—報告—
Report

Report of the JARE-54 and BELARE 2012–2013 joint expedition to collect meteorites on the Nansen Ice Field, Antarctica

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第 54 次日本南極地域観測隊と 2012–2013 年ベルギー南極観測隊との合同によるナンセン氷原における隕石探査報告

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要旨: 第 54 次日本南極地域観測隊員 4 名とベルギー南極観測隊員 6 名の合計 10 名から構成される隕石探査隊は，2012 年 12 月から 2013 年 2 月まで，セール・ロンダーネ山地南部に広がるナンセン氷原（南緯 72°30′–73°，東経 23°–25°，標高約 2900–3000 m）において隕石探査を実施した．ナンセン氷原には 2012 年 12 月 26 日から 2013 年 2 月 2 日まで 39 日間滞在した．今回の探査域は第 29 次日本南極地域観測隊以降探査が行われていない．探査の結果，採集した隕石の総数は 424 個，合計重量は約 70 kg であった．隕石発見地点は携帯 GPS に記録されたので，探査域における隕石の分布が明確になった．これは隕石集積機構解明のための基礎データだけでなく，今後の探査計画に活用できる．本稿は主に日本隊による準備期間を含む実施報告書である．

Abstract: This paper reports on a joint expedition (JARE-54 and BELARE 2012–2013) that conducted a search for meteorites on the Nansen Ice Field, Antarctica, in an area south of the Sør Rondane Mountains (72°30′–73°S, 23°–25°E; elevation 2900–3000 m). The expedition took place over a period of 39 days during the austral summer, between 26

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December 2012 and 2 February 2013. The team consisted of ten members: three researchers and one field assistant from the 54th Japanese Antarctic Research Expedition (JARE-54), and five researchers and one field assistant from the Belgian Antarctic Expedition (BELARE) 2012–2013. Previously, this area had only been searched by JARE-29. The team collected 424 meteorites, which had a total weight of about 70 kg. The search tracks of the ten members of the expedition were recorded using hand-held GPS units, and this allowed the distribution of meteorites within the searched area to be mapped. The resultant data will be useful for planning future expeditions and can be used to clarify the meteorite concentration mechanism on the ice field. This paper focuses on the activities of JARE-54 during the joint expedition.

1. Introduction

Many meteorites have been recovered from the bare ice fields of inland Antarctica. The earliest finds were by the 10th Japanese Antarctic Research Expedition (JARE-10), which collected nine meteorites from the bare ice field around the Yamato Mountains (Yoshida *et al*., 1971). Since then, more than 17000 meteorites have been recovered by JARE.

The only previous meteorite collection expeditions on the Nansen Ice Field (Fig. 1; 72° 30′–73°S, 23°–25°E; elevation 2900–3000 m; 100–140 km south of the Sør Rondane Mountains) were those of JARE-29 (Naraoka *et al*., 1990; Yanai, 1993) and the Belgian Antarctic Expedition (BELARE) of 2010–2011 (Goderis *et al*., 2011). The meteorites collected around the Sør Rondane Mountains, mainly from the Nansen and Balchen Ice Fields, are known as the Asuka meteorites (Kaiden *et al*., 2010; Tsuchiya *et al*., 2012; Yanai, 1993; Yanai *et al*., 1993). The JARE-29 winter party collected about 2000 Asuka meteorites, including one huge specimen (46 kg; A-87251 LL6) and many rare meteorites, including an angrite (Asuka (A)-881371), a lunar gabbro (A-881757), unique carbonaceous chondrites of CH3 (A-881020, A-881541, and A-881691), a Rumuruti (A-881988), and three mesosiderites (A-87106, A-881154, and A-882023). The first two joint meteorite search projects conducted by JARE and BELARE recovered 678 Asuka 09 meteorites (about 13 kg total weight) in 2009, and 230 Asuka 10 meteorites (about 6 kg total weight) in 2010 (Goderis *et al*., 2011; Tsuchiya *et al*., 2012). The number of collected meteorites normally includes a few terrestrial rocks for each expedition and this is clarified during the classification in the laboratory. In the paper, we use the collected number throughout the paper.

Here, we report on the third joint expedition by JARE-54 and BELARE, which took place in 2012–2013 with the aim of collecting Asuka meteorites, and has been preliminary reported on by Imae *et al*. (2013) and Debaille *et al*. (2013). The meteorites were collected from the Nansen Ice Field, and 424 meteorites (total weight about 70 kg) were collected, including a large ordinary chondrite (about 18 kg), carbonaceous chondrites, and achondrites. They are referred to as Asuka 12 meteorites. The average weight of the meteorites was about 180 g, much heavier than those collected during the two previous joint expeditions in the 2009–2011 and 2010–2011 austral summer seasons. Each of the meteorites with a mass greater than 50 g will be halved and shared between Japan and Belgium, as specified in the Memorandum of Understanding (MoU) contained in the plan made for JARE-51 (51st Japanese Antarctic Research Expedition, 2009). The MoU

between Japan and Belgium covering the processing of Asuka 12 meteorites, and other collaborations on Antarctic meteorites, was updated in Brussels on 24 May 2013.

2. Team members and their roles for JARE

All joint expedition team members are listed in Table 1, and the roles of JARE team members are listed in Table 2. Although all members of the joint expedition worked together during the fieldwork, the Japanese and Belgian base camps were separate; the two teams had a group dinner about once a week.

3. Pre-expedition preparation

Preparation for this expedition was mainly conducted by members of JARE-54. The detailed plan was described by 54th Japanese Antarctic Research Expedition (2012) and was summarized by Imae *et al*. (2012). The sequence of important components of the preparation phase is listed in Table 3.

3.1. Safety training

Pre-expedition safety training for JARE-54 team members is summarized in Table 3.

Table 1. Team members consisting of four JARE members and six BELARE members.

	Name and the abbreviation	Affiliation	Antarctic experience
JARE-54	Naoya Imae, NI [1)]	National Institute of Polar Research	JARE-41 (W)
	Akira Yamaguchi, AY	National Institute of Polar Research	
	Takashi Mikouchi, TM	University of Tokyo	
	Yukihisa Akada, YA [2)]	National Institute of Polar Research	JARE-49 (W) and -53 (S)
BELARE 2012–2013 [5)]	Vinciane Debaille, VD [3)]	Universite Libre de Bruxelles	BELARE 2010–2011
	Geneviève Hublet, GH	Universite Libre de Bruxelles	
	Nadia Van Roosbroek, NVR	Universite Libre de Bruxelles	
	Harry Zekollari, HZ	Vrije Universiteit Brussel	
	Wendy Debouge, WD	Universite Libre de Bruxelles	
	Christophe Berclaz, CB [4)]	International Polar Foundation	

[1)] Leader of joint team.
[2)] Field assistant for JARE.
[3)] Leader of Belgian team.
[4)] Field assistant for BELARE.
[5)] Steven Goderis (Vrije Universiteit Brussel) could stay up to 21 December, 2012.
W = Winter party.
S = Summer party.

Table 2. Roles of JARE-54 team members.

	NI	AY	TM	YA
Leader/Subleader	◎*			○
General affairs	○	◎		
Communications	◎			○
Official records	◎	○		
Photographic official record		○	◎	
Transportation by air	◎	○**		
Transportation listing	◎			○
Vehicle/Generator/Fuels			○	◎
Food	○			◎
Clothing and equipment		○		◎
Rescue and medical			○	◎
Weather observation		○	◎	
Maps and documents		◎	○	
Samples	○	◎		
GPS	◎		○	○
Safety	◎			○
Environment			○	◎

* Leader of the joint team.

** Meteorite transportation under frozen conditions.

◎ = Primary responsibility.

○ = Secondary responsibility.

NI = Naoya Imae.

AY = Akira Yamaguchi.

TM = Takashi Mikouchi.

YA = Yukihisa Akada.

3.2. Pre-expedition meetings of JARE and BELARE

3.2.1. In Brussels

Between 30 May and 1 June 2012, JARE members (NI and AY; see Table 1 for names) met several times with the scientists and logistics staff of BELARE to discuss the length of the expedition's stay on the Nansen Ice Field and the logistical support required. Meetings were held on 30 May and 1 June at both Vrije Universiteit Brussel and Université Libre de Bruxelles (ULB), and on 31 May at International Polar Foundation (IPF). Especially, the time required for the meteorite search on the Nansen Ice Field was determined by taking into consideration the area of the ice field and discussions with Alain Hubert of the IPF.

3.2.2. At National Institute of Polar Research (NIPR)

Meetings at NIPR included discussions of geoscience matters on 9 May and 16 October 2012 (see Chapter 1 of 54th Japanese Antarctic Research Expedition's (2012) expedition plan), and discussions of safety issues on 29 October 2012 (see Chapter 3 of 54th Japanese Antarctic Research Expedition's (2012) expedition plan).

Table 3. Summary of preparation and training for 2012–2013 meteorite search.

Period	Category	Locality
27 February–3 March 2012	Training for all JARE-54 members in winter season	Mt. Norikura, Nagano Prefecture
8–11 May 2012	Rescue	Mt. Harinoki, northern Japanese Alps
30 May–1 June 2012	Meeting of JARE and BELARE	Brussel
18–22 June 2012	Training for all JARE-54 members in summer season	Kusastu spring, Gunma Prefecture
11 July 2012	Preparation of freeze-dried food	Azumino, Nagano Prefecture
17 July 2012	Rescue training (1st)	NIPR
23 July 2012	Rescue training (2nd)	NIPR
30–31 July 2012	Snowmobile maintenance	NIPR
2 August 2012	Rescue training (3rd)	NIPR
24 August 2012	Meeting (1st with all JARE-54 members)	NIPR
29 August 2012	Rescue training (4th)	NIPR
4–5 September 2012	Climbing training	Mt. Fuji
14 September 2012	Rescue training (5th)	NIPR
18 September 2012	High frequency (≥3 MHz) radio communication training	Japan Radio., Co., Mitaka City, Tokyo
25 September 2012	Rescue training (6th)	NIPR
28 September 2012	Meeting (2nd with all JARE-54 members)	NIPR
October 2012	Writing expedition plan	NIPR
2–5 October 2012	Rescue training	Fire station, Murakami City, Niigata Prefecture
9–12 October 2012	Packing of food and supplies	NIPR
22 October 2012	Departure of food and supplies from NIPR	NIPR
23 October 2012	Hand-held GPS training	RESTEC, Tokyo
29 October 2012	Meeting (Safety)	NIPR
9 November 2012	Meeting (3rd with all JARE-54 members)	NIPR

NIPR = National Institute of Polar Research.

3.2.3. Dronning Maud Land Air Network (DROMLAN) flight schedules

Prof. Yoichi Motoyoshi of NIPR arranged schedules for outgoing (and return) flights from Cape Town to Novolazarevskaya Air Base (Ilyushin-76) and then to Princess Elisabeth Station (PES) (Basler Turbo) at the meetings with DROMLAN in April 2012 (St. Petersburg, Russia) and July 2012 (Portland, Oregon, USA).

3.3. Planned itinerary

The Japanese and Belgian teams were to fly independently by commercial airlines to Cape Town, South Africa, in early December 2012, from where DROMLAN operates flights to and from Antarctica (Fig. 1a). The main supplies and equipment (food and clothing; about 1000 kg) for the Japanese team would be sent in advance to the Cape Town warehouse of the Antarctic Logistics Centre International (ALCI). Arrival of the joint expedition team at the Russian Novolazarevskaya Air Base (Fig. 1a) on an Ilyushin-76 aircraft was scheduled for 6 December 2012, followed by feeder flights (Basler Turbo) to PES on the same day (Fig. 1b and c). At PES, we were to prepare for our main meteorite search and carry out a micrometeorite search in the Sør Rondane Mountains close to PES, with logistical support from Belgium (Principal Investigator, Steven Goderis). The Belgian support team was to set up base camp 1 (BC1; Fig. 1d) by using up to three large snow vehicles (Prinoth snow tractors) to carry extra snowmobiles (Ski-Doo, BRP), fuel, foods, sledges, and living quarters. After setting up BC1 (72°53′S, 24°18′E), the Belgian support team was to return to PES with the snow tractors. We planned to spend about 23 days at BC1 searching for meteorites within area B (Fig. 1d). We then planned to move to base camp 2 (BC2; 72°47′S, 24°51′E), travelling by snowmobile with the Belgian logistics support team. About 20 days were scheduled for our stay at BC2 to search for meteorites within area C (Fig. 1d).

After completion of our meteorite search, we planned to return by retracing our outward journey: from PES to Novolazarevskaya Air Base on 8 February 2013, and from Novolazarevskaya to Cape Town on 9 February 2013. The arrival of the Japanese team in Japan was planned for 14 February 2013.

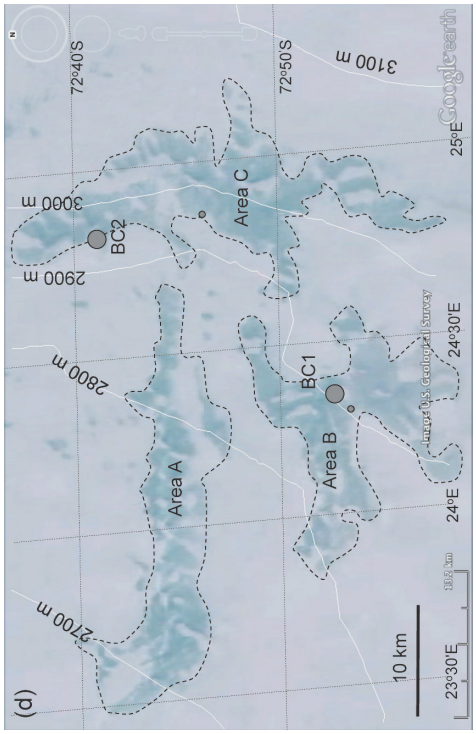
3.4. Scientific matters

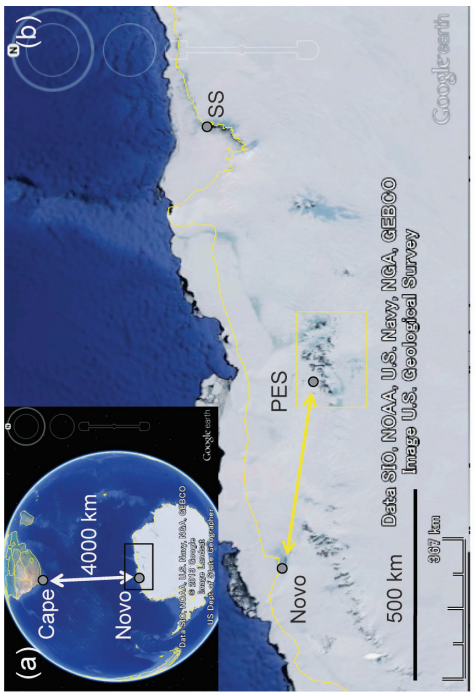
3.4.1. Definition, division, and subdivision of search areas

For convenience, three areas were defined for the meteorite searches on the Nansen Ice Field: areas A, B, and C (Fig. 1d). Area A was previously searched by JARE-29 and BELARE 2010–2011. Areas B and C had only been searched during JARE-29, and were searched again by the current expedition after a gap of quarter of a century. Twelve daily search areas (1–12) were defined in area B, and nine (1–9) in area C (Fig. 2). The size of the search areas was chosen on the basis of the areas covered per day in area A during the BELARE 2010−2011 expedition.

3.4.2. Logistics and the procedure for meteorite collection

We prepared 0.08-mm-thick ziplock polyethylene sample bags (UNIPACK, SEISANNIPPONSHA Ltd.) of various sizes to store the collected meteorites: size A (70 × 50 mm), size C (100 × 70 mm), size E (140 × 100 mm), size F (170 × 120 mm), and size K (400 × 280 mm). We also used 0.05-mm-thick powder-free polyethylene bags: 40 × 60 cm size and 20 of 100 × 120 cm size (MZ series, ADY Co., Ltd.). Other equipment included





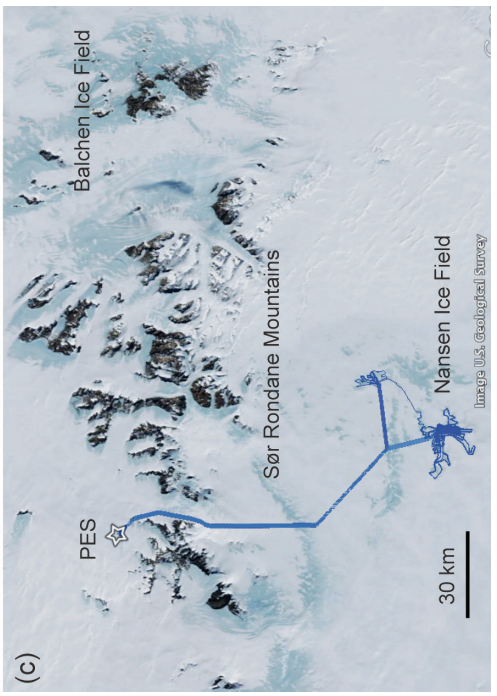


Fig. 1. Maps (from Google Earth) showing the route from Cape Town to the Nansen Ice Field and areas searched. (a) Cape Town ("Cape" on map) to Novolazarevskaya Air Base ("Novo"). The area within the rectangle is enlarged in (b). (b) Novolazarevskaya to Princess Elisabeth Station (PES). SS indicates Syowa Station. The area within the rectangle is enlarged in (c). (c) Sør Rondane Mountains and the Nansen Ice Field, about 600 km west of Syowa Station. The routes to and from the Nansen Ice Field are shown as a blue line. (d) The Nansen Ice Field divided into three search areas (A, B, and C). The planned (smaller dots) and actual positions (larger dots) of BC1 and BC2 are also shown.

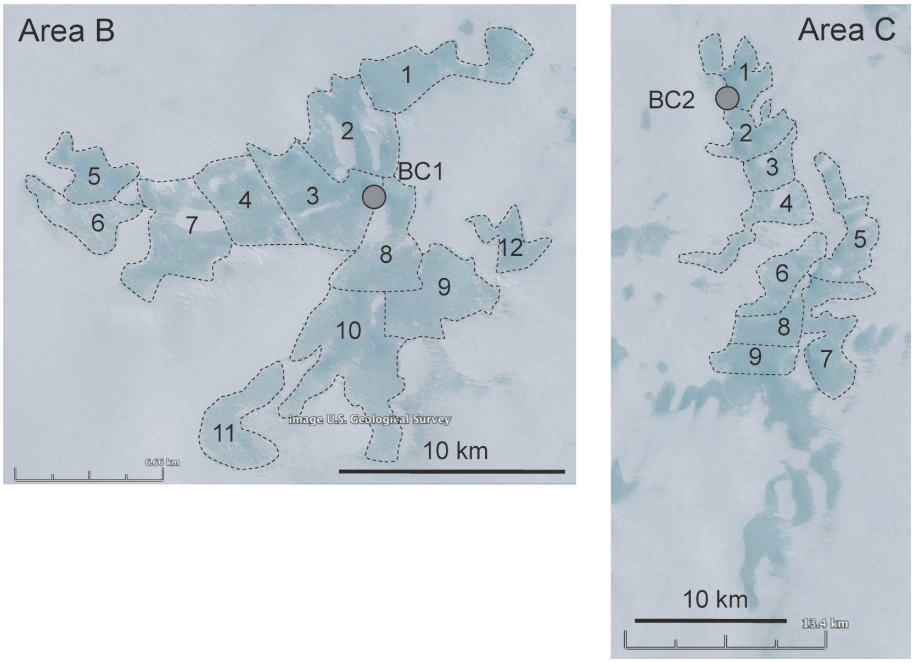


Fig. 2. Subdivisions of areas B and C for daily meteorite searches.

marker pens, measuring scales, digital cameras, and hand-held GPS units (Garmin GPSMAP 62S; mounted on each snowmobile).

On finding a meteorite: (1) the field sample number was written with a marker pen on the ice near the meteorite and a scale placed beside it; (2) photos of the meteorite (and scale) were then taken from various viewpoints; (3) the meteorite was picked up using the ziplock polyethylene bag to avoid direct contact with gloves, then sealed in the ziplock bag and stored in the field bag; and (4) the position of the meteorite find was recorded by the GPS unit.

3.4.3. Expected number of meteorite finds

The searches by JARE-29 in 1987–1989 collected 573 meteorites from area A, 698 from area B, and 311 from area C (Naraoka *et al*., 1990), and the searches by BELARE 2010–2011 collected 218 meteorites from area A (Goderis *et al*., 2011). Assuming the similar condition of each expedition, the relationship among the three areas in terms of meteorites found (i.e., 573:698:311 = 218:x:y) could be satisfied, where x and y gave the number of meteorites that we expected to collect from areas B and C, respectively. Therefore, the number of meteorites that we expected to recover from area B (x) was about 270, and from area C (y) was about 120, giving a total of 390.

3.4.4. Storage and transport of meteorites

AY and NI asked JET8 Cargo Co. Ltd. (Japan) to transport the collected meteorites (frozen) from the ALCI warehouse in Cape Town to NIPR in Tokyo.

3.5. Logistics

3.5.1. Snowmobiles

We planned to use snowmobiles (Tundra Ski-Doo as used by JARE-49, -50, and -51) for the meteorite searches. The fuel requirements (supplied from PES) were estimated to be twenty 200-L drums (total 4000 L) based on the following assumptions: 10 snowmobiles travelling 50 km per day for 40 days with a fuel consumption of 5 km/L. The two field assistants used larger snowmobiles (S7 Ski-Doo supplied by BELARE) than the rest of the team so that they could tow rescue sledges.

3.5.2. Supplies and equipment

The total weight of supplies and equipment sent by air to the ALCI warehouse in Cape Town in advance of the expedition party (food, clothing, medicine, communication equipment, and generators; Fig. 3a) was 965 kg (Table 4). The Material Safety Data Sheets (MSDS) and certificates of non-applicability (of import restrictions) required for personal notebook computers, used generators, UHF and HF radio equipment, and batteries were prepared by the Toyo Trans Company, which arranged shipment of these items from the NIPR warehouse on 3 November, arriving at the ALCI warehouse on 4 November. Two cartons containing generators and other supplies were transported to the ALCI warehouse by Singapore Airlines, arriving on 6 November.

3.5.3. Food

Freeze-dried (FD) food, mainly for the JARE-54 team's evening meals (Fig. 3b), was prepared during early July 2012 by the Nihon Freeze Dry Co. (an Asahi group company) in Azumino, Nagano Prefecture. Sufficient FD food was prepared for a 55-day expedition, plus emergency rations for an additional 20 days. There were 20 kinds of FD food sets. The daily calorie requirement per person was estimated to be at least 3000 kcal. There were three choices for breakfast: pasta, FD rice, and Chinese noodles. The total weight of the food was 357 kg, and it was packed into 33 plastic boxes that comprised 20 boxes of main meals including FD and breakfast, 3 boxes of portable rations (sausage, salami, candy, and sweet jellied adzuki-bean paste), and 10 boxes of soup, drinks, and emergency foods. Frozen food for the BELARE team was prepared at PES.

The JARE team used heat from the generator in module B to melt snow to produce drinking water: a plastic box filled with snow was set beside the generator. The volume of water consumed each day was 20–30 L.

3.5.4. Communications

The JARE team communicated with Syowa Station (SS) daily between 1900 and 1930 LT (Belgium time: GMT + 1 at PES; GMT + 3 at SS) using either an HF radio (JSB-20K at 4540.0 KHz) set up in module B, or an Iridium satellite phone set up in module A. The joint expedition members used Belgium time at PES and on the Nansen Ice Field. The Iridium satellite phone was used mainly for communication with SS as backup for the HF radio, but also for communication with team members' families in Japan. There were also two additional Iridium satellite phones for backup. VHF portable radios (Motorola GP340 supplied from PES) were used for communication among the 10 team members during meteorite searches, and between the JARE and BELARE living quarters. The UHF radios (icom, IC-UH37CTM) were used mainly for communication between JARE modules.

3.5.5. Clothing

JARE members prepared outer clothing in the field: a down jacket and trousers (Mont-

Fig. 3. (a) Supplies in the Antarctic Ligistics Centre International (ALCI) warehouse in Cape Town. (b) Packing freeze-dried food into plastic boxes in the freezer at NIPR.

Bell Co.), snow boots (Baffin), and a pair of polarized pink double anti-fog lensed goggles with a silver mirror coating (SWANS, Model HELI-MPDH). Tent shoes (North Face) were worn in the living quarters. For more details see 54th Japanese Antarctic Research Expedition (2012).

Table 4. Supplies sent in advance by air to ALCI warehouse.

Category	Main items	Containers	Number	Total weight (kg)
Vehicle	Engine oil, spare parts	Plastic boxes	1	25.0
Generator	Generator	Cardboard boxes	2	58.0
Communication	HF and UHF radios	Cardboard boxes	2	32.0
Medical	Medicines, rescue equipment	Pelican cases	3	60.5
Foods	FD food, alfa-rice, drinks, portable rations, emergency food	Plastic boxes	33	357.1
Private goods	Clothes	Duffle bags	12	202.5
Common	Camp, cooking, field goods	Plastic boxes	6	74.0
Sampling	Sample bags, marker pens	Plastic boxes	10	156.1
Total			69	965.2

3.5.6. Emergency procedures

The BELARE team was responsible for medical evacuation (MEDEVAC) in the event of serious injury or illness on the Nansen Ice Field. In the event of an emergency on the Nansen Ice Field, the trip from PES to the base camps could be completed in 3–4 hours by snowmobile. A medical doctor (also a field assistant), Jacques Richon, accompanied the joint expedition team members on the Nansen Ice Field until 2 January, when he returned to PES.

In an emergency, a call would be made to PES by Iridium phone, and SS would also be informed of the situation by Iridium phone or HF radio from the Nansen Ice Field or PES. If necessary, SS, PES, or NIPR would inform the ALCI office in Cape Town to request a DROMLAN flight for rescue. SS would inform the head of JARE-54 (Prof. Kentaro Watanabe) on the icebreaker *Shirase*, and the head of the Antarctic Operation Center (Prof. Yoichi Motoyoshi) at NIPR in Tokyo. The communication sequence at the first stage is summarized in Fig. 4 (Any emergent situation has not occurred at the present expedition.).

4. Expedition log

The duration of the JARE-54 expedition, from departure on 1 December 2012 to return on 14 February 2013, was 76 days (Table 5). The team spent 65 days in Antarctica (6 December 2012 to 8 February 2013), including 39 days on the Nansen Ice Field (26 December to 2 February; Table 5). The daily schedule on the Nansen Ice Field is shown in Table 6.

The JARE members checked the supplies transported earlier from NIPR to the ALCI warehouse at Cape Town Airport at 1000 LT on 4 December 2012. The supplies (excluding emergency kits, which were carried by team members) were in 68 parcels with a total weight of 935 kg. We attended a briefing in the ALCI office on 5 December 2012, just before our departure for Antarctica on a DROMLAN flight.

The members of both teams departed Cape Town Airport at 2315 LT on 5 December 2012 and arrived at Novolazarevskaya Air Base at 0330 LT on 6 December. During a three-

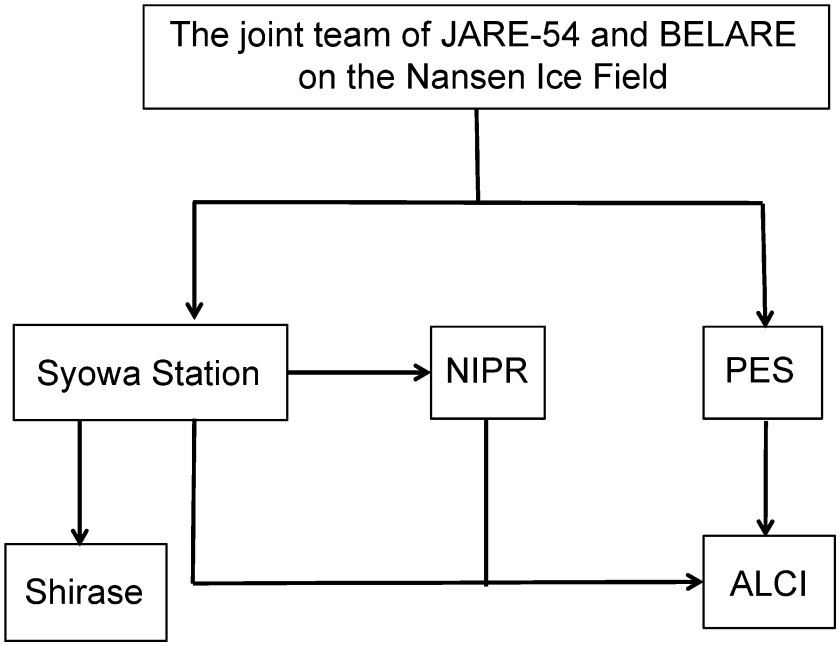


Fig. 4. Communication diagram for emergency situations.

night stay at Novolazarevskaya, the JARE team met the head of the air base to discuss the transport of meteorites from Antarctica under frozen conditions. He suggested the meteorites could be stored in an ice cave at Novolazarevskaya Air Base, if needed, even though this had not been necessary at Novolazarevskaya Air Base because of the very short transit as be described in Section 7.2. After a three-night delay due to bad weather at PES, the JARE team left the air base at 1100 LT on 9 December and arrived at PES at 1330 LT. The BELARE team left Novolazarevskaya for PES one day earlier than the JARE team.

After the expedition, the JARE (four members) and BELARE (six members) teams left PES at 1100 LT on 8 February 2013, arrived at Novolazarevskaya at 1200 LT, and then departed Novolazarevskaya at 1430 LT, arriving at Cape Town Airport at 2030 LT.

5. Preparations at PES

We spent 17 days at PES (Fig. 5a) before our departure for the Nansen Ice Field. During this period, we prepared for departure and undertook field training as follows.

(1) Snowmobile training: driving, daily maintenance procedures, fuel supply, how to use hand warmer and grip cover, and repairs (JARE and BELARE).
(2) Crampon training (BELARE only).
(3) Rescue training (JARE and BELARE).
(4) Safe handling of heavy parcels (supplies and equipment; JARE only).
(5) Crevasse rescue (Fig. 5b; JARE and BELARE).
(6) Building emergency shelters (JARE and BELARE).

Table 5. Daily log for the joint expedition to collect meteorites from the Nansen Ice Field. (1/2)

	Date		Location	Number of collected meteorites	Weight of large meteorites	Comments
December 2012	1	Sat	Departure, Tokyo			
	2	Sun	Cape Town			
	3	Mon	Cape Town			
	4	Tue	Cape Town			ALCI warehouse
	5	Wed	Departure, Cape Town			Briefing at ALCI office, D5 flight
	6	Thur	Arrival, Novo Air Base			
	7	Fri	Novo Air Base			
	8	Sat	Novo Air Base			BELARE to PES
	9	Sun	To PES			
	10	Mon	PES			Rescue training for crevasse
	11	Tue	PES			
	12	Wed	PES			
	13	Thu	PES (Module)			Logistic meeting
	14	Fri	PES (Module)			
	15	Sat	PES (Module)			Meeting and training for the meteorite search
	16	Sun	PES (Module)			Holiday
	17	Mon	PES (Module)			Glaciologists arrival
	18	Tue	PES (Module)			Meeting for safety
	19	Wed	PES (Module)			Maintenance of magnetometer and meeting of the meteorite search
	20	Thu	PES (Module)			Training for snowmobile driving and rescue
	21	Fri	PES			Feeder flight
	22	Sat	PES			To Keteleresbreen by snowmobiles
	23	Sun	PES			Holiday and sledge connection
	24	Mon	PES			Departure of support by Snowvehicles and meeting for safety by FAs
	25	Tue	PES			Briefing
	26	Wed	To BC1	0		Departure to Nansen
	27	Thu	BC1 (area B)	4		Preliminary search
	28	Fri	BC1 (area B)	-		Waiting for departure due to bad weather
	29	Sat	BC1 (area B)	-		Waiting for departure due to bad weather
	30	Sun	BC1 (area B)	-		Waiting for departure due to bad weather
	31	Mon	BC1 (area B)	1		Preliminary search
January 2013	1	Tue	BC1 (area B)	23		No. 8 *
	2	Wed	BC1 (area B)	30		No. 10
	3	Thu	BC1 (area B)	66	1.6 kg, 1.2 kg	No. 5 & 6
	4	Fri	BC1 (area B)	19	2.6 kg	No. 11
	5	Sat	BC1 (area B)	50		No. 3
	6	Sun	BC1 (area B)	17	1.3 kg, 1.1 kg	No. 2
	7	Mon	BC1 (area B)	6		Moraine

* The number corresponds to the subdivision of area B and C in Fig. 2.

We held several meetings at PES to discuss the following matters related to fieldwork on the Nansen Ice Field.

(1) Logistics (by Alain Hubert).

(2) How to recognize meteorites and appropriate handling of them (by AY and VD).

Table 5. Daily log for the joint expedition to collect meteorites from the Nansen Ice Field. (2/2)

	Date		Location	Number of collected meteorites	Weight of large meteorites	Comments
	8	Tue	BC1 (area B)	-		Holiday
	9	Wed	BC1 (area B)	85		No. 7
	10	Thu	BC1 (area B)	13	6.6 kg. 2.2 kg	No. 9 & 12
	11	Fri	BC1 (area B)	23		No. 4
	12	Sat	BC1 (area B)	-		Waiting for departure due to bad weather
	13	Sun	BC1 (area B)	29		No. 8, 9 & 10
	14	Mon	BC1 (area B)	-		Preparation for moving to BC2
	15	Tue	To BC2	2		No. 1 & 2
	Number of collected meteorites on area B			368		
January 2013	16	Wed	BC2 (area C)	-		Waiting for departure due to bad weather
	17	Thu	BC2 (area C)	-		Waiting for departure due to bad weather
	18	Fri	BC2 (area C)	-		Waiting for departure due to bad weather
	19	Sat	BC2 (area C)	-		Waiting for departure due to bad weather
	20	Sun	BC2 (area C)	-		Waiting for departure due to bad weather
	21	Mon	BC2 (area C)	-		Waiting for departure due to bad weather
	22	Tue	BC2 (area C)	-		Waiting for departure due to bad weather
	23	Wed	BC2 (area C)	-		Waiting for departure due to bad weather
	24	Thu	BC2 (area C)	-		Waiting for departure due to bad weather
	25	Fri	BC2 (area C)	-		Waiting for departure due to bad weather
	26	Sat	BC2 (area C)	-		Waiting for departure due to bad weather
	27	Sun	BC2 (area C)	-		Waiting for departure due to bad weather
	28	Mon	BC2 (area C)	8	18.5 kg	No. 2
	29	Tue	BC2 (area C)	46	4.1 kg	No. 1
	30	Wed	BC2 (area C)	1		No. 3 & 2, ice sampling
	31	Thu	BC2 (area C)	-		
	1	Fri	BC2 (area C)	-		
	2	Sat	To PES	1		Back to PES, support team departs for BC2
	3	Sun	PES			
	4	Mon	PES			Support team arrives back at PES
	5	Tue	PES			De-briefing
	6	Wed	PES			
	7	Thu	PES			
February 2013	8	Fri	Cape Town via Novo			D10 flight
	9	Sat	Cape Town			
	10	Sun	Cape Town			ALCI office
	11	Mon	Cape Town			ALCI office
	12	Tue	To Dubai			
	13	Wed	Dubai			
	14	Thu	Tokyo			
	Number of collected meteorites on area C			56		
	Total number of collected meteorites			424		

* The number corresponds to the subdivision of area B and C in Fig. 2.

(3) Schedule of activities on the Nansen Ice Field (by NI).
(4) Risks of working in cold conditions and at high altitude; avoiding illness and injury (by Jacques Richon).

Table 6. Daily schedule on Nansen Ice Field.

Belgium time *	Item
8:00	Wake-up
9:00	Weather observation (JARE)
9:30	Pre-briefing (NI, VD, CB, and YA) at JARE module
10:00	Breakfast
11:00	Preparation for departure
12:00	Departure for meteorite search
12:00–17:00 (19:00)	Meteorite search
19:30	Weather observation (JARE)
19:50	Communication with Syowa (JARE)
20:00	Communication with PES (BELARE)
20:30	Briefing (all members) at BELARE container
21:00	Dinner
23:00–	Sleep

* We used Belgium time (Syowa time −2 h) because the latitude of the search area is similar to that of Belgium.

At PES, the JARE members stayed in the living quarters that would later be transported to the Nansen Ice Field, to become accustomed to them and test their facilities. The JARE quarters included a kitchen and dining space in module A, and a diesel generator (100 V) and toilet (Wrappon, Nihon-safety Co., Ltd.) were placed at the entrance of module B. A 200 V generator housed in one of the BELARE containers was used as a cooking heater and to charge the VHF portable radios. The JARE team therefore used compatible portable VHF radios (Motorola) from PES on the Nansen Ice Field. Propane gas was used in the kitchen of the BELARE quarters.

6. Nansen Ice Field

6.1. Meteorite search in area B

Our search focused on the southwestern Nansen Ice Field until the middle of January, during which time we stayed at BC1 (72°52′19.6″S, 24°20′28.0″E; 2909 m elevation). The Belgian support team (Alain Hubert, Kristof Soete, and Erik Verhagen) left PES on 24 December (two days before the expedition scientists) to set up BC1 in preparation for the expedition party, who travelled on three Prinoth snow tractors towing sledges carrying the JARE and BELARE living quarters, as well as fuel and food supplies (Fig. 6a). The expedition members travelled from PES to the Nansen Ice Field (BC1) on 26 December on eleven snowmobiles (Fig. 6b) and were accompanied by Jacques Richon, who was also the navigator on the journey to the ice field. The trip to BC1 took about seven hours, passing the base camp used during the 2010–2011 expedition to area A and arriving at BC1 at about 1400 LT. Several problems arose during the trip: the snowmobile driven by the field assistant with BELARE overheated at the start of the journey, a sledge was overturned

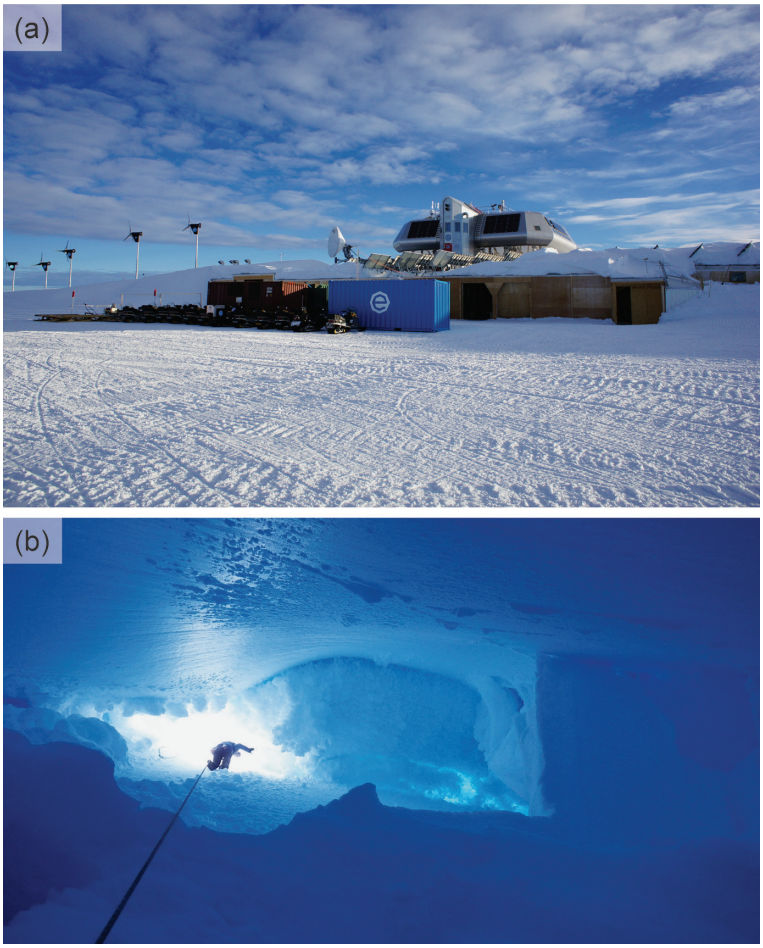


Fig. 5. (a) Princess Elisabeth Station (PES). (b) Crevasse rescue training.

during the trip, goggles became fogged at times, and some of the group suffered mild frost bite on their faces and fingers. Weather conditions deteriorated when we arrived on the plateau, where we experienced strong winds, snow drifts, and poor visibility.

The location of BC1 (about 2 km north of the planned location) was determined by Alain Hubert during his reconnaissance trip. At BC1, the JARE and BELARE living quarters were about 30 m apart (Fig. 7a and b) and were connected by electric cables. Snowmobiles were parked about 100 m west of the living quarters, and the Lehman sledge used to store fuel and food was south of the JARE living quarters (Fig. 7b). Snow drifts that developed at the camp site are clearly visible in Fig. 7a.

Weather observations (twice daily at 0900 and 1930 LT) using a potable type (Kestrel 4500, NIELSEN-KELLERMAN) by the JARE team during the time spent in area B provided the following data. Temperatures ranged from −22.4℃ to −14.4℃ (average −18.2℃), wind speeds were 2.1–18.0 m/s (average 10.1 m/s), and atmospheric pressure was 671.9–688.7 hPa (average 682.4 hPa; see Table 7 and Fig. 8). Weather conditions were good

Fig. 6. (a) Departure of the IPF support team to the Nansen Ice Field. (b) Departure of expedition members for a meteorite search on the Nansen Ice Field.

during our stay in area B (26 December to 15 January). Of the 21 days working from BC1, 15 days were devoted either to meteorite searches or camp moves.

During our meteorite searches, we drove the ten snowmobiles in V-formation, with a field assistant (YA or CB) at the apex of the V (Figs. 9 and 10a). Our speed in formation was usually less than 10 km/h. Small mobile GPS units mounted on the snowmobiles (Fig. 10b) were used for navigation, as well as to record the routes followed during the search and the locations of the meteorites found. These data were used to map the meteorite distribution on the ice field (Figs. 11 and 12).

Most of the search tracks of the expedition members show closely spaced lines, reflecting the V-formation used during the search. Single tracks indicate areas where the

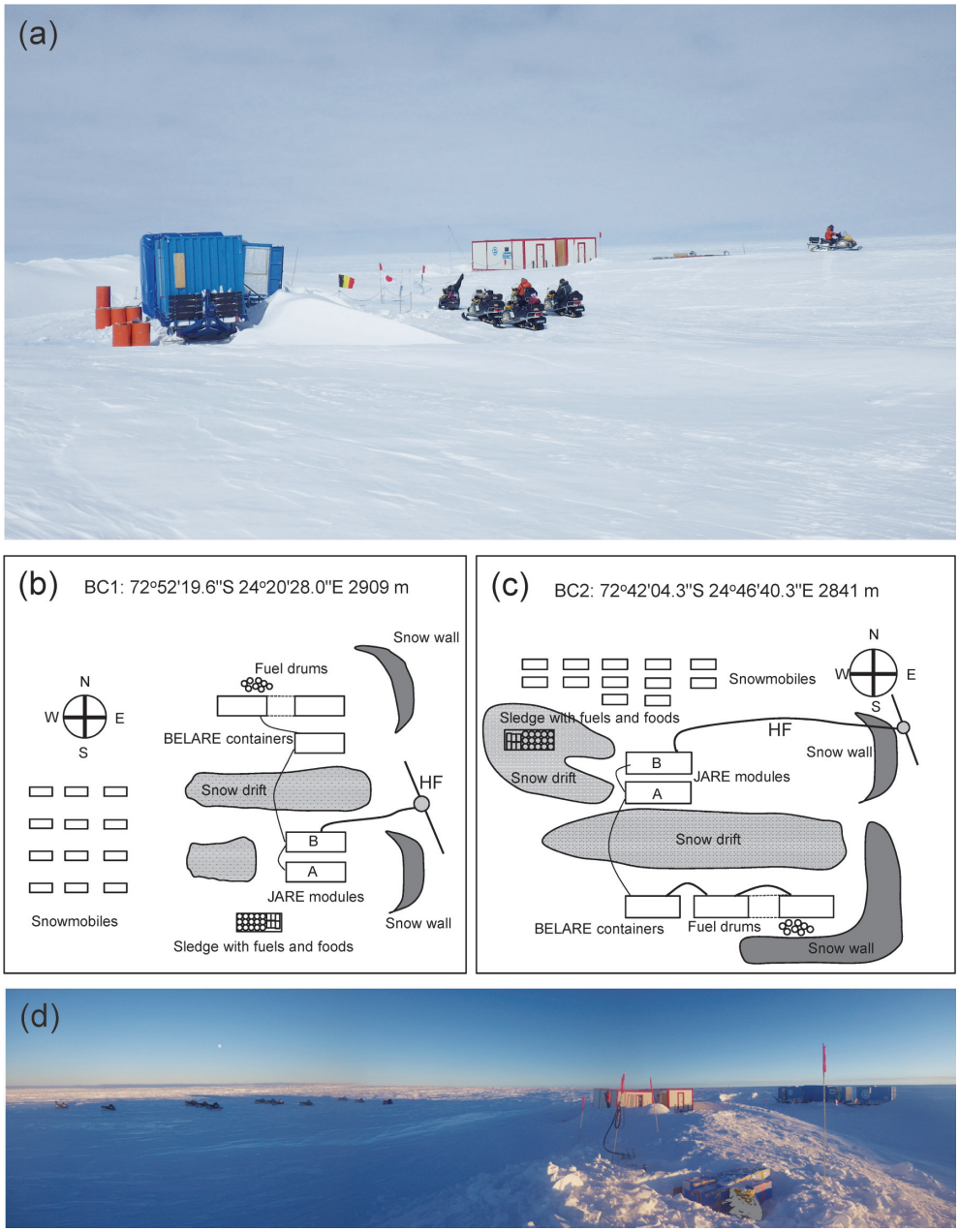


Fig. 7. Photos and plan views of BC1 and BC2. (a) BC1 viewed from the northwest. (b) and (c) Plan views of BC1and BC2, respectively. (d) BC2 viewed from the west.

expedition team travelled in single file because snow conditions were bad or because there were crevasses in the area. Some GPS data were not recovered, which explains why there are fewer than ten tracks in some areas where the snowmobiles were travelling in

Table 7. Detailed weather

Camp Name	Coordinates	Elevation	Observers	Time (LT)	Pressure (hPa)	Temperature (°C)	Weather
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2012/12/26 19:30	685.2	-21.3	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2012/12/27 10:30	682.4	-20.8	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/27 19:30	681.0	-21.2	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Yamaguchi	2012/12/28 8:05		-21.5	Blizzard
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/28 9:00	680.5	-21.0	Blizzard
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2012/12/28 12:00	681.4	-20.0	Blizzard
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/28 19:30	681.7	-20.4	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/29 8:30	676.1	-22.4	Blizzard
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/29 9:10	676.7	-22.0	Blizzard
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	All	2012/12/29 12:10	675.9	-20.5	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	All	2012/12/29 19:30	674.4	-20.0	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/30 9:30	680.2	-18.5	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/30 12:00	681.8	-18.7	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2012/12/30 19:30	684.7	-18.9	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/30 23:00	685.1	-19.0	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2012/12/31 9:00	683.2	-18.9	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/31 12:00	683.4	-18.3	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2012/12/31 19:30	684.2	-18.0	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/1 9:00	687.0	-16.2	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/1 19:30	687.8	-16.0	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/2 9:00	688.0	-15.1	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/2 19:30	686.4	-17.5	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/3 9:00	686.6	-16.9	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/3 19:30	688.6	-17.6	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/4 9:00	688.7	-17.2	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/4 19:30	687.8	-17.5	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/5 9:00	683.5	-18.3	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/5 11:00	682.9	-17.5	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/5 19:30	680.2	-17.8	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/6 9:00	680.0	-18.3	Fine

V-formation (Figs. 11 and 12).

Typical field occurrences of meteorites found in area B are shown in Fig. 10c. The highest concentration of meteorites was found in search area 3 of area B (Figs. 2, 11, and 12); the lowest concentration was in search area 12 (Figs. 2, 11, and 12). The weights (and dates found) of the seven largest meteorites from area B were as follows: 6.6 kg (10 January), 2.6 kg (4 January), 2.2 kg (10 January), 1.6 kg (3 January), 1.3 kg (6 January), 1.2 kg (3 January), and 1.1 kg (6 January), all of which were ordinary chondrites. In total, 368 meteorites were collected in area B (Table 5).

observations. (1/3)

Wind direction (magnetic)	Wind direction (corrected)	Wind speed (m/s)	Visibility	Cloud Cover (10)	Clouds (Upper)	Clouds (Middle)	Clouds (Lower)	Humidity (%)	Remarks
SE	E	11.5	~100 m	1	1Ci	-	-	71.2*	Snow drift (4 m high)
SE	E	10.3	~500 m	0	-	-	-	79.1*	Snow drift (4 m high)
SE	E	10.1	~50 m		-	2As	-	100*	Snow drift (3 m high)
-	-	15.0	-	-	-	-	-	-	Snow drift
SE	E	13.6	~20 m	-	-	-	-	92.1*	Snow drift
SE	E	11.0	~20 m	-	-	-	-	100*	Snow drift
SE	E	8.5	~50 m	8	8Cs	-	-	86.7*	Snow drift
SE	E	18.0	<10 m	-	-	-	-	68.0*	Snow drift
SE	E	18.0	~20 m	-	-	-	-	88.6*	Snow drift
SE	E	18.0	~10 m	-	?Cs	-	-	95.0*	Snow drift (10 m high)
SE	E	17.0	~10 m	-	?	-	-	94.5*	Snow drift (10 m high)
ESE	ENE	12.5	~10 m	-	-	-	-	92.1*	Snow drift (4 m high)
SE	E	8.5	~20 m	-	-	-	-	98.3*	Snow drift (4 m high)
SE	E	6.9	~50 m	4	4Ci	-	-	98.1*	Snow drift
SE	E	7.1	~500 m	10	-	10As	-	72.5*	Snow drift
SE	E	13.0	~50 m	7	7Ci	-	-	100*	Snow drift
SE	E	12.0	~100 m	2	2Ci	-	-	100*	Snow drift (10 m high)
SE	E	12.5	~50 m	-	-	-	-	95.1*	Snow drift (10 m high)
SE	E	8.0	~100 m	9	-	4Ac, 5As	-	100*	Snow drift (10 m high)
SE	E	4.8	>30 km	3	3Ci	-	-	81.2	-
ESE	ENE	7.5	>30 km	8	8Cs	-	-	83.7	Snow drift
SE	E	7.8	>30 km	1	1Ci	-	-	77.5	Snow drift
SE	E	10.0	>30 km	4	4Ci	-	-	78.9*	Snow drift
SE	E	6.5	>30 km	2	2Ci	-	-	78.6*	Snow drift
SE	E	9.2	>30 km	6	6Ci	-	-	81.1*	-
SE	E	8.8	>30 km	10	-	10As	-	78.9*	-
SE	E	12.5	>30 km	5	3Ci, 2Cc	-	-	83.3*	Snow drift
SE	E	12.0	~5 km	4	4Ci	-	-	75.3*	Snow drift (3 m high)
SE	E	12.8	~5 km	10	-	10As	-	77.5*	Snow drift (5 m high)
SE	E	10.3	>30 km	8	-	8Ac	-	85.2*	Snow drift

The schedule for a typical day (Table 6) was as follows. There was a pre-search briefing at 0930 LT. If weather conditions were good, we left BC at 1200 LT and spent 4 to 6.5 hours searching. On our return to BC, we refueled the snowmobiles for the next day. Gasoline drums were stored on a Lehman sledge, and the snowmobile gas tanks were filled using a high-speed pump. The JARE snowmobiles (Tundra Ski-Doo) usually required 10–20 L on a daily basis, but the larger BELARE snowmobiles (S7 Ski-Doo) required 20–30 L. The distance travelled is shown on Table 8.

After AY and TM checked the meteorites collected that day, they were stored in plastic

Table 7. Detailed weather

Camp Name	Coordinates	Elevation	Observers	Time (LT)	Pressure (hPa)	Temperature (°C)	Weather
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/6 19:30	680.8	-17.6	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/7 9:00	678.6	-18.4	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/7 19:30	677.8	-19.2	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/8 9:00	680.2	-17.2	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/8 12:00	680.3	-15.6	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/8 19:30	679.4	-18.2	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi+Yamaguchi	2013/1/9 9:00	679.2	-14.7	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/9 19:30	681.8	-15.0	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/10 9:00	684.6	-15.6	Cloudy
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/10 19:30	686.0	-16.5	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/11 9:00	686.1	-16.9	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/11 19:30	685.8	-20.1	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/12 9:00	685.2	-19.9	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/12 19:30	685.7	-17.6	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/13 9:00	686.2	-15.8	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/13 11:00	685.8	-14.4	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/13 19:30	682.9	-15.5	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/14 9:00	679.2	-16.5	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/14 19:30	675.5	-17.5	Fine
Nansen BC1	S72°52'19.4", E24°20'27.9"	2908	Mikouchi	2013/1/15 9:00	671.9	-20.7	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/15 19:30	678.1	-21.8	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi+Yamaguchi	2013/1/16 10:45	681.0	-22.2	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi+Yamaguchi	2013/1/16 19:30	682.4	-19.4	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	All	2013/1/17 9:00	681.4	-22.0	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi+Yamaguchi	2013/1/17 19:30	684.8	-18.2	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi+Yamaguchi	2013/1/18 9:00	683.7	-19.4	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi+Yamaguchi	2013/1/18 19:30	683.6	-19.1	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/19 9:00	684.1	-20.9	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi+Yamaguchi	2013/1/19 12:45	683.3	-18.9	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/19 19:30	684.3	-19.3	Cloudy

boxes outside the living quarters. We made our daily radio contact with PES (2000 LT) and SS (1950 LT), and reported the number of meteorites found. At 2030 LT, there was an evening briefing to plan the next day's search. The field guides then prepared the route to be followed, which was designed to maximize the area covered without exceeding a total travel distance of 48 km (Table 8), thus avoiding a long day in the harsh environment.

As health and safety matters at BC1, some team members suffered facial frostbite during the journey from PES to BC1, and there were several falls from snowmobiles in areas of sastrugi development, which were caused by the poor visibility and lack of visual contrast

observations. (2/3)

Wind direction (magnetic)	Wind direction (corrected)	Wind speed (m/s)	Visibility	Cloud Cover (10)	Clouds (Upper)	Clouds (Middle)	Clouds (Lower)	Humidity (%)	Remarks
SE	E	5.9	>30 km	1	1Ci	-	-	67.9*	-
SE	E	6.8	~1 km	10	-	10As	-	85.0*	-
SE	E	7.9	>30 km	0	-	-	-	72.4*	-
SE	E	6.6	~100 m	10	-	10Ns	-	100*	-
SE	E	6.8	1~2 km	10	-	10As	-	78.9*	-
SE	E	6.5	~100 m	10	-	10Ns	-	79.7*	-
E	NE	3.4	~5 km	10	-	10Ns	-	84.3*	-
ENE	NNE	2.1	~5 km	9	-	9Ns	-	89.1*	-
SE	E	5.7	>30 km	10	-	10Ns	-	94.4*	-
SE	E	4.3	>30 km	1	1Ci	-	-	81.3*	-
SSE	ESE	9.2	>30 km	0	-	-	-	89.5*	Snow drift
S	SE	12.6	~5 km	0	-	-	-	82.4*	Snow drift
SSE	ESE	15.0	~100 m	0	-	-	-	84.4*	Snow drift (3 m high)
SSE	ESE	13.9	~1 km	0	-	-	-	80.4*	Snow drift
SSE	ESE	11.1	>30 km	0	-	-	-	77.8	-
SE	E	9.6	>30 km	0	-	-	-	70.4	-
SSE	ESE	10.4	>30 km	0	-	-	-	74.1	-
SSE	ESE	13.1	>30 km	5	5Cs	-	-	78.1	-
SSE	ESE	10.9	>30 km	0	-	-	-	70.5	-
SSE	ESE	11.1	~5 km	0	-	-	-	83.2	-
SE	E	10.6	~100 m	7	7Ci	-	-	98.9*	Snow drift (3 m)
SE	E	10.5	~20 m	-	-	-	-	100*	Snow drift (5 m)
SE	E	11.1	~50 m	-	-	-	-	90.7*	Snow drift (5 m)
SE	E	14.5	~5 m	-	-	-	-	100*	Snow drift (5 m)
SE	E	11.6	~30 m	9	-	9Ns	-	94.1*	Snow drift (5 m)
SE	E	13.5	~10 m	-	-	-	-	100*	Snow drift (5 m), Wind: >13.5 m/s
SE	E	13.1	~30 m	10	-	10Ac	-	94.2*	Snow drift (3 m)
ESE	ENE	10.3	~100 m	10	-	10Ac	-	94.9*	Snow drift (3 m)
SSE	ESE	11.2	~100 m	6	3Ci	3Ac	-	100*	Snow drift (3 m)
ESE	ENE	9.6	~200 m	10	-	10As	-	99.2*	Snow drift (3 m)

during snow drifts or cloudy weather. There was only one (minor) injury related to these falls. One member of the BELARE team suffered shoulder pain after a fall and required one day of rest (13 January).

On the morning of 14 January, the step at the entrance to JARE module A was completely buried by a snow drift; it took about four hours to uncover the step. The weather was too bad for fieldwork, so meteorites ready for transport were packed and our move to area C was considered. The decision was made to give priority to the northern part of area C, because a previous search (JARE-29) indicated it to be the most promising area. New

Table 7. Detailed weather

Camp Name	Coordinates	Elevation	Observers	Time (LT)	Pressure (hPa)	Temperature (°C)	Weather
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/20 9:00	685.8	-21.2	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/20 19:30	687.3	-20.7	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/21 9:00	686.2	-21.8	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/21 19:30	685.2	-20.1	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/22 9:00	684.6	-20.7	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/22 19:30	684.7	-19.2	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/23 9:00	681.9	-20.7	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/23 19:30	680.4	-21.2	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/24 13:30	677.7	-20.5	Blizzard
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/24 19:30	676.4	-21.1	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847					
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/25 14:00	678.2	-20.1	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/25 19:30	678.8	-20.5	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/26 9:00	675.6	-22.1	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/26 19:30	674.5	-22.4	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/27 9:00	676.4	-25.0	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/27 19:30	678.1	-22.9	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/28 9:00	680.8	-22.7	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/28 19:30	684.1	-23.9	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/29 8:00	684.7	-21.5	Cloudy
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/29 19:30	682.0	-23.2	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/30 9:00	676.7	-25.4	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/30 19:30	672.8	-27.1	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/31 12:50	673.3	-23.4	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/1/31 19:30	675.5	-25.0	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/2/1 9:00	679.1	-25.3	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/2/1 19:30	679.9	-23.1	Fine
Nansen BC2	S72°42'4.14", E24°46'40.08"	2847	Mikouchi	2013/2/2 6:20	676.6	-27.0	Fine

Refer Imae *et al.* (2012) for the symbols used for clouds.

route coordinates were sent to PES, and the revised search plan was agreed by Alain Hubert. The rest of the day was spent packing and preparing for the move to area C. At 0400 LT on 15 January, Alain Hubert, Kristof Soete, and David Rigotti arrived at BC1 with two Prinoth snow tractors, having travelled overnight from PES. At around 0900 LT on 15 January, the clearing of snow dunes around the camp by the snow tractors began. The members left BC1 on ten snowmobiles at 1130 LT (about one hour before the snow tractors' departure), for a final two hours of meteorite searching in area B (search area 1, no meteorites found), before moving on to area C.

Weather conditions deteriorated in the afternoon, with increasing snow drifts and wind.

observations. (3/3)

Wind direction (magnetic)	Wind direction (corrected)	Wind speed (m/s)	Visibility	Cloud Cover (10)	Clouds (Upper)	Clouds (Middle)	Clouds (Lower)	Humidity (%)	Remarks
SE	E	11.1	~100 m	10	-	10As	-	99.6*	Snow drift (3 m)
SE	E	8.8	>30 km	9	4Ci	5As	-	79.4*	Snow drift (3 m)
SE	E	13.4	~100 m	7	4Ci, 3Cs	-	-	91.2*	Snow drift (3 m)
SE	E	10.6	~200 m	9	3Ci	6Ns	-	83.1*	Snow drift (3 m)
SE	E	14.1	~100 m	9	2Ci	7As	-	95.1*	Snow drift (3 m)
SE	E	10.7	~500 m	6	6Ci	-	-	100*	Snow drift
SE	E	14.2	~200 m	1	1Ci	-	-	91.5*	Snow drift (3 m)
SE	E	15.8	~10 m	0	-	-	-	95.5*	Snow drift (5 m)
SE	E	12.5	~10 m	-	-	-	-	100*	Snow drift (5 m)
SE	E	12.3	~10 m	10	-	10Ns	-	95.4*	Snow drift (5 m)
		20.0							
SE	E	11.1	~20 m	10	-	10Ns	-	100*	Snow drift (5 m)
SE	E	11.3	~20 m	10	-	10Ns	-	99.8*	Snow drift (5 m)
SSE	ESE	15.2	~50 m	10	-	10As	-	86.1*	Snow drift (5 m)
SSE	ESE	14.5	~50 m	0	-	-	-	100*	Snow drift (5 m)
SSE	ESE	12.8	~100 m	0	-	-	-	99.5*	Snow drift (3 m)
SE	E	9.1	>30 km	0	-	-	-	78.2	Snow drift
SE	E	7.2	>30 km	1	1Ci	-	-	89.1	Snow drift
SSE	ESE	5.1	>30 km	0+	Ci	-	-	82.7	Snow drift
SE	E	2.5	>30 km	10	-	10As	-	81.2	-
SSE	ESE	4.8	>30 km	0+	-	Ns	-	84.3	-
SSE	ESE	8.8	~10 km	2	-	2Ac	-	95.2	Snow drift
SSE	ESE	11.9	~10 km	0	-	-	-	85.2	Snow drift
SSE	ESE	8.9	>30 km	0	-	-	-	73.6	-
SE	E	8.4	>30 km	0	-	-	-	67.4	-
SE	E	4.3	>30 km	0	-	-	-	85.9	-
-	-	0.0	>30 km	0	-	-	-	76.5	-
SE	E	5.5	>30 km	2	2Ci	-	-	77.2	-

The trip from BC1 to BC2 took 5.5 hours (route shown in Fig. 1c). There was a technical problem with one of the snowmobiles (driven by YA), which we were able to fix (see also Section 6.4.4), and the ten members arrived at BC2 at 1630 LT. Visibility had deteriorated to about 5 m by the time we reached BC2, and the wind was strong, so an emergency tent was set up for shelter while we waited for the support team to arrive with the snow tractors, about 20 minutes later. The JARE and BELARE living quarters were ready by 1730 and 1830 LT, respectively, and the weather continued to deteriorate.

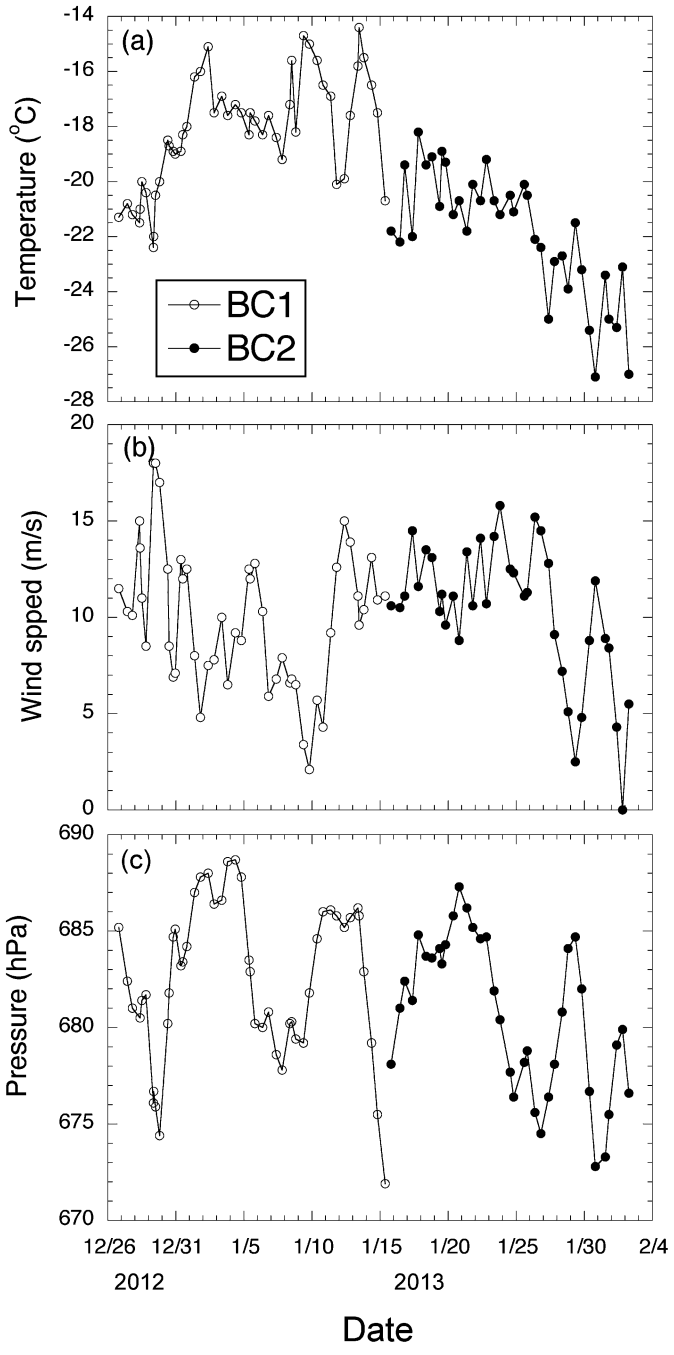


Fig. 8. Temperature, wind speed, and atmospheric pressure observed daily at 0900 and 1930 LT from 12 December 2012 to 2 February 2013. The raw data are shown in Table 7.

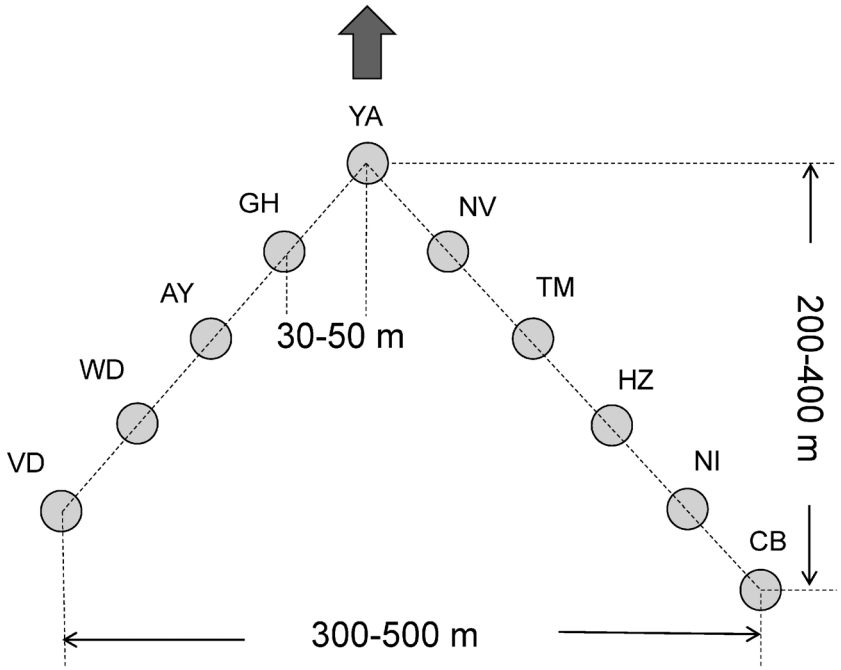


Fig. 9. Schematic plan view of the V formation of snowmobiles (circles) during meteorite searches. The arrow shows the direction of movement. Initials of expedition members (see Table 1) are marked beside their position in the formation.

6.2. Meteorite search in area C

The remainder of our time on the ice field was meteorite search in area C staying at BC2 (72°42′04.3″S, 24°46′40.3″E; 2841 m elevation) in the northeastern Nansen Ice Field (Fig. 1d). As it had been decided to focus on the northern part of area C, BC2 was set up about 10 km north of the planned position (Fig. 1d). However, after we had set up at BC2 (Fig. 7c and d), blizzard conditions persisted for 12 consecutive days. During the worst period, visibility was less than 5 m, severely restricting outdoor activities. Even though the JARE and BELARE living quarters were separated by only 30 m (Fig. 7c), movement of team members between them was kept to a minimum during this period. The arrangement of living quarters at BC2 (Fig. 7c) was the reverse of that at BC1 (Fig. 7b); JARE modules at BC2 were on the northern side of the site rather than the southern side, as at BC1. The Lehman sledge used for storage of fuel and food was west of the JARE modules (Fig. 7c), and was completely buried by a snow drift for the 12 days of the blizzard (Fig. 7d). The sledge had to be uncovered for access to food, fuel for the generator and snowmobiles, and stored meteorites. The sledge was eventually pulled out by one of the Prinoth snow tractors at the end of our stay at BC2. The extent of the snow drifts after the blizzard at BC2 is shown in Fig. 7c. Snowmobiles were parked about 100 m north of the living quarters (Fig. 7c) and were not seriously affected by snow drifts.

Twice daily weather observations by the JARE team at BC2 provided the following data (Table 7 and Fig. 8). Temperatures were between −27.1℃ and −18.2℃ (average −21.9℃),

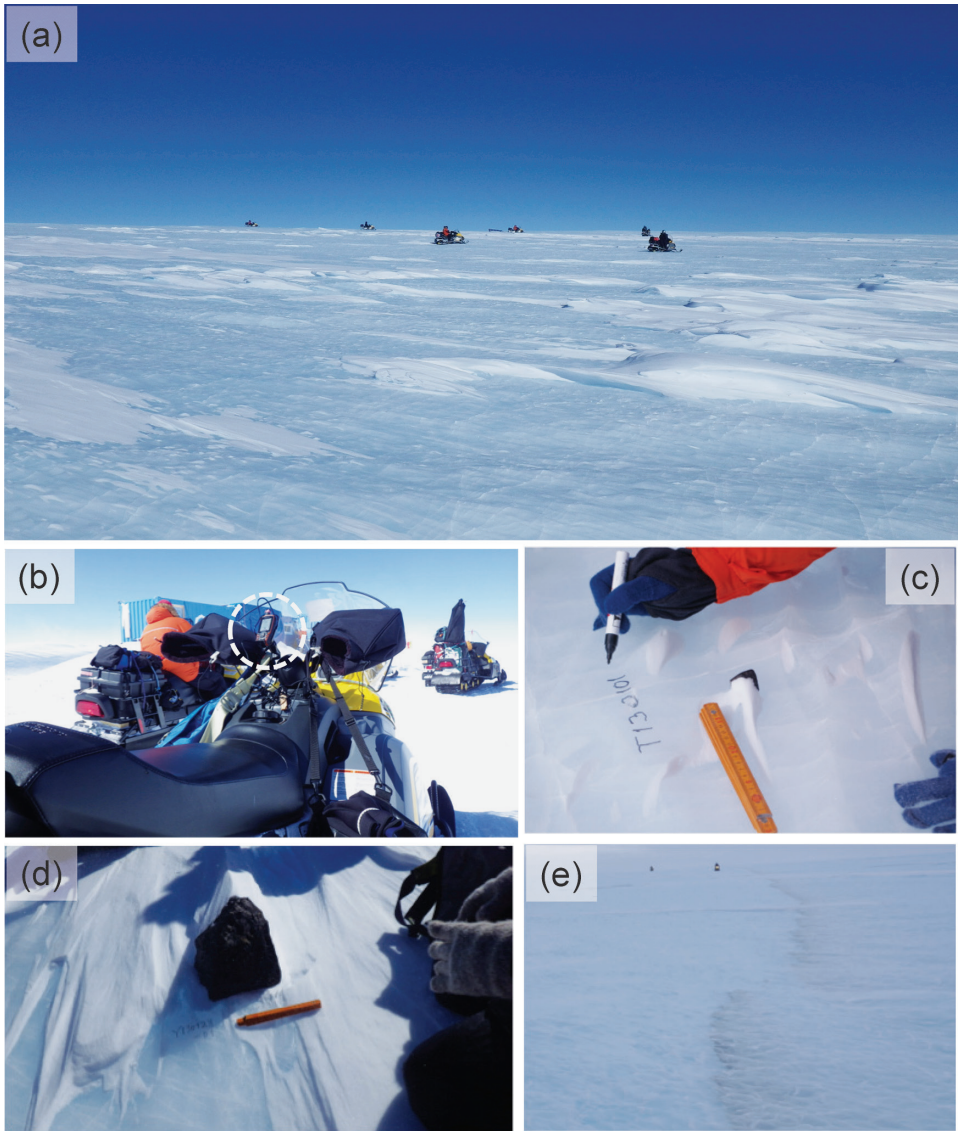


Fig. 10. Photos taken on the Nansen Ice Field expedition. (a) Photo during the meteorite search. (b) Hand-held GPS unit (within a circle) for navigation mounted on snowmobiles. (c) Preparing to photograph a chondritic meteorite found by TM on 1 January. (d) The largest meteorite found during the expedition (28 January), an ordinary chondrite weighing about 18 kg. (e) Dirty ice band bearing a volcanic ash deposit in area C.

wind speeds were 0.0–15.8 m/s (average 10.6 m/s), and atmospheric pressure was 672.8–687.3 hPa (average 680.6 hPa). During our stay at BC2 (15 January to 2 February), the weather conditions were very bad. Outside work was possible on only four days: three days of meteorite searches and one day to return to PES. JARE and BELARE team members had dinner together more often than the once-a-week average during this period of bad

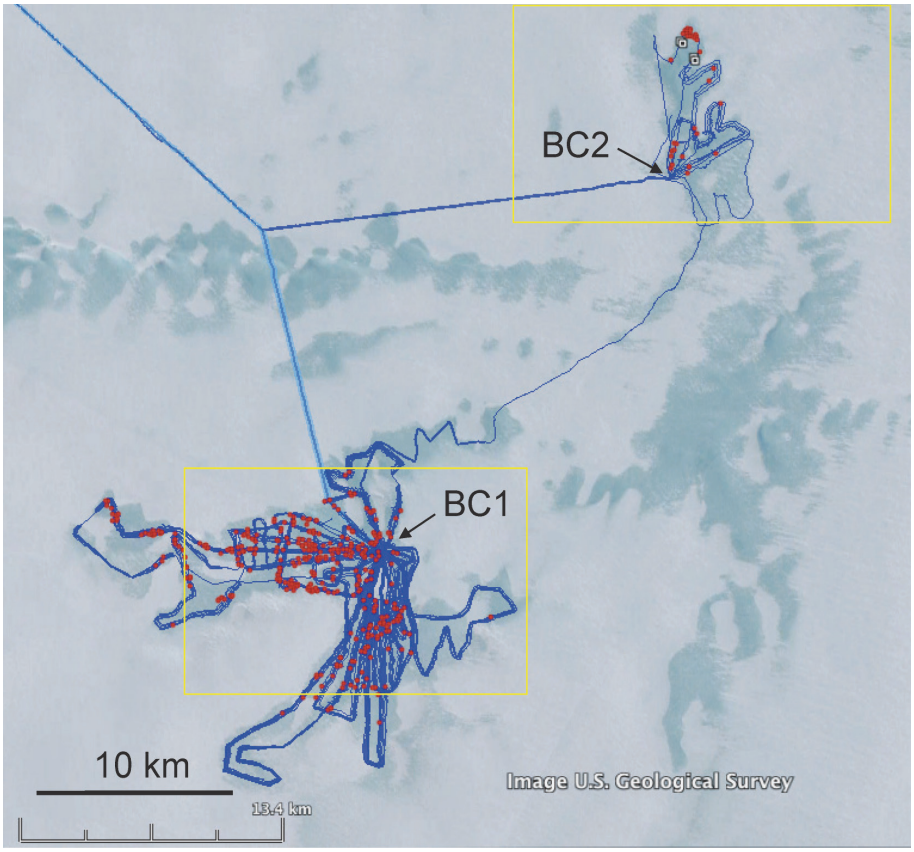


Fig. 11. Map (Google Earth) showing snowmobile routes (blue line) and locations of meteorites (red points) found in areas B and C. Sampling locations of ice bearing volcanic ash (black dotted circles) in area C are also indicated. The close-up views of the rectangular areas are shown in Fig. 12.

weather. The low temperature and blizzard conditions caused technical problems with two snowmobiles, which required us to use the two backup snowmobiles thereafter. During the stay at BC2, snow drifts accumulated regularly at the entrance to JARE module B, obstructing the door and blocking the flow of exhaust gases from the generator. It was often necessary to shovel snow away from the entrance to the module.

In total, 56 meteorites were collected in area C (Figs. 11 and 12). The largest meteorite collected during the entire expedition was from area C (about 18 kg; Fig. 10d). The second largest meteorite from area C weighed 4.1 kg (found on 29 January). However, the concentration of meteorites in area C was considerably lower than that in area B. The detailed tracks of the snowmobiles and the locations of the meteorites are shown in Figs. 11 and 12.

After completion of the meteorite search on 30 January, a band of dirty ice was sampled (Figs. 10e, 11, and 12). Naraoka *et al*. (1991) sampled ice at many locations on the Nansen Ice Field and concluded that most of the dirty layers represented volcanic ash deposits. A few kilograms of dirty ice were collected, which can be used for further study

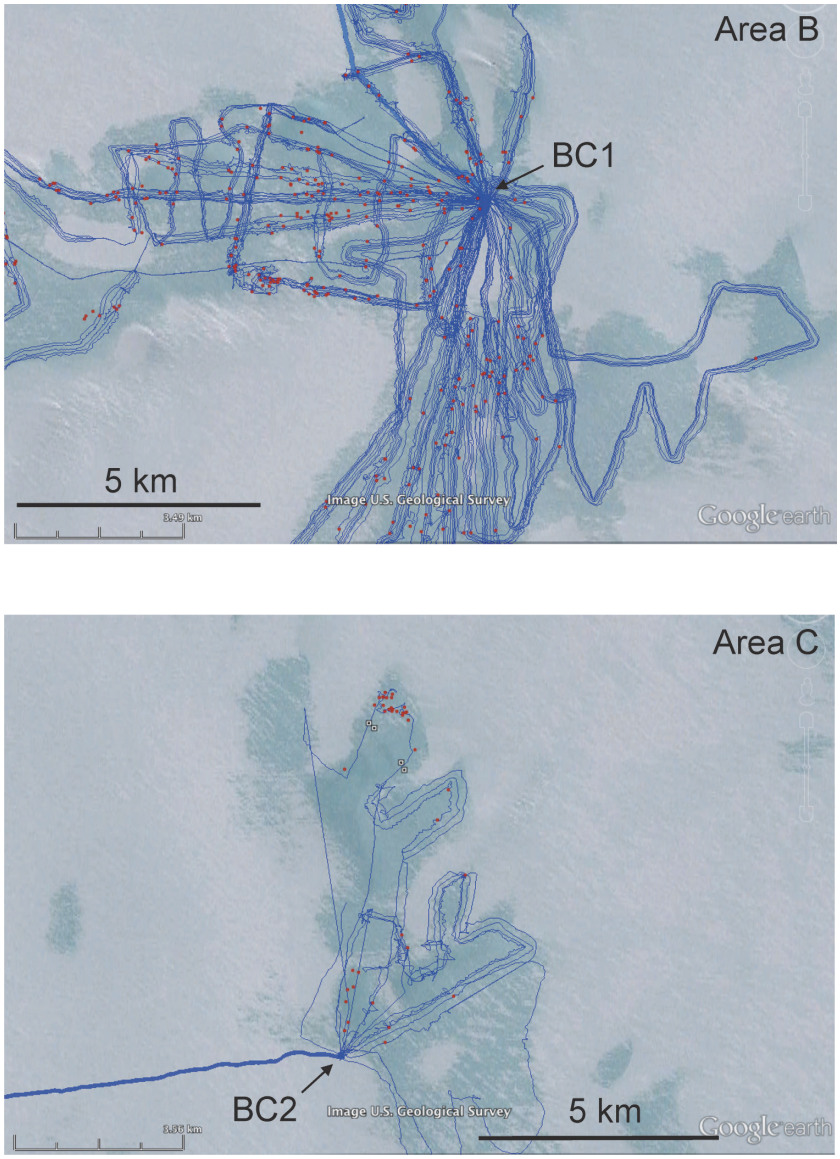


Fig. 12. Close-up view of area B and C in Fig. 11. The recovered 412 points among collected 424 in total meteorites are plotted. Map (Google Earth) showing snowmobile routes (blue line) and locations of meteorites (red points) found in areas B and C. Individual snowmobile routes are also indicated.

when required.

We prepared for our return to PES on 31 January and 1 February. The most important tasks were to pack the meteorites, check the list of samples, and remove snow from the fuel sledge, which was completely buried by snow. We returned to PES, in very good weather, on 2 February. The trip took 4.5 hours, and one meteorite was found along the way.

Table 8. Daily distances (km) driven by snowmobiles.

Snowmobile (abbreviation of the driver)	S7 and JARE 51-4 (YA) *	JARE 51-8 (NI)
26 December 2012	122	119
27 December 2012	10	-
28 December 2012	-	-
29 December 2012	-	-
30 December 2012	-	-
31 December 2012	5	-
1 January 2013	27	28
2 January 2013	29	31
3 January 2013	44	39
4 January 2013	41	37
5 January 2013	19	21
6 January 2013	20	19
7 January 2013	11	11
8 January 2013	-	-
9 January 2013	43	37
10 January 2013	46	48
11 January 2013	25	28
12 January 2013	-	-
13 January 2013	35	37
14 January 2013	-	-
15 January 2013	35	38
16 January 2013	-	-
17 January 2013	-	-
18 January 2013	-	-
19 January 2013	-	-
20 January 2013	-	-
21 January 2013	-	-
22 January 2013	-	-
23 January 2013	-	-
24 January 2013	-	-
25 January 2013	-	-
26 January 2013	-	-
27 January 2013	-	-
28 January 2013	20	19
29 January 2013	29	33
30 January 2013	35	18
31 January 2013	-	-
1 February 2013	-	-
2 February 2013	122	122
Total	718	684

* YA used Ski-doo S7 from 26 December 2012 to 15 January 2013, and JARE 51-4 from 28 January 2013 to 2 February 2013.

6.3. Summary: meteorites found and weather conditions on the Nansen Ice Field

We estimated that we would recover 270 meteorites from area B, but actually collected 368. However, for area C we estimated finding 120 meteorites but collected only 56, and this was because we were unable to search the southern part of the area. The final number

of meteorites collected was 424, which is close to the pre-expedition estimate of about 390 given in Section 3.4.3. The total weight of meteorites recovered was about 70 kg, which was much greater than the amount recovered by previous expeditions to area A in 2010–2011 (*ca*. 6 kg) and to the Balchen Ice Field in 2009–2010 (*ca*. 13 kg). The tracks and locations of meteorites obtained by hand-held GPS will be useful for planning future expeditions and provide basic data that will help to clarify the meteorite concentration mechanism.

The minimum temperature during the expedition was −31℃, which was an unscheduled temperature reading made with a digital temperature meter in the early morning of 31 January (therefore not shown in Table 7 and Fig. 8). The same temperature was also recorded (unscheduled) by the Kestrel 4500 instrument at around midnight on January 30. The temperature decreased considerably after the middle of January, and during the bad weather of 15–26 January, wind speeds were very high and visibility was very poor.

6.4. Problems encountered during the expedition

6.4.1. Snowmobiles

There were several snowmobile breakdowns during the course of the expedition. On 2 January, JARE snowmobile no. 49-4 (used by a BELARE team member) had to be towed back to BC1 by another snowmobile to repair a broken sprocket. Following the blizzard at BC2 (28 January onwards), several snowmobiles could not be driven, and it took several days to repair them. Three snowmobiles broke down over a short period of time during the meteorite search on 28 January. The V-belts were removed and the drive pulleys were released from these snowmobiles so they could be towed back to BC2 by the other snowmobiles.

6.4.2. Heaters in JARE modules

Two sets of diesel-fuelled heaters (a Webasto FF heater of an Air Top Evo 3900 type) were used in each JARE module. At BC1, one heater in each module broke down, probably because of their use at an elevation above 2200 m (not guaranteed by the manufacturer). At BC2, all of the JARE heaters failed. Fortunately, BELARE was able to provide a spare heater (a 3.3 kW STANLEY stove) for JARE. Without this spare heater, the failure of the JARE heaters would have been a very serious problem.

6.4.3. Other problems in JARE modules

Significant frost in the bedrooms of both JARE modules was problematic. An increase in the concentration of carbon monoxide (up to 52 ppm) was detected by the sensor when the JARE members used the cassette gas stove instead of the electric hot plate.

6.4.4. Danger caused by periods of poor visibility

The weather and visibility deteriorated during the move from BC1 to BC2. During the trip, a metal component of the caterpillar track of a snowmobile (S7 Ski-Doo, driver YA) broke, and this snowmobile was towing a rescue sledge in the last position of the convoy. This damaged snowmobile (S7 Ski-Doo) was left behind, having checked the position with a hand-held GPS. (The abandoned snowmobile was later picked up by the support team.) The rescue sledge was then transferred to another snowmobile (Ski-Doo JARE 51-8, driver NI), and YA rode with HZ on the snowmobile (Ski-Doo JARE 49-4). The snowmobile (Ski-Doo JARE 51-8), now towing the rescue sledge, was in the second to last position of the convoy. The last snowmobile (Ski-Doo JARE 49-4 with YA and HZ) in the convoy

contacted NI by radio, and informed them of the problem that a pin connecting the towing sledge was disconnected with the snowmobile (JARE 51-8) due to the accidentally released pin.

During the recovery operation, NI called the field assistant (CB) leading the convoy and CB stopped the convoy and drove back to assist. During this period, three members (YA, NI, and HZ) were separated from the main party by about 1–2 km. Visibility at the time was less than 10 m. Following snowmobile tracks would have been difficult because there were no clear snowmobile tracks on the bare ice area. However, CB had entered his position in his GPS before leaving the main party, so the three members were able to re-join the main party. This was a very important learning experience regarding the dangers of bad visibility.

6.4.5. Medical matters

Many of the expedition team members suffered minor frostbite during the expedition, mainly on the cheeks and fingertips. Several instances of frostbite on the face were experienced by BELARE members because they wore helmets that were not suitable for this type of weather; i.e., they were not fully closed and did not protect the face from cold winds. The affected team members made a full recovery after leaving Antarctica. On a few occasions, snowmobile rollovers occurred during meteorite searches in areas of sastrugi. On 27 January at BC2, a team member suffered an asthma attack as clearing snow from a snowmobile while facing into the strong wind, but recovered after taking medication. The effects of undertaking strenuous activity in a breathtaking wind should not be underestimated.

7. Post-expedition activities

7.1. Retrieval of living quarters

After the expedition team returned to PES, Alain Hubert and Kristof Soete of the IPF support team departed for the ice field to collect the living quarters, returning two days later. Expedition members then cleaned the living quarters and prepared inventories of their contents.

7.2. Shipment of meteorites to NIPR

It was essential that the meteorites remained frozen during transport to NIPR. This was achieved as follows. On the Nansen Ice Field, meteorites were packed into polyethylene and cloth bags, and stored with refrigerants in three cool boxes (Fig. 13a and 13b), each of which was covered with expanded polystyrene and then placed in a corrugated cardboard box. The total weight of the three parcels (excluding cool boxes) was 74.1 kg (#1, 14.4 kg; #2, 16.4 kg; #3, 43.3 kg). Subtracting the weights of polyethylene and cloth bags, the approximate total mass of the collected meteorites was thus estimated to be about 70 kg. The meteorites were transported from the Nansen Ice Field to PES by Lehman sledge (Fig. 13c). During the days before departure from PES (2 to 8 February), the cool boxes were stored in a freezer. They were removed from the freezer immediately before the 1.5 hour flight to Novolazarevskaya Air Base on 8 February. Within 30 minutes of arrival at Novolazarevskaya, the meteorites were loaded onto a DROMLAN (Ilyushin-76) flight to

Fig. 13. (a) and (b) Packing meteorites into cool boxes for transport from the Nansen Ice Field to the ALCI warehouse in Cape Town. (c) Cool boxes with outer insulation layer.

Cape Town. Only two of the three cool boxes were placed in a freezer in the Ilyushin warehouse due to the limited capacity. And the one was stored in the usual warehouse. At Cape Town Airport (on 8 February), they were immediately transferred to a freezer in the ALCI warehouse.

The JET8 cargo company transported the meteorites from Cape Town to NIPR. Before departure, they removed the meteorites from the cool boxes used thus far and placed them in three 5-cm-thick insulated cardboard boxes (internal dimensions 790 × 400 × 340 mm, 107 L) lined with solid carbon dioxide. The meteorites arrived at NIPR on 5 March, after the supply of additional solid carbon dioxide at Narita airport on 28 February.

At NIPR, we found that the dirty ice samples stored with the collected meteorites had not melted at all, indicating that the samples were frozen throughout their transport from the Nansen Ice Field to the freezer in NIPR. After defrosting the collected meteorites under low-pressure conditions, the classification and curation of the meteorites began in the laboratory at NIPR.

7.3. Return of other supplies and equipment

Approximately 500 kg of material was sent by surface shipment from the ALCI warehouse in Cape Town to Tokyo, and this arrived at the NIPR on 9 May.

7.4. Food supplies remaining after the expedition

Twelve plastic boxes of FD food (including five plastic boxes of emergency rations)

remained after the expedition. FD food was consumed for a total of 47 days and we had prepared food for 55 days plus 20 days for emergencies. As we had a lot of spare time during the bad weather, especially the 12 days from 16 to 27 January, the JARE team often used the ingredients instead of the routine FD food. The only portable food carried during meteorite searches was candies, because of the difficulty of eating other types of food without taking off gloves and goggles, which was inadvisable in the cold and often windy field conditions. Thus, two boxes of portable rations (sausage, salami, candy, and sweet jellied adzuki-bean paste) were also left over, as were some condiments and powder for making drinks. All remaining food (except FD food) was left in a container at PES for the next expedition.

8. Summary

1. We collected 424 meteorites with a total weight of about 70 kg. The heaviest meteorite was an ordinary chondrite weighing about 18 kg.
2. The number of meteorites collected was close to the forecast based on previous expeditions.
3. The meteorites collected during this expedition will be referred to as Asuka 12 meteorites.
4. The snowmobile tracks recorded by hand-held GPS units provide a clear picture of the areas searched and the distribution of meteorites found on the Nansen Ice Field.

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