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Chemistry of the snow on Mt. Chanbai, China

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Abstract

Mt. Chanbai is the mountain that rises to the border of China and North Korea, and is located to the windward of Hokuriku and Tohoku district, Japan where a lot of snow falls under the winter monsoon condition. Snow samples were collected at three points of the north slope of Mt. Chanbai on the 12th of March, 1996. Snowfall is observed from 7th to 9th of March when snow clouds are associated with the cyclone. This new snow layer is distinguished clearly on the 12th of March at each point. Depth of snow cover at a high altitude site is more than that at a lower site. Amount of snowfall at a high altitude site is also more than that at a lower site. Lower layer at both higher sites has metamorphosed to depth hoar. SO_4^{2-} and NO_3^- are the major anions for all snow samples. Ca^{2+} and NH_4^+ are the major cations for all samples except one sample. Ca^{2+} and NH_4^+ neutralize the acidic ions ; i.e. SO_4^{2-} and NO_3^-, and pH of snow samples indicates not so low value. A mutual relationship between the $\delta^{18}O$ value of the surface layer and the altitude of sampling point is recognized.

1. Introduction

The seasonal wind i.e. the winter monsoon that blows from China and Siberia, plays an important role in the control of the weather of Japan in winter. Also, it is conceivable that acid substances are carried from China and Korea by the winter monsoon. Nevertheless, little research regarding the chemistry of snow on the windward side of the winter monsoon that blows to Japan has been reported. Mt. Chanbai (2,749 m) is the mountain that rises to the border of China and North Korea, and is located to the windward of Hokuriku and Tohoku district, Japan where a lot of snow falls under the winter monsoon condition. The aim of this paper is to describe the chemical characteristics of snow on the windward side of the winter monsoon that blows to Japan.

2. Experimental methods

Snow samples were collected at three points (A, B and C in Fig. 1) of the north slope of Mt. Chanbai, China on the 12th of March, 1996. At each point, a snow trench was dug through the snow cover to the ground surface. The wall facing north was made vertical and smooth, following which the snow stratigraphy was observed. Snow samples were taken from each layer with a clean plastic scoop. Each collected snow sample was filtered through a 0.45 micron pore size membrane filter. Conductivity and pH of filtered samples were measured with a conductivity meter and pH meter, respectively. The concentrations of major ions (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, F^-, Cl^-, NO_2^-, NO_3^-, SO_4^{2-}) were determined by ion chromatography (Dionex DX-500, 2020i/SP). The isotopic composition of oxygen-18 ($\delta^{18}O$) was determined by a mass spectrometer (Finnigan MAT : delta S) on CO_2 equilibrated with samples.

3. Results and discussion

3.1. Climatic condition

The Research Station of Chanbai Mountain Forest Ecosystems is established by the Chinese Academy

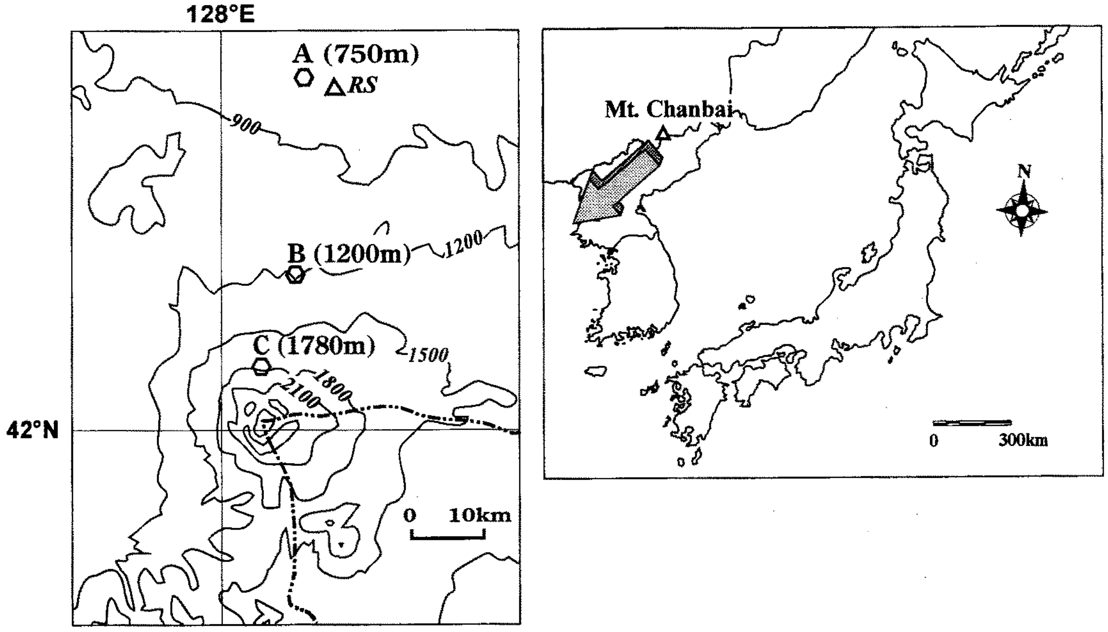

Fig. 1. Location of study site.
RS : Research Station of Chanbai Mountain Forest Ecosystems, Chinese Academy of Science.

of Science at the north slope of Mt. Chanbai (Fig. 1). There is a meteorological observation field, and air temperature, precipitation and snow depth are observed every day. Monthly mean air temperature (from 1990 to 1995), monthly precipitation and monthly maximum snow depth (from 1982 to 1995) at the Research Station of Chanbai Mountain Forest Ecosystems are shown in Fig. 2. As for these several years, there is not a remarkable difference in a seasonal change of a temperature. Minimum of the monthly mean air temperature is observed on January every year. Daily minimum air temperature usually reaches −20 ℃ or less. Maximum of the monthly mean air temperature is usually observed in July, and is about 20 ℃. Annual mean air temperature is 3.7 ℃ for this period. Annual peak of precipitation is recorded in summer. Mean monthly precipitation in July is 177 mm. Annual amount of precipitation is 739 mm. There is little precipitation in winter. Mean monthly precipitation in January is only 8 mm. However, monthly maximum depth of snow cover is 22 cm on February. The Research Station of Chanbai Mountain Forest Ecosystems is in a piedmont of Mt. Chanbai. At a higher altitude, it is expected that more snow falls and it is colder than the station in winter.

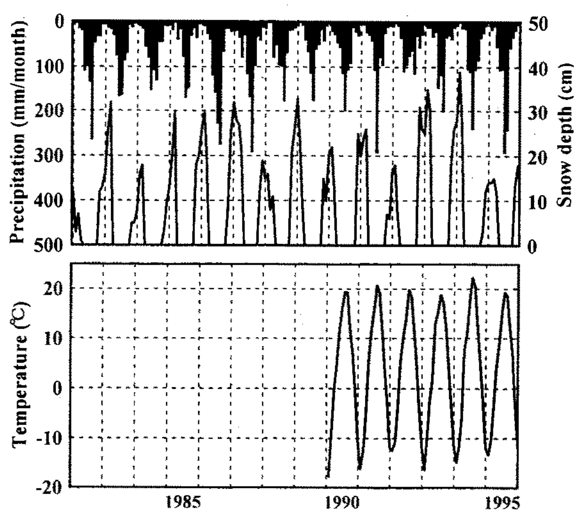

Fig. 2. Monthly mean air temperature, monthly precipitation and monthly maximum snow depth at the Research Station of Chanbai Mountain Forest Ecosystems.

Mt. Chanbai has a caldera on the summit, and the caldera has a prominent lake called Tian-chi. There is a meteorological station (2,623.5 m) near the Tian-chi. Annual amount of precipitation is 1,332.6 mm. Mean monthly precipitation in July and August is more than 300 mm. Mean amount of precipitation during a winter (from December to March) is only 81.5 mm. Mean monthly air temperature of coldest month (January) is −23.2 ℃.

3.2. Meteorological condition before sampling

Daily maximum and minimum air temperatures and daily precipitation from 1st to 14th of March, 1996 at the Research Station of Chanbai Mountain Forest Ecosystems are shown in Fig. 3. Snowfall is observed from 7th to 9th of March when snow clouds are associated with the cyclone. Total amount of precipitation for three days is 11.7 mm at the Research Station of Chanbai Mountain Forest Ecosystems. Daily maximum air temperatures from 8th to 11th of March are below 0 ℃, and this new snow layer is retained without snowmelt until 12th of March when snow layer is sampled. This snow layer is distinguished clearly on the 12th of March at each point.

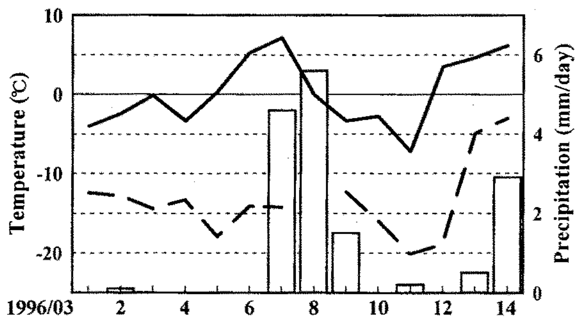

Fig. 3. Daily maximum- and minimum- air temperature and daily precipitation at the Research Station of Chanbai Mountain Forest Ecosystems.

3.3. Chemical property of sampled snow cover

The stratigraphy of snow cover at each sampling point is shown in Fig. 4. Chemical property of each snow layer is also shown in Fig. 4. Depth of snow cover at point-A, the lowest site, is only 13 cm. On the other hand, depth of snow cover at points-B and -C is 52 cm and 97 cm, respectively. It is clear that depth of snow cover at a high altitude site is more than that at a lower site. The upper snow layer is considered to have been accumulated from 7th to 9th of March at each point. Amount of snowfall during this period at a high altitude site is also more than that at a lower site. Stratification of snow cover at both point-B and -C is similar. Lower layers at both sites have metamorphosed to depth hoar and middle layers at both are compacted snow. Upper layers at both points-B and -C are new snow with lightly compacted snow which is accumulated from 7th to 9th of March. Points-B and -C are located at relatively high altitude and daily minimum air temperature at both sites is considered to be about −20 ℃ or less. And depth of snow cover at both sites is several tens centimeter, so temperature gradient in the snow cover becomes considerably steep. Snow cover has metamorphosed to depth hoar under these condition.

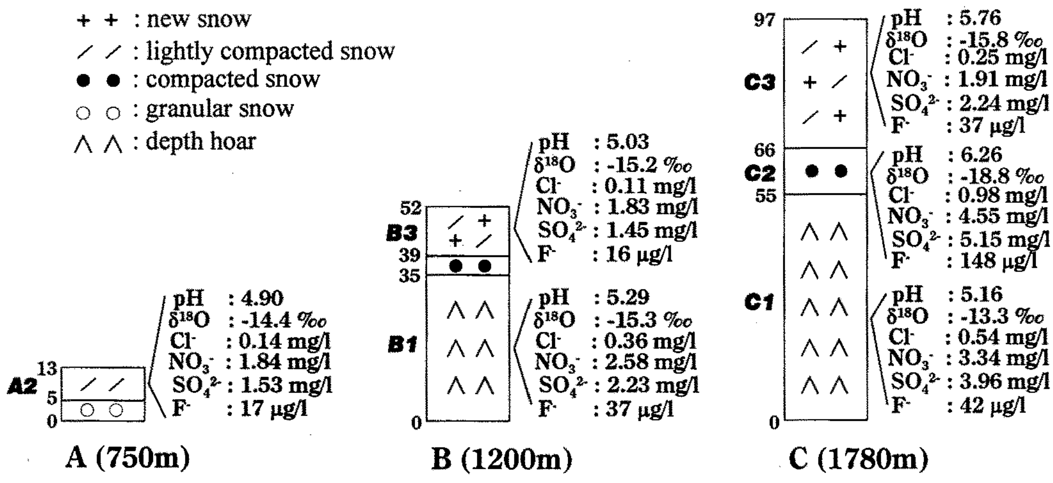

Fig. 4. Stratigraphy of snow cover at each sampling point and chemical property of each snow layer.

Figure 5 shows a relationship between the total concentration of cations and the total concentration of anions of each snow layer. Concentration of H^+ is calculated from pH value. Total concentration of anions which are analyzed indicate nearly equal to total concentration of cations for the all snow layers. There is a wide variation of the total concentration of cations of snow layers, ranging from 69.4 μeq/l at layer-A2 to 242.6 μeq/l at layer-C2. As shown in Fig. 5, new snow which accumulated from 7th to 9th of March has low concentrations of chemical constituents. On the other hand, old snow layers at point-C have relatively high concentrations of chemical constituents.

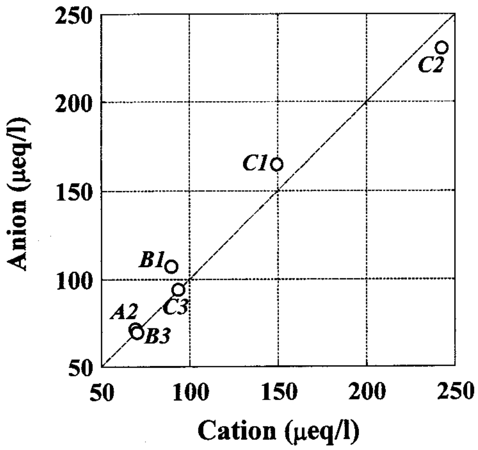

Fig. 5. The relationship between the total concentration of cations and the total concentration of anions of each snow layer. Symbles of each layer are shown in Fig. 4.

Ion concentration and ion balance for each snow layer is shown in Fig. 6. Concentration of H^+ is calculated from pH value. SO_4^{2-} and NO_3^- are the major anions for all samples. These anion balance is similar at Quebec, Canada (Suzuki *et al.*, 1993) where is situated at the east end of continent same as Mt. Chanbai. On the other hand, Cl^- is the major anion of snow at the Japan sea side area of Japan Islands (Suzuki, 1983 ; Suzuki and Endo, 1994). SO_4^{2-} and NO_3^- are the major anions of snow samples on Mt. Chanbai, nevertheless pH of snow indicate not so low value. Ca^{2+} and NH_4^+ are the major cations for all samples except sample of C2. Ca^{2+} and NH_4^+ which are scavenged by snow particles are considered to be originated from loess and fertilizer. These cations neutralize the acidic ions ; i.e. SO_4^{2-} and NO_3^-, and pH of snow indicates not so low value.

A relationship between the altitude of sampling site and the $\delta^{18}O$ value of each surface snow layer which is accumulated from 7th to 9th of March is shown Fig. 7. A mutual relationship between the $\delta^{18}O$ value of the surface layer and the altitude of sampling point is recognized. The condensation and freezing temperatures are important factors determining the $\delta^{18}O$ value of precipitation samples (Dansgaard, 1964). A good correlation is observed between the temperatures where the precipitation is formed and the $\delta^{18}O$ of winter precipitation (Suzuki and Endo, 1995). It is well known that the cyclone system firstly precipitates

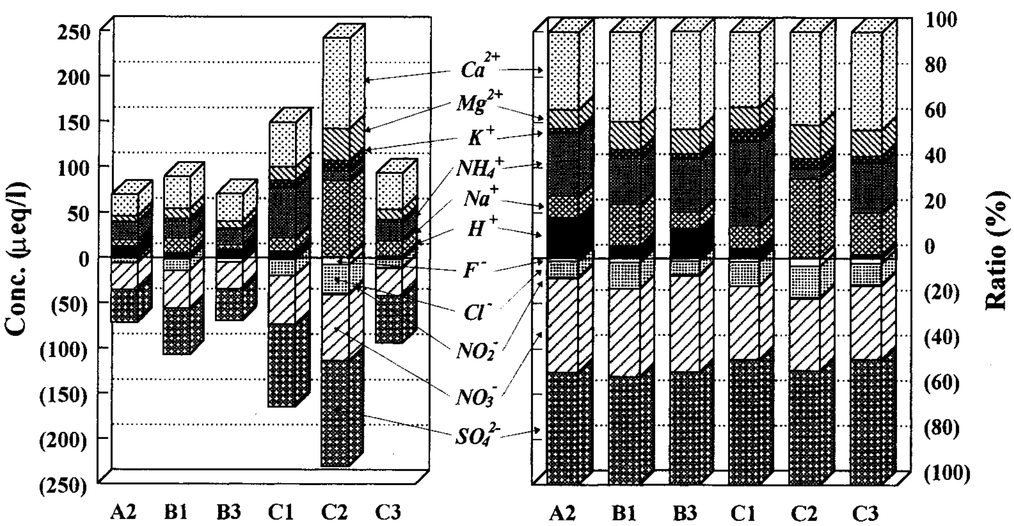

Fig. 6. Ion concentration and ion balance for each snow layer.

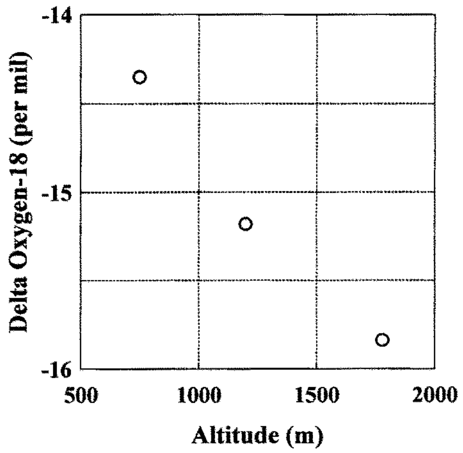

Fig. 7. The relationship between the altitude of sampling site and the $\delta^{18}O$ value of each surface snow layer.

heavy isotopic particles. North-westerly wind is observed during the accumulation of the surface layer. It is not clear why the relation shown in Fig. 7 is observed. However, the so-called "altitude effect of $\delta^{18}O$" is observed.

4. Conclusion

Snow samples were collected on the 12th of March, 1996 at three points of the north slope of Mt. Chanbai that rises to the border of China and North Korea, and is located to the windward of Hokuriku and Tohoku district, Japan where a lot of snow falls under the winter monsoon condition. Snowfall is observed from 7th to 9th of March when snow clouds are associated with the cyclone. This new snow layer is distinguished clearly on the 12th of March at each point. Depth of snow cover at a high altitude site is more than that at a lower site. Amount of snowfall at a high altitude site is also more than that at a lower site. Lower layer at both points-B and -C has metamorphosed to depth hoar. SO_4^{2-} and NO_3^- are the major anions for all snow samples. Ca^{2+} and NH_4^+ are the major cations for all samples except one sample. Ca^{2+} and NH_4^+ which are scavenged by snow particles are considered to be originated from loess and fertilizer. Ca^{2+} and NH_4^+ neutralize the acidic ions ; i.e. SO_4^{2-} and NO_3^-, and pH of snow samples indicates not so low value. A mutual relationship between the $\delta^{18}O$ value of the surface layer and the altitude of sampling point is recognized. The so-called "altitude effect of $\delta^{18}O$" is observed.

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