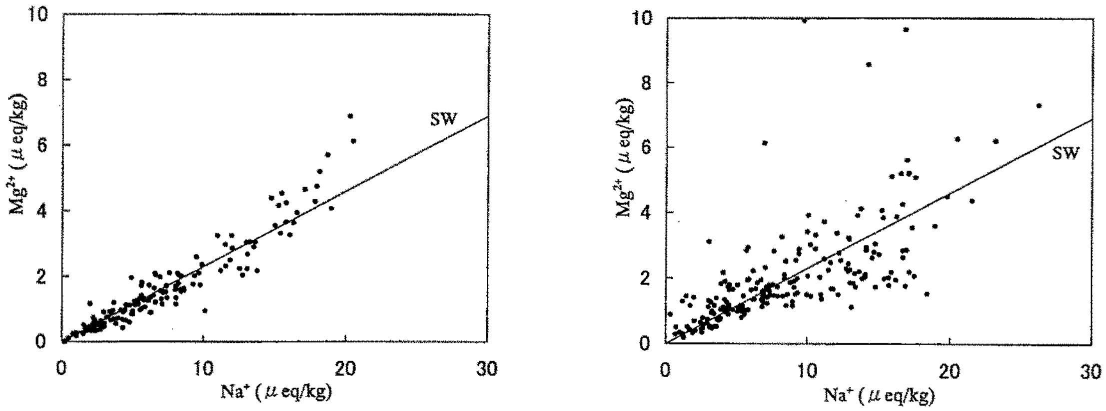

Fig. 4. Relationship between Na^+ concentrations and Mg^{2+} concentrations in the top of 15m (left panel) and below 15m (right panel) in the S25 core. SW indicates the ratio in the case of seawater.

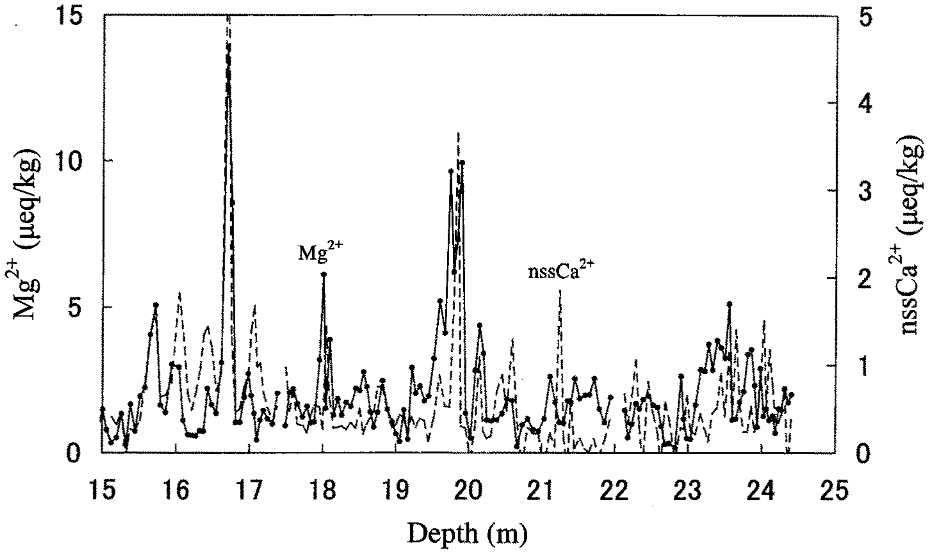

Fig. 5. Vertical profiles of the concentrations of Mg^{2+} and $nssCa^{2+}$ in the S25 core.

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