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Dating of an Ice Core from the Høghetta Ice Dome in Spitsbergen by ^{210}Pb Analysis

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Abstract

The ^{210}Pb dating method was applied to ice core samples which were collected from the top of an ice dome called Høghetta in northern Spitsbergen by the Japanese Arctic Glaciological Expedition 1987. The ^{210}Pb activity was found to decrease exponentially with depth from surface to about 10 m depth. The activity of ^{210}Pb below 10 m depth were nearly constant. The accumulation rate of the ice core, averaged over 10 m depth, was estimated as 18±4 cm-ice/yr. This value shows good agreement with the average accumulation rate obtained by different method.

1. Introduction

In 1987, the Japanese Arctic Glaciological Expedition (JAGE) made the successful ice core drilling at the top of the Høghetta ice dome (79°17'N, 16°50'E, 1200 m a.s.l.) in northern Spitsbergen (Watanabe and Fujii, 1988). They obtained complete ice core samples down to the bedrock at 85.61 m depth. *In-situ* measurement of pH and EC (Kamiyama *et al.*, 1989), observation of air bubbles (Kameda *et al.*, 1989) and sand particles (Fujii *et al.*, 1990) had already been performed and clarified about paleoenvironment of northen Spitsbergen. Fujii *et al.* (1990) also estimated an average accumulation rate of the ice sheet, 20 cm-ice/yr, from ^{3}H content in the surface 3 m of the core samples. However, it is not yet performed radiochemical dating about the samples. In this paper we present the results of the analysis of ^{210}Pb in the ice core from the Høghetta ice dome and determine its average acuumulation rate by using the ^{210}Pb dating method.

A natural radionuclide, ^{210}Pb (half-life 22.3 yrs) is a member of the ^{238}U series. The brief decay scheme after ^{226}Ra is cited together with the half-lives of daughter nuclides as follows :

$$^{226}\mathrm{Ra} \xrightarrow[1620\mathrm{yrs}]{} {}^{222}\mathrm{Rn} \xrightarrow[3.82\mathrm{days}]{} \text{short lived nuclides} \longrightarrow$$

$$^{210}\mathrm{Pb} \xrightarrow[22.3\mathrm{yrs}]{} {}^{210}\mathrm{Bi} \xrightarrow[5.01\mathrm{days}]{} {}^{210}\mathrm{Po} \xrightarrow[138\mathrm{days}]{} {}^{206}\mathrm{Pb(stable)}$$

Radon-222 which is produced by the decay of ^{226}Ra in soil migrates toward the earth's surface and escapes into the atmosphere. Then the ^{222}Rn decays out with a ralatively short lifetime and produces ^{210}Pb in the atmosphere. The ^{210}Pb and its daughter nuclides are isotopes of metals having low vapor pressures at room tenperature and, thus, exist as a solid form aerosols in the atmosphere. These aerosols containing ^{210}Pb are removed from the atmosphere by wet or dry deposition and deposit earth's surface includes the Høghetta ice dome in the Arctic region. The activity of the ^{210}Pb then decreases as a function of time at a rate controlled by its half-life. This phenomenon permits age determinations of snow and ice deposited within the 100 years or so (Crozaz *et al.*, 1964 ; Crozaz and Langway, 1966 ; Picciotto *et al.*, 1971).

2. Analytical method

The detailed sampling method have already been described elsewhere (Watanabe and Fujii, 1988 ; Fujii *et al.*, 1990). The ice core samples were transported to Japan and stored in a cold temperature room of the National Institute of Polar Research until analysis.

Thirteen samples were picked up from top to 65.

Table 1. Results of ^{210}Pb analysis in the ice core samples from the HØghetta ice dome, northern Spitsbergen

Sample	Depth (m)	Weight (kg)	Chemical yield (%)	^{210}Pb (dpm/kg)*
SV-1	0.00-0.20	1.13	86	6.62±0.14
SV-2	2.22-2.72	1.12	86	4.65±0.08
SV-3	5.17-5.56	0.87	82	4.30±0.11
SV-4	7.03-7.34	0.94	86	4.05±0.15
SV-5	9.88-10.32	1.20	84	3.29±0.07
SV-6	11.99-12.37	1.26	86	2.95±0.07
SV-7	14.97-15.30	0.90	83	3.36±0.10
SV-8	16.46-16.76	0.86	84	3.17±0.08
SV-9	19.72-20.06	1.11	82	3.21±0.06
SV-10	35.90-36.40	0.94	81	3.35±0.28
SV-11	45.60-46.02	0.92	82	3.17±0.10
SV-12	54.59-55.20	1.00	87	2.85±0.09
SV-13	64.92-65.43	0.96	85	2.65±0.10

* The error denotes 1 σ value derived from the counting statistics.

4 m depth of the core and removed contamination during the drilling by cutting the outer 0.5 cm of each block. The depth and weight of each samples are shown in Table 1. We have measured the ^{210}Pb through α-activity of ^{210}Po. The method described here is similar to that of Harada and Tsunogai (1985) but includes minor modifications.

The sample was melted in a glass beaker by using microwave oven and acidified with 20 ml of conc. HNO_3. Then 10 mg of Pb, as a $Pb(CH_3COO)_2 \cdot 3H_2O$ solution, and 1.5 g of $CaCl_2$ carriers were added to the sample solution, and it was stirred vigorously. After 6 hours or more, Pb and Po were coprecipitated with $CaCO_3$ by adding 25 ml of conc. NH_4OH and 2.5 g of Na_2CO_3 dissolved in water, and stood overnight.

The precipitate was filtered and dissolved with 0.5 M HCl. The solution was transferred into a 100-ml Teflon beaker with 1 ml of 20% $NH_2OH \cdot HCl$ and the initial ^{210}Po in the sample was removed by electroplating onto the silver disc at 80 °C for more than 3 hours. The remaining solution was diluted to exactly 50 ml of 2 M HCl solution. Chemical yield of Pb was determined from 1 ml aliquot of this solution by the atomic absorption spectrophotometry. Then an approximately 10 dpm of ^{209}Po tracer was added to the solution and stored for more than 3 months.

Polonium-210 produced from ^{210}Pb during storage and ^{209}Po from tracer were electroplated onto silver disc by the procedure described above. The α-activities emitted from each nuclides were measured more than 1000 counts by a α spectrometer consisting of silicon surface-barrier detectors and a multichannel pulse-height analyzer. Reagent blank was measured by the same procedure as the sample and subtracted from the activity of the sample. The concentration of ^{210}Pb was calculated from the $^{210}Po/^{209}Po$ activity ratio.

3. Results and discussion

The concentrations of ^{210}Pb (dpm/kg) in the ice core samples and the chemical yield of Pb are shown in Table 1. The error denotes 1σ value derived from the counting statistics. The concentrations measured have been taken to represent the middle of the depth interval covered by each sample.

The concentration of ^{210}Pb at the top of the ice core was 6.62±0.14 dpm/kg. This value decreases with depth to 3.29±0.07 dpm/kg at the fifth layer (9.88-10.32 m). The average concentration from 0 m to 12.37 m was calculated to be 4.31±0.04 dpm/kg. This value is somewhat larger than the concentration of ^{210}Pb, 2.9±0.5 dpm/kg, at the top (0−12 m) of the ice core which was collected from the Camp Century, Greenland in 1961 (Crozaz and Langway, 1966). Although we cannot make clear this defference at the present, this may be due to the temporal and spatial variations of atmospheric deposition rates of ^{210}Pb and the defference of geographical feature between the two stations. The concentration of ^{210}Pb in rainwater at the United Kingdom varied from 1.4 to 9.3 dpm/kg (average 5.0 dpm/kg) (Burton and Stewart, 1960). Turekian *et al.* (1983) also reported that the concentration of ^{210}Pb in the total deposition at New Haven, USA was 1.8−17.1 dpm/kg (average 9.5 dpm/kg). The concentration of ^{210}Pb at the top of the core which obtained in this study lies in these range.

The concentrations of ^{210}Pb below 10 m depth

were nearly constant and the average concentration for 9 data under the fifth layer were 3.11 ± 0.04 dpm/kg. Although it is not possible to determine the source of these ^{210}Pb at the present, one possible explanation is the ^{210}Pb will be supported from its parent nuclide in the mineral particle which is contained in the ice core. At any rate, if we consider the average concentration, 3.11 ± 0.04 dpm/kg, is background value for ^{210}Pb in the ice core, the concentrations of ^{210}Pb which originates in atmosphere ($^{210}Pb_{unsupported}$) are calculated by subtracting this average from upper 4 data.

The time elapsed since deposition of a sample at a depth z below the surface can be calculated from its activity of $^{210}Pb_{unsupported}$, provided that the initial activity of this nuclide has remained constant :

$$A_z = A_0 \cdot e^{-\lambda t},$$

where

A_z : activity of $^{210}Pb_{unsupported}$ at depth z,
A_0 : activity of $^{210}Pb_{unsupported}$ at the surface ($z=0$),
λ : decay constant of ^{210}Pb ($3.11\times10^{-2}yr^{-1}$), and
t : age of the sample.

When the rate of annual water accumulation is constant such that $a=z/t$, where a is the annual rate of accumulation, then :

$$\ln A_z = -z\cdot\lambda/a + \ln A_0.$$

This is the equation of a straight line in coordinates of $\ln A_z$ and z whose slope is $-\lambda/a$ and whose intercept on the ordinate axis is $\ln A_0$. Thus the accumulation rate a can be calculated from the slope (Crozaz *et al.*, 1964 ; Crozaz and Langway, 1966 ; Picciotto *et al.*, 1971).

Plot of the natural logarithm of $^{210}Pb_{unsupported}$ activity in the samples versus depth are shown in Fig. 1. The straight line in the figure is obtained by the least-square method. As the correlation coefficient of this straight line is 0.90, we can consider the $^{210}Pb_{unsupported}$ decay exponentially with depth from surface to about 10 m depth. The average accumulation rate over 10 m depth, 18 ± 4 cm-ice/yr, is determined from the slope of this line, -0.17 ± 0.04. This accumulation rate well agrees with the value, 20 cm -ice/yr, which is estimated by ^{3}H content in the core samples (Fujii *et al.*, 1990).

The radiochemical approach by using ^{210}Pb is particularly useful to determine ice accumulation rates without personal interpretation. Detailed analysis of ^{210}Pb with sampling at short intervals of depth and over wide areas will provide us useful information for estimating paleoclimatic condition of the earth. Furthermore, if we measure other long-lived radioisotopes in ice core samples, average accumulation rate over long period will be available.

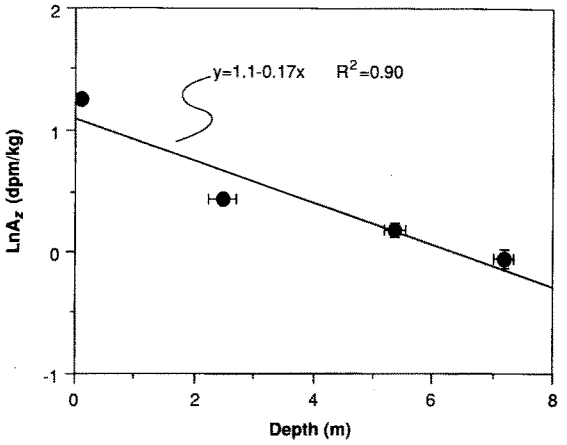

Fig. 1. Plot of the natural logarithm of $^{210}Pb_{unsupported}$ activity versus depth. The straight line in the figure is obtained by the least-square method. The horizontal bars and the vertical bars indicate the depth interval and the counting error, respectively.

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References

1. Burton, W.M. and Stewart, N.G. (1960) : Use of long-lived natural radioactivity as an atmospheric tracer. Nature, **186**, 584–589.
2. Crozaz, G. and Langway, C.C., Jr. (1966) : Dating Greenland firn-ice cores with Pb–210. Earth Planet. Sci. Lett., **1**, 194–196.
3. Crozaz, G., Picciotto, E. and De Breuck, W. (1964): Antarctic snow chronology with Pb^{210}. J. Geophys. Res., **69**, 2597–2604.
4. Fujii, Y., Kamiyama, K., Kawamura, T., Kameda, T., Izumi, K., Enomoto, H., Nakamura, T., Hagen, J.O., Gjessing, Y. and Watanabe, O. (1990): 6000-year climate records in an ice

core from the Høghetta ice dome in northern Spitsbergen. Annals of Glaciology, **14**, 85–89.

5. Harada, K. and Tsunogai, S. (1985) : A practical method for the simultaneous determination of ^{234}Th, ^{226}Ra, ^{210}Pb and ^{210}Po in seawater. J. Oceanogr. Soc. Japan, **41**, 98–104.
6. Kameda, T., Kawamura, T., Fujii, Y. and Enomoto, H. (1989) : Shapes and distribution of air bubbles in an ice core from Åsgårdfonna, Spitsbergen. Bull. Glacier Res., **7**, 221–226.
7. Kamiyama, K., Fujii, Y., Watanabe, O., Izumi, K., Satow, K., Kameda, T. and Kawamura, T. (1989) : *In-situ* measurements of electrical conductivity and pH in core samples from a glacier in Spitsbergen, Svalbard. J. Glaciol., **35**, 292–294.
8. Pocciotto, E., Crozaz, G. and De Breuck, W. (1971) : Accumulation on the South Pole-Queen Maud Land Traverse, 1964–1968. Antarctic Snow and Ice Studies II, ed. by A.P. Crary, Am. Geophys. Union, Washington, D.C., 257–315.
9. Turekian, K.K., Benninger, L.K. and Dion, E.P. (1983) : ^{7}Be and ^{210}Pb total deposition fluxes at New Haven, Connecticut and at Bermuda. J. Geophys. Res., **88**, 5411–5415.
10. Watanabe, O. and Fujii, Y. (1988) : Outlines of the Japanese Arctic Glaciological Expedition in 1987. Bull. Glacier Res., **6**, 47–50.