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Stratigraphy and ice grains of a 25.3 m ice core from Sofiyskiy Glacier, Russian Altai Mountains, in 2001

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Abstract

This paper focuses on results of visual stratigraphy and ice grain analysis of a 25.3 m ice core from Sofiyskiy Glacier, Russian Altai Mountains, recovered in July 2001. It was found that the ice core consists of firn, icy granular firn, ice layer, infiltration-recrystalization ice and infiltration ice. Infiltration ice consisted of thick ice layer with large ice grains of 5 to 10 mm and sparse air bubbles, and infiltration-recrystalization ice consisted of small ice grains of 1 to 2 mm. Volume percentages of the ice layer and infiltration ice are considered as an index of snow melting at the surface. It was also found that ice layer and infiltration ice are frequently observed at 7 m, 13.5 to 16 m, 18 to 19 m and 21.5 to 23.5 m in depths, suggesting warmer summers within several years when snow/ice at present depths was near the surface taking account of percolation of melt water.

1. Introduction

Glaciological investigation was carried out on the accumulation area of Sofiyskiy Glacier, Russian Altai Mountains during 15 - 24 July 2000 as a Japan-Russia joint research project. The purpose of this investigation was to reconstruct climate and environment records in the past through ice core study (Fujii *et al.*, 2002) since recent climate warming has been remarkable in Siberia (*e.g.* Chapman and Walsh, 1993; Weller, 1998) and Sofiyskiy Glacier is located on the southern fringe of the Siberian plain.

We obtained an ice core to a depth of 12.3 m and made a 3 m deep pit work in 2000 filed season and a 25.3 m ice core drilling and 4 m deep pit work in 2001 season. Analytical results of the 12.3 m core (stratigraphy, grain size and density), borehole temperature, stratigraphy for the 3 m deep pit, meteorological observations, stable isotope and chemical analyses of the 12.3 m core have already been published (Fujii *et al.*, 2000; Fujii *et al.*, 2002; Kameda *et al.*, 2003). This paper describes stratigraphy and ice grains of the 25.3 m ice core.

2. Coring site, ice core and analytical method

Figure 1 shows the location of Sofiyskiy Glacier. This glacier is located at South Chuiskiy Range, Russian Altai Mountains in the southern part of Altai Republic, Russian Federation. Figure 2 shows a map of camping site on Sofiyskiy Glacier. The GPS locations for GPS1 and GPS2 of the Fig. 2 are 49°47′40″N, 87°43′44″E and 49°47′41″N, 87°43′43″E, respectively. However, these sites corresponds to 49°47′10″N, 87°43′43″ and 3,450 m a.s.l. on the topographical map of this region published by ROSKATOGRAFIYA (1/200,000; 1996).

Ice cores were obtained by using a hand-auger in 2000 and 2001. The cores consisted of firn and ice. Visual stratigraphy was in situ recorded in a core processing trench, and thin sections of thickness 0.6 to 0.9 mm were made in situ for observations of ice grains.

3. Analytical results and discussions

Figure 3 shows typical photographs of firn, icy

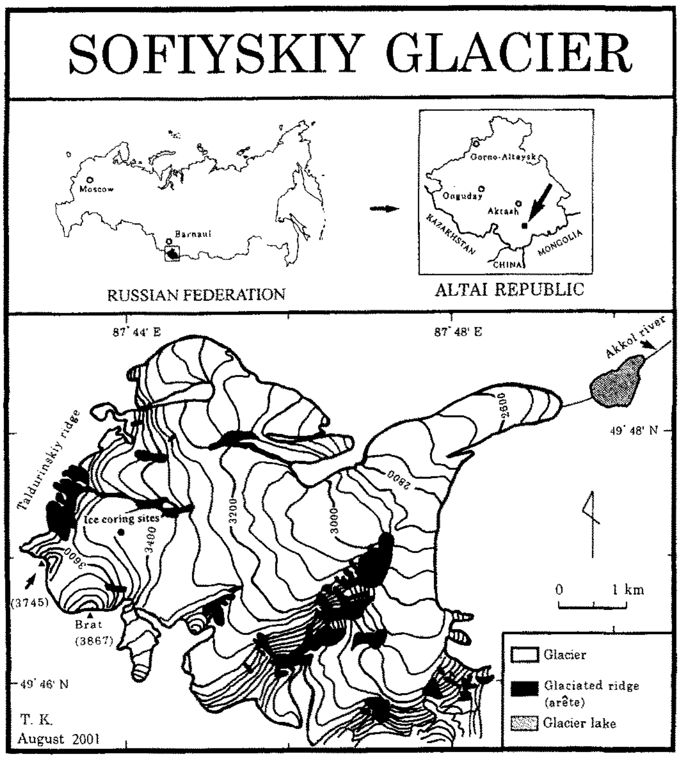

Fig. 1. The location of the ice coring site (solid circle) on Sofiyskiy Glacier.

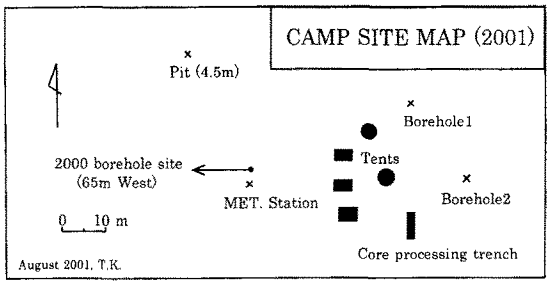

Fig. 2. Camp site map on Sofiyskiy Glacier.

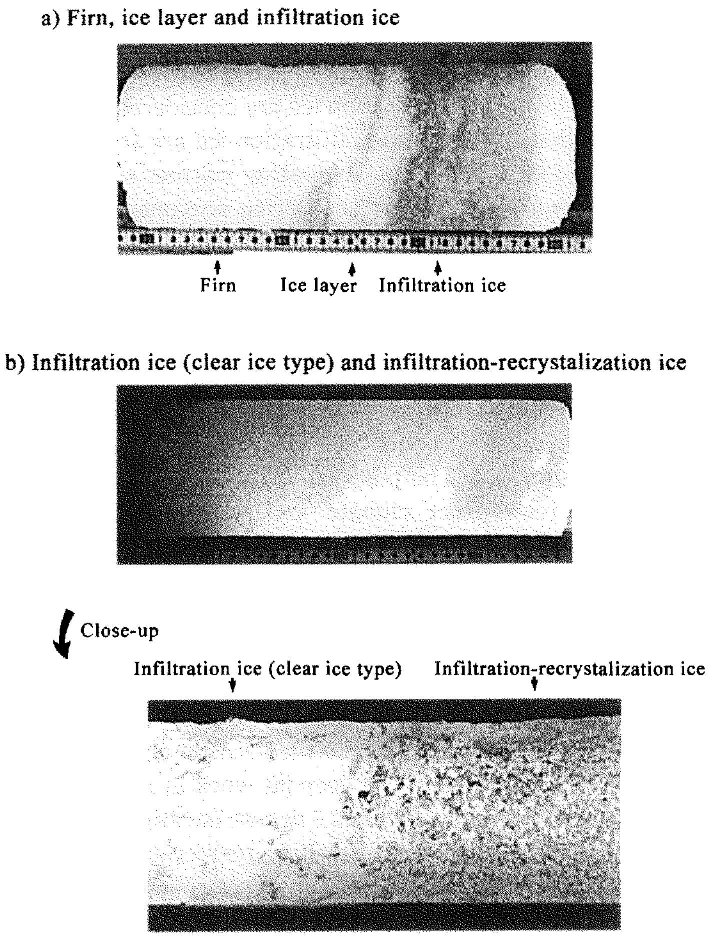

Fig. 3. Photos of core samples showing a) firn, ice layer and infiltration ice and b) infiltration ice and infiltration-recrystalization ice.

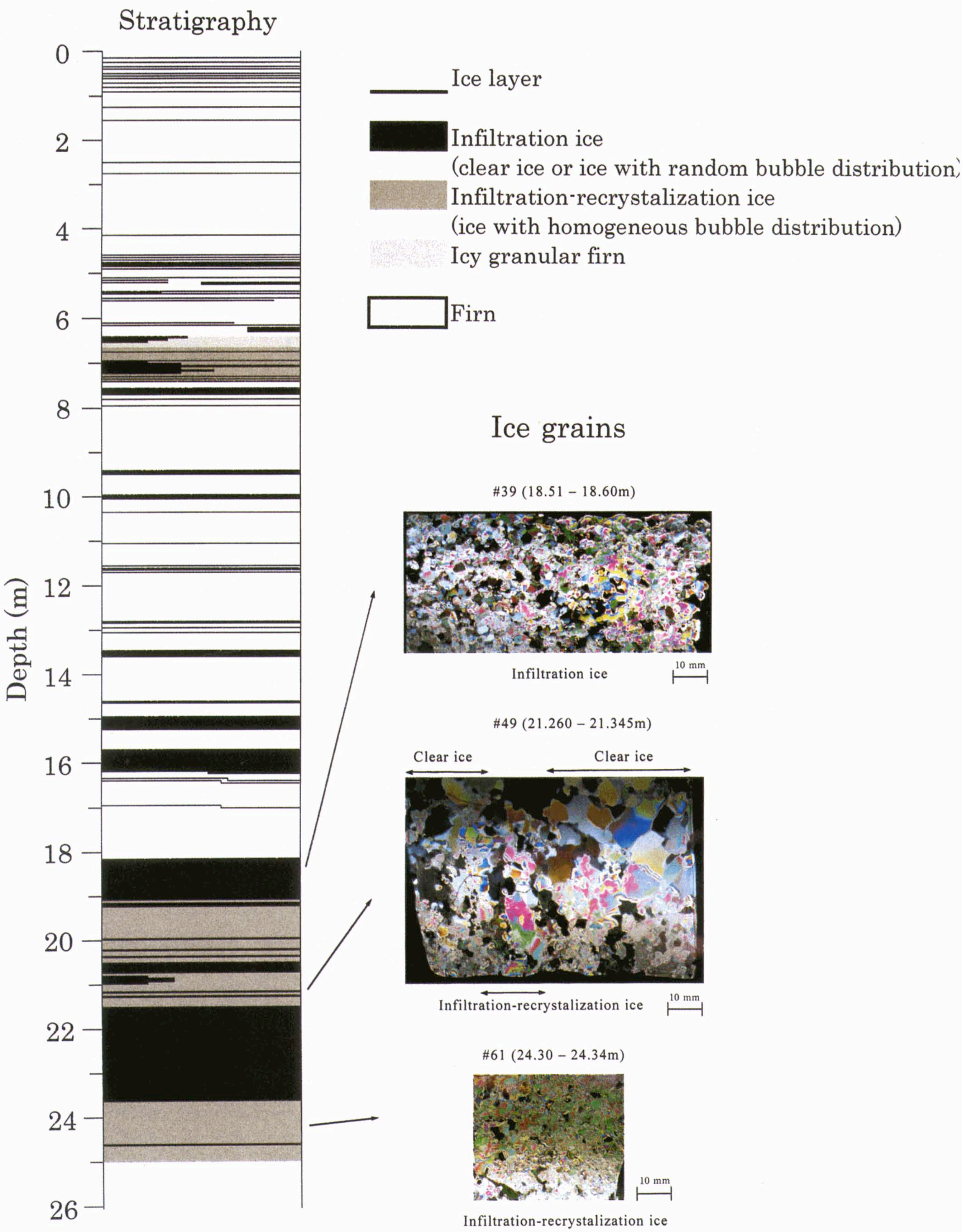

Fig. 4. Stratigraphy of the 25.3 m ice core and the cross-polarized photos of thin section of infiltration ice and infiltration-recrystalization ice.

granular firn, ice layer, infiltration-recrystalization ice and infiltration ice. Icy granular firn refers to coarse and granular firn which contains ice. Ice layer refers to ice thinner than 10 mm. Infiltration-recrystalization ice refers to ice with large air bubbles, which are probably remnant of pore space in firn. Infiltration ice refers to clear ice or ice with sparse air bubbles. Terminology for infiltration-recrystalization ice and infiltration ice come from Shumskii (1964).

Figure 4 shows stratigraphy of the 25.3 m ice core and the cross-polarized photos of thin section of infiltration ice and infiltration-recrystalization ice. Firn with ice layers was observed from the surface to 6.5m in depth, infiltration-recrystalization ice and infiltration ice were found from 6.5 to 7.5 m in depth. Then firn with ice layers appeared again in the depths from 6.5 to 18 m. Infiltration ice is also observed between 15 and 16.5 m in depth. Infiltration-recrystalization ice and infiltration ice appeared from 18m to 25.3 m in depth and no firn layers were found in this depth range.

Crystal size of infiltration ice (ice with sparse air bubbles) at 18.51-18.60 m and 21.265-21.345 m in depth ranges from 2 to 4 mm and from 5 to 10 mm, respectively as shown in Fig. 4. On the other hand, crystal size of infiltration-recrystalization ice at 24.30-24.34 m in depth is rather small as 1 to 2 mm as shown in Fig. 4. It is, therefore, clear that infiltration ice has the larger crystal size than infiltration-recrystalization ice, because infiltration-recrystalization ice was formed under less melt water condition and grain growth was slow comparing with the case of infiltration ice (*e.g.* Tusima, 1978).

Thickness of ice layer and infiltration ice in ice cores were selected as an index of surface melting (melt features) because ice layer and infiltration ice are formed by refreezing of saturated water in snow grains and water is supplied by percolation of melt water at the snow surface. Figure 5 shows a volume percentage of melt features (*MFP*) at 1m-depth interval of the ice core. Ice percentage equation (Koerner, 1977; Kameda *et al.*, 1995) is used for the calculations:

$$MFP(\%) = 0.9S_i/(0.9S_i + \rho_f S_f) \times 100,$$

where S_i is the measured cross-sectional area of melt features, and S_f is the that of firn per 1m length, respectively. This equation corrects for the effect of depth on firn compaction. It is found from the figure that *MFP* shows peaks higher than 50% at 7-8, 15-16, 18-20, and 22-24 m in depth. These peaks may indicate warmer summers within several years when snow/ice at present depths was near the surface taking account of percolation of melt water.

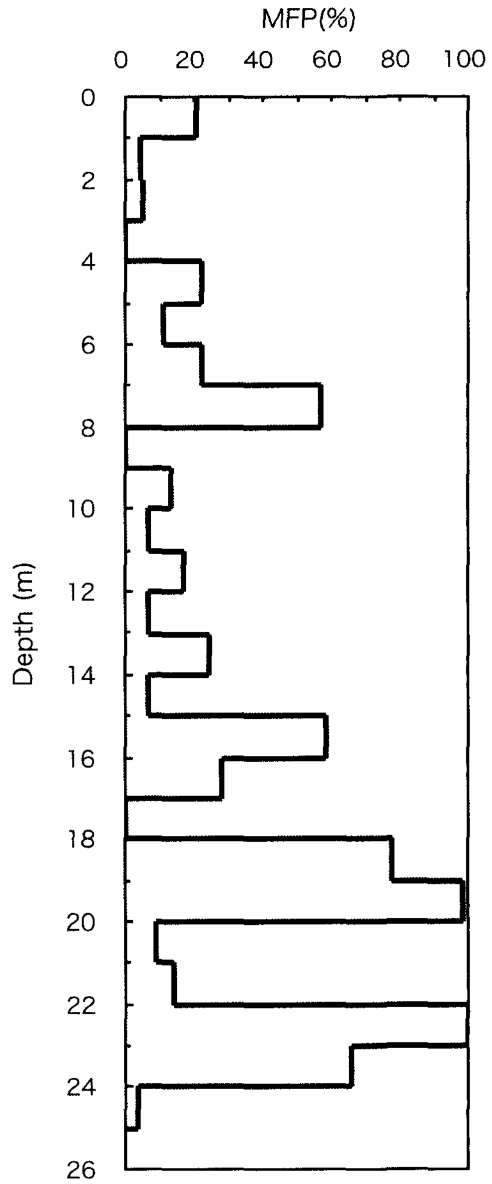

Fig. 5. Volume percentage for melt features (*MFP*) at 1m depth interval of the ice core.

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