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Report

Field observations of the Japanese Arctic Glaciological Expeditions in Svalbard from 1993 to 1995

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Abstract: The Japanese glaciological expedition continued its research in Svalbard from 1993 to 1995. The main interest is to clarify fluctuations of present and past Arctic environments. Ice coring provides past, and snow surveys present, climatic information. The corings were carried out on the central glacier in 1993, on small glacier near the seashore in 1994 and on a large glacier in the northernmost island in 1995. The snow survey was carried out mainly in 1994.

1. Introduction

The Arctic plays an important role in the global environment as a heat sink. Snow and ice cover the Arctic region, fluctuations in which affect the global climate. At the same time, environments far from the Arctic, such as biomass burning in the tropical regions and human activities in urban areas, affect the Arctic environment through transportation processes in the atmosphere (Legrand *et al.*, 1992).

Precipitation processes, fluctuating with season and year, importantly affect the glaciological environment. The annual fluxes of water and other substances onto the glacier through precipitation determine the composition of snow layers of the glacier. Snow layers record the glaciological environment produced by precipitation and metabolic processes after deposition.

A deep ice core obtained from a glacier is an archive of the snow layers. The record, observed in the deep ice core, has a close relationship with the atmospheric conditions at the times of deposition and sedimentation. The diagenetic process as well as the metabolic one will possibly alter the record. Through snow and ice surveys at various sites in Svalbard, we will try to obtain the information recorded in ice cores.

In the Arctic, Svalbard is the northernmost group of islands, in a unique environment. The Greenland Sea nearby brings warm water into the Arctic Ocean, where the climate is comparatively calmer than any other location in the similar latitude. In addition, the Greenland polynia occurring between Svalbard and Greenland, one of the biggest polynias in the ocean, is a major heat source to the atmosphere and brings water vapor into the Arctic region while driving a deep oceanic current toward the tropics. The climatic condition affects the glaciological environment in the Arctic. At the same time, the mass balance of the glaciers affects the climate through the area of snow cover and inflow rate of fresh water to the ocean. There are many glaciers located at various sites in Svalbard.

Each glacier has a unique glaciological environment (Hagen and Riestel, 1990). Some represent only local environments, and others appear to be correlated with the global climate (Ono, 1996).

The Japanese Arctic Glaciological Expedition in 1987 (JAGE-87), succeeded in obtaining an ice core at the top of Asgørdfonna (Høghetta) as the first experience in Svalbard for a Japanese glaciological group (Watanabe and Fujii, 1988). The ice drilling reached the bedrock at about 70 meters depth from the glacier surface. It was revealed that the core contained a 6000-year environmental record. Frozen petals and bacteria, preserved in the ice core near the bedrock, suggest the existence of 5000 to 6000 year old fossil ice formed in the warmest period after the last glacial period. The core record suggested that there was a big unconformity in deposition in the core, possibly because of the occurrence of a hiatus period. In the upper part of the core, we were able to trace almost continuous sedimentation back to a hundred years ago, and in the lower part, to detect the evidence for the occurrence of ice layers in a few thousand years during the warmer periods (Fujii *et al*., 1990).

The coring site was located on the summit of the glacier. The depth of ice confirmed by drilling was not as deep as that estimated by radio echo sounding around the surrounding area. We might have been drilling in an old glacier, perhaps an isolated ice cap on top of the mountain.

The objective of research from 1993 to 1995 is to discuss the local fluctuation, revealed in the ice core on some locations in Svalbard.

2. Objectives of each expedition

2.1. General view

The project in 1993 was considered to be the second phase of JAGE-87. The prime objective was to obtain more precise and detailed information about the last 6000-year environmental records for comparison with those obtained by JAGE-87. Another coring over the top near by would help to clarify the paleo glacier environments through comparison of both ice core records.

The coring was carried out in Asgørdfonna, about 10 km north from the highest peak of Høghetta. The site was also a dome-like plateau, with flat glacier surface spread more widely than the site in 1987.

The research in 1994 was concentrated near Ny-Ålesund (NAL), one of the small settlements in Svalbard. Research on snow chemistry, as well as the atmospheric observations such as aerosol sampling, was carried out at NAL, including glaciological research on a glacier named Breggarbreen near by. Because the snow has a close relation to the atmospheric environment, the research was concentrated on the snow deposition and accumulation process as well as the metabolic process, with a shallow coring operation.

The operation in 1995 was treated as one of the Japanese Glaciological contributions for the Ice core Circum-Arctic Paleoclimate Program (ICAPP) of the International Arctic Scientific Committee (IASC). The target glaciers were located in the northern part of Svalbard. The northeast island, Nordaustlandet, is located in a unique position in Svalbard, low altitude and much snow cover near the Arctic Ocean. The glacier is also located near the Arctic Ocean, and any fluctuation of sea ice is reflected in the glacier environment

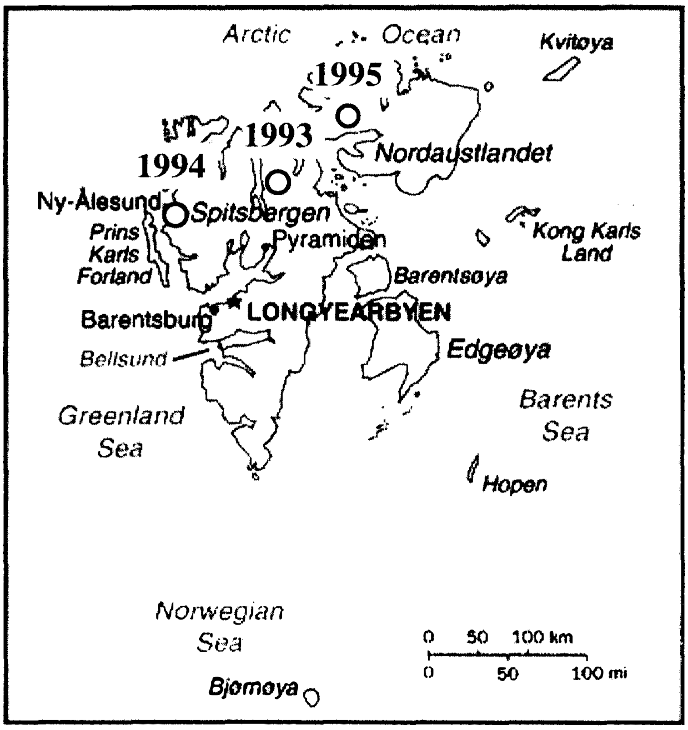

Fig. 1. Main observation sites in 1993, 1994 and 1995.

Table 1. Sampling sites with coring depth.

Sampling site	Location	Position	Year	Coring depth
Asgørdfonna	Spitsbergen	79°27′N, 16°43′E, 1140 m a.s.l.	1993	185.3 m
Ny-Ålesund	Spitsbergen	78°55′N, 11°56′E, 8 m a.s.l.	1993-94	49.0 m
Austre Brøggerbreen	Spitsbergen	78°52′N, 11°56′E, 450 m a.s.l.	1994	9.39 m
Vestfonna	Nordaustlandet	21° 1′N, 79°58′E, 600 m a.s.l.	1995	210.0 m
Høghetta Ice Cap	Spitsbergen	79°17′N, 16°50′E, 1200 m a.s.l.	1987	87.0 m
Snofjella basin	Spitsbergen	79° 8′N, 13°17′E, 1190 m a.s.l.	1992	24.4 m
Snofjella basin	Spitsbergen	79° 8′N, 13°19′E, 1160 m a.s.l.	1992	83.9 m

directly. The glaciological environment there will possibly reflects the Arctic environment with small local fluctuation. Japanese glaciological activities in the Arctic region, including the project, were introduced by Watanabe (1996).

Core records and snow surveys in Svalbard can help to clarify the Arctic glaciological environment and its local fluctuation. All the sampling sites are shown in Fig. 1 and Table 1 with coring depths. In Fig. 1, the main site in each year was marked in open circles on the map of Svalbard, obtained from the web site of the University of Texas central libraries (http://www.lib.utexas.edu/Libs/PCL/Map_collection/Map_collection.html).

2.2. Expedition in 1993

In the 1993 expedition, we tried to decrease the helicopter payload while carrying a

Table 2. Field members in 1993 coring.

Participant	Longyearbyen	Glacier	Ny-Ålesund
Kokichi Kamiyama	6/16–6/20, 7/19	6/20–7/14	7/14–7/19
Yoshitaka Suzuki	6/16–6/20, 7/19	6/20–7/14	7/14–7/19
Tsutomu Uchida	6/16–6/20, 7/19	6/20–7/14	7/14–7/19
Yoshitaka Yoshimura	6/16–6/20, 7/19	6/20–7/14	7/14–7/19
Akiyoshi Takahashi	6/16–6/20, 7/2–7/3	6/20–7/2	
Yoshiyuki Fujii	7/9–7/10, 7/19	7/10–7/14	7/14–7/19

drilling system capable of reaching more than 200 m depth. Under the situation, we tried to carry out the expedition with the smallest possible number of members, 4 members, for daily routine duties, plus specialists to developing the new drills (Takahashi, 1996) as shown in Table 2. The coring site was located at 79°27′N, 16°43′E at an altitude of 1140 m a. s. l. We obtained two cores of 185.3 and 49.0 m depth. The surface stratification of the snow and ice layers was observed on a snow pit wall nearby, and non-contaminated snow samples were obtained from the newly cut vertical snow walls.

2.2.1. Ice coring

Some of the scientific and logistic equipment, such as generators and tents, was stored at the Rabben station (R/S) of the Japanese Arctic Environmental Research Center (AERC) in NAL and other items at the home laboratory in Japan. All the luggage was gathered at Longyearbyen (LYB), a unique commercial airport in Svalbard, where we checked all of the coring instruments, assembling the winch with the mast to operate the drilling system. After obtaining food and oil, we prepared to leave for our coring site in Asgørdfonna by commercial helicopter with about 3000 kg of luggage. We reached the glacier on 16 June. One week of delay was forced by the weather because of difficulties in the first landing on the glacier. The drilling was done from 23 June to 12 July, 1993. The field members in the 1993 coring are listed in Table 2.

2.2.2. Sample procedure *in situ*

The drilling was done mainly by 3 members, and the logistic support by 1 member. During the coring operation, the sunshine became strong in the Arctic and the snow surface melted down gradually. The drill was stored in a bore hole at about 6-m depth from the surface to keep it in cold condition. Once ice packed the bore hole together with the drill, probably by freezing of melt water, and the drill was stuck until we recovered by digging a pit to the depth.

The core samples were cut less than 50 cm length and stored in a snow pit to keep them solid. It was difficult for us to maintain the pit under strong sunshine. At the coring site, vertical profiles of ice density, by measuring the core weight, and glacier temperature, using the bore hole, were observed. The visible stratification of the snow and ice layers, observed in the core samples, was recorded with the shapes and density of bubbles in the core sample. The observation and recording work was shared among 4 members. The vertical distribution of temperature and stratigraphy were discussed by Uchida *et al.* (1996).

2.2.3. Core storage and sample procedure in Ny-Ålesund

Some of the core samples were stored in the cold laboratory at R/S of AERC in NAL and others in the commercial cold room at LYB, depending upon the operation of helicopters. Some of the surface snow samples were studied to determine biological activity after pre-treatments at NAL.

2.3. Expedition in 1994 together with core analyses at Ny-Ålesund

The expedition in 1994 was mainly aimed at sampling of precipitation and snow cover around NAL.

2.3.1. Background

For some elements of the core analyses, the samples must be preserved in the solid state. For example, measurement of electric conductivity (ECM) is only valid in the solid state. The ECM profile of the core is used to identify volcanic layers and to determine the period of sedimentation of ice core layers. To carry out some of the core analyses in situ or in a laboratory near the coring site is essential. Some chemical substances possibly change their concentration in the liquid phase, so they should be determined as soon as possible after melting. A cold room was opened at R/S of AERC in late 1994. We did some analyses of the ice core obtained in 1993 in the cold room. Some of the treated core samples were later subjected to the detailed study in the home laboratory in Japan.

Precipitation characteristics are basic information for determining the environmental record from the ice core analyses. Coring at Snofjella near NAL was carried out in 1992 (Takahashi *et al*., 1993). The site is considered to be representative of western Svalbard. In considering the core record, it is important to know the input from the atmosphere into the glacier. We tried to investigate the snow fallout and metamorphic process through the sedimentation process.

2.3.2. Field activity

Winter in 1993/1994:

The snow sampling and the core analyses were carried out at R/S of AERC in NAL, where two members stayed from 12/03 to 12/16 in 1993. Sampling was conducted of the snow fallout and snow pit. There was unusual heavy rain fall just before our arrival, causing the surface snow to melt down. After the rainfall, a little precipitation was observed during the stay.

1993 Core samples from the surface to 46 m were promised to be provided for obtaining vertical profiles of the artificial radionuclides, gross beta activities and Cs-137, to clarify the surface accumulation rate during the last several decades, under cooperative work with scientists of Norsk Polarinstitutt (Norwegian Polar Institute), Drs. J. O. Hagen and B. Lefauconnier. The core samples from the surface to 46-m depth in the upper part of the 185.3 m core were used for the investigation.

All of the core samples about 50 cm length, the 49.0 m core and rest of the 185.3 m core, were cut into half vertically. Each vertical half core was kept frozen in the cold laboratory in R/S. The other half was cut 10 cm horizontally into small pieces. Each piece was melted, after removing surface material which might have been artificially contaminated during the procedure. After analyzing the core samples in liquid phase, for example measuring electrical conductivity, pH and hydrogen peroxide (H_2O_2), the melted samples were carried to the home laboratory for future analyses. H_2O_2 should be determined just after melting, while it is difficult to process the whole core in a short stay.

Summer in 1994 and winter in 1994/1995:

In late summer 1994, precipitation and surface snow were sampled at NAL and also

Table 3. Field members for the research in Ny-Ålesund.

Participant	Duration in Ny-Ålesund	Seasons
Kokichi Kamiyama	12/03-12/15	Winter late in 1993
Makoto Igarashi	12/03-12/15	Winter late in 1993
Kokichi Kamiyama	02/01-03/15	Winter early in 1994
Makoto Igarashi	02/01-03/15	Winter early in 1994
Kokichi Kamiyama	8/22-9/20	Summer in 1994
Makoto Igarashi	8/22-9/20	Summer in 1994
Hideaki Motoyama	8/22-9/20	Summer in 1994
Fumihiko Nishio	9/01-9/15	Summer in 1994
Makoto Igarashi	1/19-3/23	Winter late in 1995
Kokichi Kamiyama	1/19-2/2, 3/1-3/14	Winter late in 1995
Yoshitaka Suzuki	2/23-3/23	Winter late in 1995

at Brøggerbrean near NAL. A 10 m core was also obtained from the glacier. Some parts of the core samples obtained in 1993, being stored in NAL, were melted for analysis. Snow sampling with core treatment was carried out at R/S. ECM measurement was carried out in the cold laboratory in NAL on stored solid cores in 1993 and on the 10 m core in 1994. Processing of the 1993 core was continued during the summer and winter. Finally, 652 pieces of melted samples were obtained from the surface to 50-m depth, and 1623 pieces from 50 m to 185 m.

For snow sampling as well as core analyses, field members stayed in NAL. The field members for the research in NAL are listed in Table 3.

2.4. Expedition in 1995

For coring in NordAustlandet, we cooperated with Russian and Norwegian scientists. In the past ten years, Russian scientists have been active in glaciological and geological research in northern Svalbard. They were familiar with NordAustlandet, especially on the view point of the logistics. They supported us in radio communication between our camp and the Russian settlement Barentsburg on Spitsbergen, and in helicopter operation and field observations. For forecasting the weather for helicopter landing, information from Barentsburg and Polish station received via Russian radio was useful. The large Russian helicopter, capable of carrying more than 3000 kg of luggage plus fuel for 400 miles of flight, made the operation much easier.

2.4.1. Duration and participants

Field members in the 1995 coring are listed in Table 4. In LYB, we prepared camping supplies with food, and checked the condition of all of the equipment, especially the drilling system. All of the members gathered in Barentsburg waiting for the helicopter, the operation of which depended on the weather over the target glacier. After drilling up to about 200 meters depth, we prepared to leave the glacier. After waiting for a week during heavy snowfall, we flew to NAL for core storage.

2.4.2. Coring procedure

In the field we tried to perform core analyses in situ. Three members were assigned to the drilling, and one to maintenance of ice core samples. The other 3 members were used only for the core analyses. These daily duties were rotated among these 7 members. The

Table 4. Field members in 1995 coring.

Participant	Longyearbyen	Barentsburg	Glacier	Ny-Ålesund
Kokichi Kamiyama	5/11-5/15, 6/16-6/17	5/15-5/19	5/19-6/11	6/11-6/16
Hideaki Motoyama	5/11-5/15, 6/16-6/17	5/15-5/19	5/19-6/11	6/11-6/16
Hideki Narita	5/11-5/15, 6/16-6/17	5/15-5/19	5/19-6/11	6/11-6/16
Sumito Matoba	5/11-5/15, 6/16-6/17	5/15-5/19	5/19-6/11	6/11-6/16
Moriatsu Miyahara	5/11-5/15, 6/16-6/17	5/15-5/19	5/19-6/11	6/11-6/16
Hideaki Yamazaki	5/11-5/15, 6/16-6/17	5/15-5/19	5/19-6/11	6/11-6/16
Arkihop	5/11-5/15, 6/16-6/20	5/15-5/19	5/19-6/11	6/11-6/16
Tevenkov	5/11-5/15, 6/16	5/15-5/19, 6/16-	5/19-6/11	6/11-6/16
Andry		5/15-5/19, 6/11-	5/19-6/11	6/11
Zinger	5/11-5/15	5/15-		

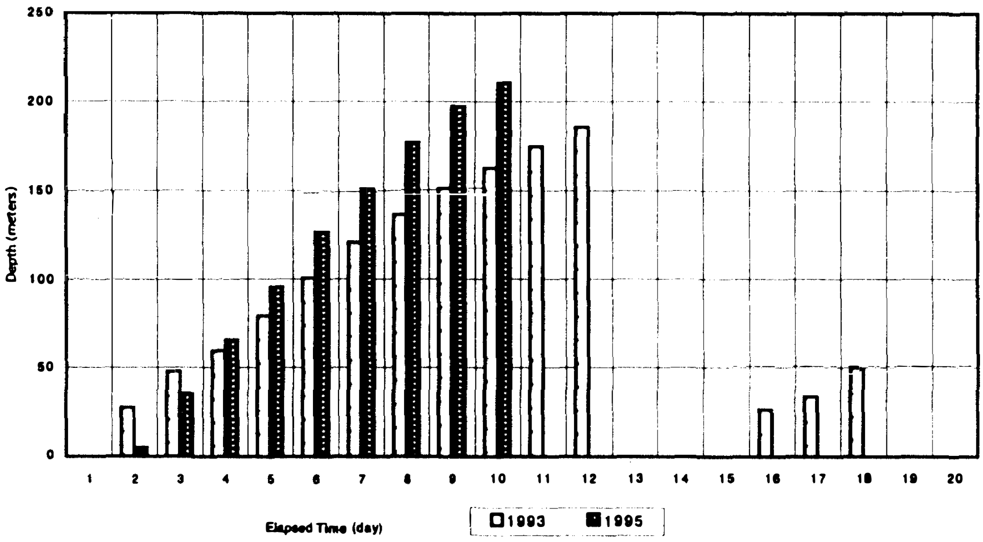

Fig. 2. Daily progress on the drilling depth in 1993 and 1995.

daily progress of drilling depth is shown in Fig. 2, with comparison to 1993. The delay in coring speed in 1993 was mainly due to the difficulty of removing core samples from the barrel.

All of the core samples were stored in the cold laboratory of AERC in NAL, where some ECM measurements were carried out by 2 members.

3. Activities

3.1. Observations and samples

Here we list our equipment in 1995 for the convenience of future research, in Table 5. Additional equipment was carried to obtain data immediately and reduce the risk and weight of samples carried back, at same cost in increased weight and number of members needed.

Some of the samples are still being analyzed. By determining the local and seasonal

Table 5. List for field equipment for core observation.

Equipments	Objection	Expedition
Core card	Record of core segments	93, 95
Core table, recording paper, camera,	Exact measurement for core lengths Observation for stratigraphy	93, 95
Band saw	Cutting cores vertically into half column Half column is cut into segments with cutting off the surface to keep from contaminant	95
Electric oven	Pretreated solid ice core sample into liquid phase	95
Portable electrical conductivity meter	Measurement of electrical conductivity for liquid core	95
Portable pH meter	Measurement of pH for liquid core	95
Flow line UV detector	Measurement of 210 nm absorbance for liquid core for estimating NO_3 concentration	95

fluctuations found in the core analysis and snow survey, we clarify the glaciological environment in the Svalbard region.

3.2. Observations in Svalbard

Expeditions were carried out also in 1998 and 1999, after missing 1996 and 1997. The expeditions in 1998 and 1999 were concentrated on Austfonna in NordAustlandet, the largest glacier in Svalbard, where the observation sites were the farthest from the main island of Spitsbergen among the glaciers in Svalbard. The expeditions were co-operative work with the Norsk Polarinstitutt. Reports on the expedition 1999 has been presented elsewhere (Watanabe *et al.*, 2000). Detailed reports, including these observations, have also been presented in the report for the scientific fund of the Ministry of Education, Science, Sports and Culture, No. 08041114 in Japanese (Watanabe, 1998).

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