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An overview of the Japanese glaciological studies on Mt. Logan, Yukon Territory, Canada in 2002

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Abstract

During the spring of 2002, we recovered a 220.52 m ice core and made relevant glaciological observations on Mt. Logan, Yukon Territory, Canada. This paper outlines the 2002 field studies and describes the core analyses that are planned. Meteorological measurements and stratigraphy of the core and a pit at King Col, the drill site, indicated very little summer melting at King Col. The annual snow accumulation rate at King Col between May 2001 and May 2002 was 0.6 m w. e., which is only a third to a half of that for the previous year.

1. Introduction

The Arctic is a key region being studied to gain a better understanding of global change. To define the spatial and temporal variability of climatic and environmental changes across the entire Arctic, the Ice-Core Circum-Arctic Paleoclimate Program (ICAPP) was initiated under the International Arctic Committee (IASC) and Past Global Changes (PAGES) of the International Geosphere-Biosphere Programme (IGBP). Since the inception of ICAPP, several new ice cores have been retrieved from sites having little ice-core data (*e.g.* Fisher *et al.*, 1998; Grumet *et al.*, 2001; O'Dwyer *et al.*, 2000; Watanabe *et al.*, 2001; Goto-Azuma *et al.*, 2002; Yalcin and Wake, 2001). However, most past ice-core sites have been in the North Atlantic sector of the Arctic. Ice core records from North-West Col on Mt. Logan (Holdsworth *et al.*, 1988; 1992, Moore *et al.*, 2001) and Eclipse Icefield (Yalcin and Wake, 2001) in the Yukon Territory, Canada have been the only ice core proxy data from the western North American Arctic. Due to the large elevation difference between the two sites (former and latter being 5340 and 3017 m a.s.l., respectively), they are distinct records despite their proximity.

To better understand altitudinal and temporal variability of climatic and environmental changes in the North Pacific sector of the Arctic, which is one ICAPP goal, the ice-core records from North-West Col and Eclipse Icefield need to be extended further back in time, and a core from an intermediate elevation needs to be retrieved. In 2001 and 2002, ice cores were drilled at Prospector-Russell Col (5340 m a.s.l.) on Mt. Logan by a Canadian team, at King Col (4135 m a.s.l.) on Mt. Logan by a Japanese team, and on Eclipse Icefield (3017 m a.s.l.) by an American team. Relevant glaciological and meteorological observations were also made during the 2000-2002 field seasons.

The objectives of ice-core drilling and field studies at King Col are to understand (1) decadal variations of climate in the North Atlantic sector of the Arctic, (2) history of anthropogenic air pollution and transportation pathways of the air-pollutants, and (3) flow dynamics of a cold mountain glacier. This paper presents an overview of the field studies done on Mt. Logan by the Japanese team in 2002, and ongoing analyses of the King Col core.

2. Fieldwork

2.1. Research activities

During the 2002 field season, the Japanese team did the following field studies on Mt. Logan, Yukon Territory, Canada (Fig. 1).

(1) Ice coring at King Col (KC) to a depth of 220.52 m with an electro-mechanical drill.

(2) Borehole temperature measurement at KC in the 220.52 m-deep hole.

(3) On-site stratigraphy observation and processing

of the 220.52 m core.

(4) Ice thickness measurement at KC by radar echo sounding.

(5) Surface topography survey at KC.

(6) Strain net measurement at KC.

(7) Snow stake measurement at KC.

(8) Meteorological observations at KC.

(9) Fresh snow sampling at KC.

(10) Snow pit studies including pit-wall sampling at KC and Quintino Sella (QS).

(11) Ice coring at KC and QS with a hand corer and borehole temperature measurements on the resulting boreholes.

(12) Measurements of body temperature, pulse rate and blood oxygen content at QS, King Trench (KT), and KC.

Most of the fieldwork was done at KC because the first priority of the 2002 field campaign was to drill an ice core there. A photograph of KC is presented by Shiraiwa *et al.* (2003, this issue). Dates of the major field studies are summarized in Table 1, and details of (1), (2), and (4)-(7) are reported by Shiraiwa *et al.* (2003, this issue).

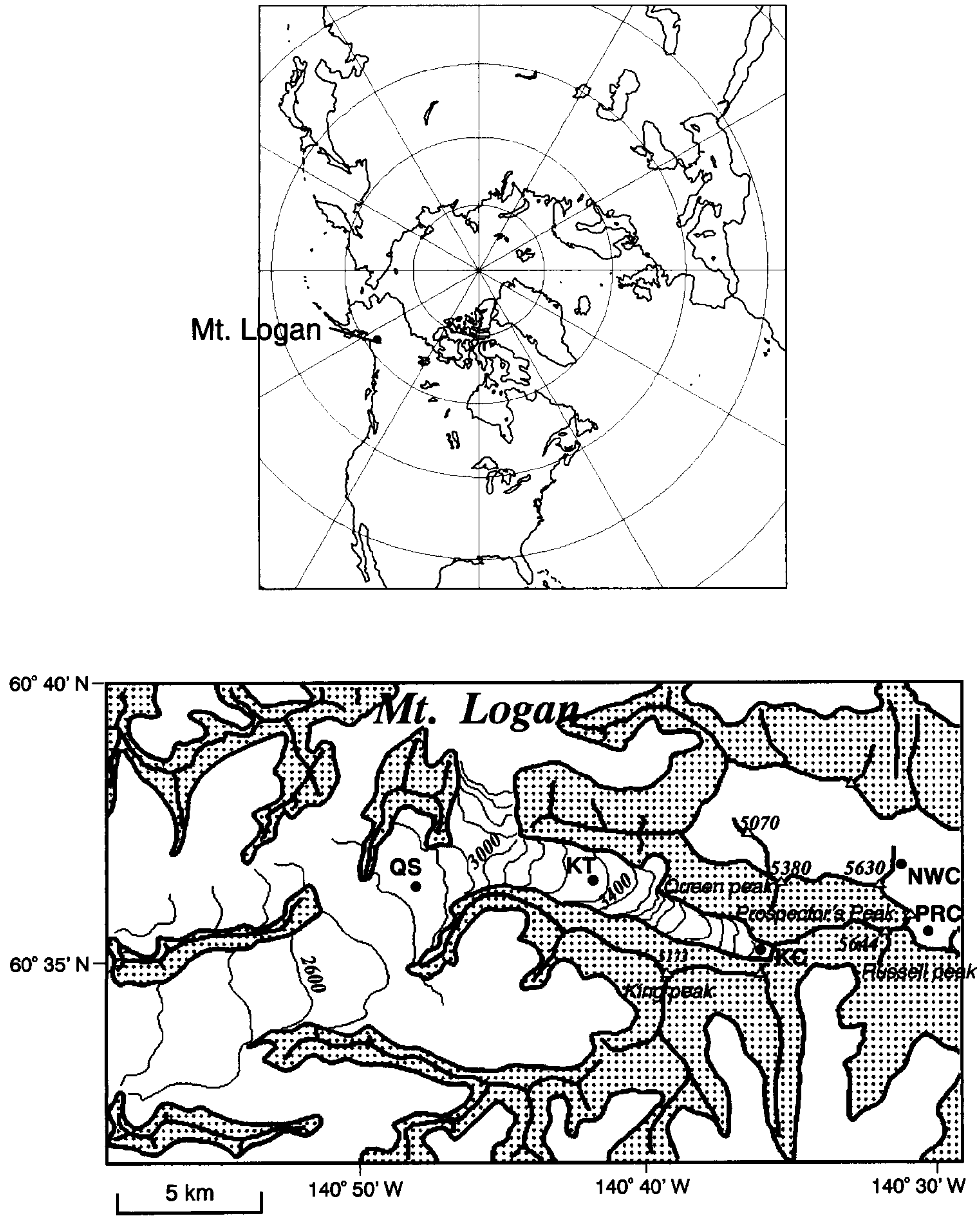

Fig. 1. Map of the field study sites. (a) Location of Mt. Logan. (b) Study sites on Mt. Logan. QS: Quintino Sella (2800 m) KT: King Trench (3300m) KC: King Col (4135m) PRC: Prospector-Russell Col (5340m) NWC: North-West Col (5340m)

Table 1. Dates of field studies and logistics in 2002

Date \ Site	QS	MP	KT	KC
4/26-4/27	Personnel and equipment flown to QS			
4/29	Pit studies Hand coring (8.69m)			
4/30				Made a cache with UTO
5/1-5/4	Skied back and forth for acclimatization			
5/5	On skis			
5/8				Flown by TNH
5/9-5/10				Set up camp Rader echo sounding
5/11-5/12				Preparation for ice coring & ice core processing
5/13-5/23				Ice core processing
5/13-5/30				Ice coring (220.52m) Fresh snow sampling
5/23-5/30				Pit studies Hand coring (9.4m)
5/30-5/31				Borehole temp. measurement
5/11-6/1				Meteorological and snow stake obsevations
6/3				2 persons & 1/2 cores flown to Chitina by UTO
6/4				Surface topography survey
6/5				Radar echo sounding
6/9		2 persons flown by TNH		
6/10	Pit studies			
6/12		2 persons flown by TNH 1/2 cores & gear flown by TNH		
	4 persons, 1/2 cores & gear flown from QS to Kluane Lake (TNH & Aklak Inc.)			

MP : Mid-point between QS and KT
UTO : Ultima Thule Outfitters
TNH : Trans North Helicopters
Solid and dotted arrows show movement of personnel and cargo, respectively.

2.2. Members

The Japanese members of the 2002 field campaign are as follows.

Kumiko Goto-Azuma (National Institute of Polar Research): leader and glaciologist
Takayuki Shiraiwa (Institute of Low Temperature Science, Hokkaido University): chief driller and glaciologist
Sumito Matoba (National Institute of Polar Research): chemist
Takahiro Segawa (Tokyo Institute of Technology): biologist
Syosaku Kanamori (Institute of Low Temperature Science, Hokkaido University): glaciologist
Tetsuhide Yamasaki (Avangnaq): driller

2.3. Logistics

The easiest access to Mt. Logan is to fly to QS. We have chartered a turbo-charged Single Otter plane from the Alaskan aircraft operator Ultima Thule Outfitters, and flew in the personnel and equipment from Chitina, Alaska to QS. The personnel then skied from QS to KT for acclimatization, and most of the equipment was flown to KC on the Single Otter plane. The dates of our logistic operations on Mt. Logan are summarized in Table 1.

We had originally planned to use the Alaskan Single Otter for our entire aircraft mission. However, due to a cross-border flying problem that arose after we flew out half of the ice cores and two persons to Chitina, we could not use the Alaskan operator any longer to pull out the camp and to fly out the rest of the ice cores and members. So we had to use Canadian aircraft operators to fly us to Kluane Lake, Yukon Territory instead of Chitina. We chartered a Bell Jet Ranger 206 helicopter from Trans North Helicopters for flying between KC and QS, and a Twin Otter plane from Aklak Inc. for flying between QS and Kluane Lake.

Although the cross-border flying problem complicated our logistics substantially, all ice cores safely arrived in Japan. The ice cores flown to Chitina were shipped to Anchorage, Alaska by a freezer truck and then directly flown to Japan. The rest of the cores flown to Kluane Lake were shipped to Vancouver, Canada via Whitehorse, Yukon Territory by freezer trucks and then sent to Japan by a boat equipped with a freezer container. When we checked all of the cores in a freezer facility in Japan, we did not find any evidence of melting during transportation.

2.4. Meteorological observations and snow pit studies

We made meteorological observations from May 11 through June 1, 2002 at KC. Weather, cloud amount, cloud type, and visibility were recorded. Air temperature was measured with a thermister, and wind speed and direction were measured with an anemometer installed on a tripod. All meteorological observations were made both in the morning and in the evening. Results are shown in Table 2. Air temperature and wind speed are plotted in Fig. 2.

KC was frequently covered with clouds or fog, which delayed our aircraft mission. Wind speed at KC was usually below 5 m s^{-1}. During our one-month stay at KC, there was only one major windstorm. It started in the morning of May 20, lasted until the early evening, and bent a few poles of the drill tent. It also scoured the new snow that deposited during May 13-17; snow depths measured with snow stakes decreased by about 0.1 m (Shiraiwa *et al.*, 2003, this issue) and it formed sastrugi 0.1–0.2 m high. Air temperatures in the morning and evening during May 11–June 1, 2002 at KC never reached the melting point. No snow melting was observed throughout the observation period, even during the day, although snow attached to plywood, tents etc. sometimes melted during the midday due to the strong solar radiation.

We did pit-studies at KC and QS. At KC, we dug six pits and collected pit-wall samples from two of the pits that were 1.8 and 2.7 m deep. The pit-wall samples will be analyzed for stable isotopes, ion chemistry, trace metals, and microbiology. The rest of the pits were 1-1.3 m deep and used for density and snow temperature measurements only. To investigate at QS the effects of snow melting on stable isotopes, ion chemistry and microbiology, we dug a pit and collected pit-wall samples before and during the major melt-season.

Figure 3 shows the visible stratigraphy of a 2.7 m-deep pit dug at KC on May 25–May 26, 2002. The top 0.585 m of the pit consisted of new snow and compacted snow, which were likely deposited during winter 2001/2002 and spring 2002. Between 0.585 and 0.935 m depths, we found a soft hoar layer and soft faceted-grained layers. This depth segment likely corresponds to the snow deposition in late summer/fall 2001. Below this depth and down to 1.09 m, we found hard granular snow layers, a relatively hard faceted-grained layer, and an ice layer 2 mm thick. The layers between 0.935 and 1.09 m are probably the major summer layers of 2001. A 10 mm thick ice layer, located further down at 1.21 m, was likely caused by refreezing of meltwater from the upper major summer layers. A distinct, brownish, dirt layer was at 1.54 -1.59 m of the KC pit. This layer likely contains dust blown from the Gobi Desert by a dust storm and arrived on Mt. Logan in late April 2001 (Zdanowicz, personal communication). Below the Gobi dust layer, the stratigraphy was mainly hard, wind-packed snow that presumably deposited in winter 2000/2001 and early spring 2001.

This Gobi dust layer was also observed in May 2001 near the snow surface at KC. Therefore, snow

Table 2. Results of meteorological observations at King Col in 2002.

Date & time	Weather	Cloud amount	Cloud type	Air temperature (°C)	Wind speed (m/s)	Wind direction	Visibility (km)
5/11 09:00	c	10	Ac	−18.9	1	E	3
5/11 21:00	s	10	Ac	−20.3	0		0.5
5/12 09:00	f	2	Ac1 As1	−22.1	0.8	ENE	10
5/12 21:00	f	1	Ac	−22.8	2.2	ESE	50
5/13 08:00	f	6	Ac	−20.9	2.6	ESE	50
5/13 20:00	s	10	Ac	−15.2	4.1	E	0.5
5/14 08:00	f	8	Ac	−16.9	0		50
5/14 20:00	s	10	Ac	−16.7	1.5	E	3
5/15 08:15	s	10	Ac	−22.8	4	ENE	5
5/15 20:00	s	10	Ac	−19.1	5	ENE	0.5
5/16 08:00	c b	10	Ac	−18.6	3.7	ESE	5
5/16 20:00	s	10	Ac	−13.3	2.6	ENE	0.5
5/17 08:00	c	9	Ci	−12.8	1	SE	50
5/17 20:00	g			−14.3	0		0.5
5/18 08:00	f	0	Ac	−16.7	4.9	NE	50
5/18 20:00	c	9	Ac	−14.6	6.7	W	50
5/19 08:00	f b	1	Ac	−13.7	7.1	ENE	50
5/19 20:00	f	1	Ac	−11.2	2.7	NNW	50
5/20 08:00	f	1	Ac	−8	0		50
5/20 20:10	f	0		−10.2	2	NNE	50
5/21 08:00	f	1		−13.7	2	SSW	50
5/21 20:00	f			−7	0.7	NE	50
5/22 08:00	f	8	Ac	−9.4		SE	50
5/22 20:12	s			−11.7	0.5	SSW	0.1
5/23 08:10	f	1	Ci	−11.6	4	SW	50
5/23 20:00	f	3		−9.1	0.6	SSE	50
5/24 08:00	f	3	Ac2 As1	−14.1	2	N	50
5/24 19:50	c	9	Ac	−8.5	0.9	SW	50
5/25 07:55	f	0		−13.1	1.1	WNW	50
5/25 20:00	f	0		−6.9	1.5	S	50
5/26 08:00	f	0		−13.3	1.5	ESE	50
5/26 20:00	f	1	Ac As	−7.3	1.8	SW	50
5/27 13:40	c	9	Ac As	−5.2	2.9	NNE	0.5
5/27 20:14	c	10		−9.8	2.9	NNE	10
5/28 08:00	s			−11.4		NE	0.05
5/29 08:00	s	10	Ac	−12.6		SE	5
5/29 20:00	s	10		−15.2	2.5	ENE	0.3
5/30 08:00	s	9	As	−18.3	3.8	ENE	1
5/30 21:00	f	4	Ac	−16.8	2.1	SW	50
5/31 07:55	f	1	Ac	−20.5	1.3	SSW	50
5/31 21:00	f	8	Ac	−14.1	0.9	ENE	1
6/ 1 08:10	c	9	Ac	−17.7	2.8	E	0.5

c : cloudy
s : snowing
f : fine (cloud amout 0–8)
b : blowing snow
g : foggy

Ac : Altocumulus
Ci : Cirrus
As : Altostratus

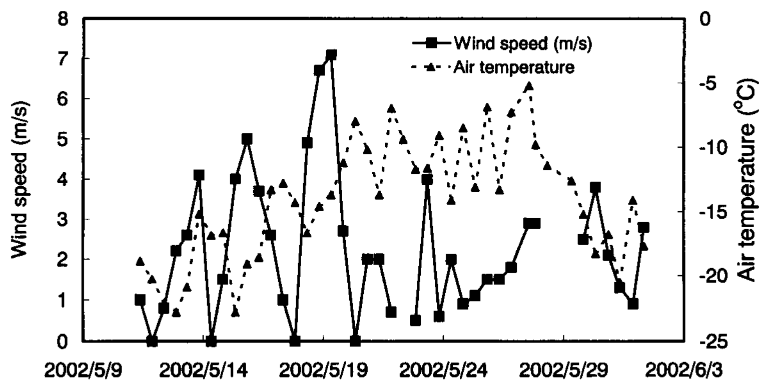

Fig. 2. Wind speed and air temperature at King Col.

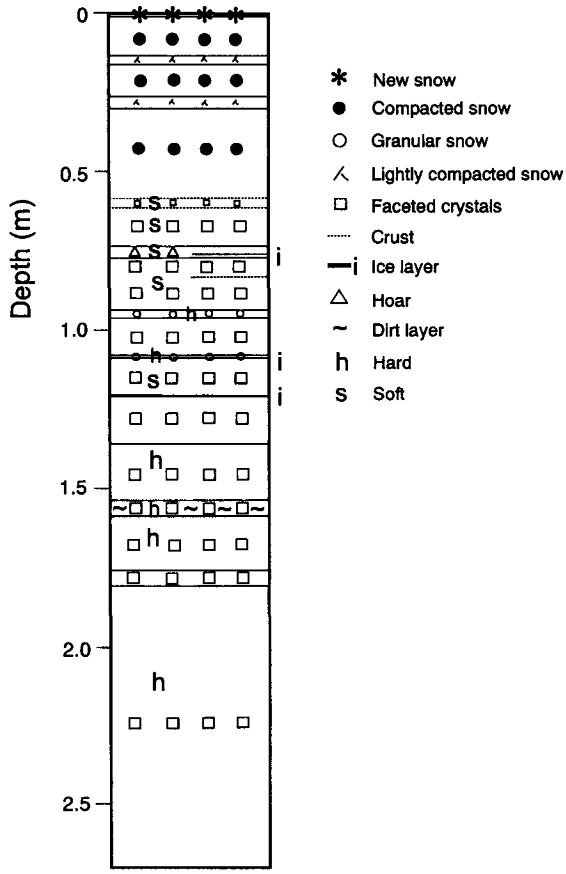

Fig. 3. Visible stratigraphy of a pit at King Col. The GPS coordinates of the pit was 60°35'20"N, 140°36'11.4"W.

accumulation between May 2001 and May 2002 was about 1.59 m. According to the density profile in Fig. 4, the net snow accumulation between May 2001 and May 2002 was about 0.6 m w. e. a^{-1}. Observations in May 2001 indicated that the net snow accumulation between spring 2000 and spring 2001 was about 3.9 m, which suggests a large year-to-year variation of snow accumulation rate at KC.

The visible stratigraphy of the pit, the low snow temperatures of the pit (Fig. 4), and the lack of surface melting during the three field seasons (July 24-August 1, 2000, May-June 2001, and May-June 2002) confirms that KC has very little summer melting. Very little melt effects are expected on physical, chemical, and biological stratigraphy of the KC core.

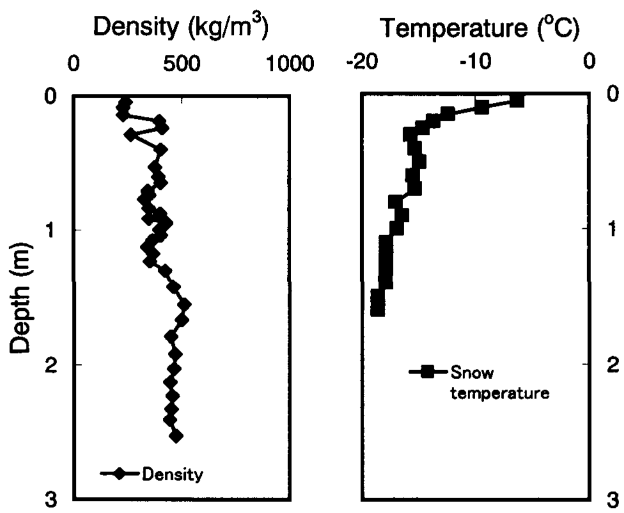

Fig. 4. Density and temperature profiles of a pit at King Col.

3. Processing and analyses of the King Col ice core

We dug a science trench at King Col to process the core. In the trench, we used a light-table to observe the stratigraphy of the whole 220.52 m core. Also, the top 30 m of the core was cut in half along the core axis. A half of the core (cross section E in Fig. 5) was then (1) cut into 0.05-0.06 m long segments, (2) melted in either pre-cleaned plastic bottles or Whirl Pak plastic bags after the sample surface was removed with clean ceramic knives and disposable plastic gloves, (3) decanted into pre-cleaned plastic bottles, and (4) refrozen in the science trench. Samples bottled in the field will be analyzed for $\delta^{18}O$, δD, ion chemistry, and microbiology.

Planned analyses of the cross section regions of the KC core (Fig. 5) are listed in Table 3. Below 30 m, section D will be archived for potential future studies such as detailed geochemical analyses of dust and tephra particles.

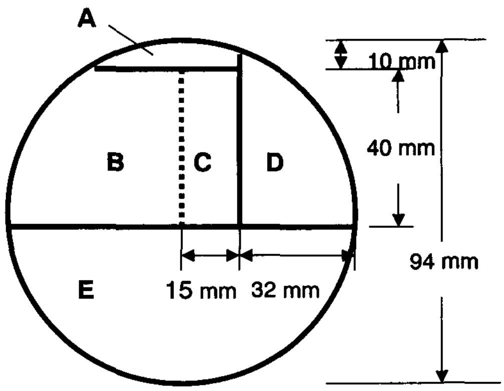

Fig. 5. Core cutting plan.

Table 3. Planned analyses of the King Col core.

Depth (m)	Cross-section	Planned analyses	Sampling interval
0-30	A	Tritium	Continuous, sample length to be decided
	B+C	Non-destructive density measurement with X-rays (Hori *et al.*, 1999)	Continuous
	B	Trace metals	Every 1-2m
	C	Vertical thin-section analyses (crystal size etc.)	Continuous
	D	Insoluble particles (size and number)	Continuous, sample length to be decided
	E	$\delta^{18}O$, δD, ions, snow algae, bacteria	Continuous, sample length 0.05-0.06m
30-70	A	Tritium	Continuous, sample length to be decided
	B+C	Non-destructive density measurement with X-rays	Continuous
	B	Trace metals	Every 1-2m
	C	Vertical thin-section analyses (crystal size etc.)	Continuous
	D	Archive	
	E	$\delta^{18}O$, δD, ions, insoluble particles, snow algae, bacteria	Continuous, sample length 0.05-0.06m
70-220.5	A	Tritium	Continuous, sample length to be decided
	B	Trace metals Horizontal thin-section analyses (crystal size, ice fabrics etc.) DNA	Every 1-2m To be decided Two samples in total
	C	Vertical thin-section analyses (crystal size, ice fabrics etc.)	Continuous
	D	Archive	
	E	$\delta^{18}O$, δD, ions, insoluble particles, snow algae, bacteria	Continuous, sample length to be decided

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