—報告—
Report

A detailed record of the BELARE 2019–2020 meteorite recovery expedition on the Nansen Ice Field, East Antarctica

Steven Goderis[1], Mehmet Yesiltas[2], Hamed Pourkhorsandi[3], Naoki Shirai[4*], Manu Poudelet[5], Martin Leitl[5], Akira Yamaguchi[6], Vinciane Debaille[3] and Philippe Claeys[1]

2019–2020 年ベルギー南極観測隊による東南極ナンセン氷原における隕石探査報告

Steven Goderis[1]・Mehmet Yesiltas[2]・Hamed Pourkhorsandi[3]・白井直樹[4*]・Manu Poudelet[5]・Martin Leitl[5]・山口　亮[6]・Vinciane Debaille[3]・Philippe Claeys[1]

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要旨:　2019–2020 年の夏期に，東南極セール・ロンダーネ山地南部においてベルギー南極観測隊（BELARE）により隕石探査を実施した．ナンセン氷原には，2020 年 1 月 15 日から 2 月 6 日まで 23 日間滞在し，採取した隕石の総数は 66 個，合計重量は約 8 kg であった．ナンセン氷原での隕石集積機構を解明するために，隕石の他に氷，火山灰層や岩石の破片も採取した．採取した隕石は，凍結したまま国立極地研究所に輸送された．これら採取した隕石が国際隕石学会の隕石命名委員会に認可された後，分類データは Meteorite Newsletter で公開される．

キーワード:　隕石探査，南極隕石，ナンセン氷原

Abstract:　This report summarizes the Belgian Antarctic Expedition (BELARE) 2019–2020 meteorite search and recovery expedition near the Sør Rondane Mountains of East Antarctica during the 2019–2020 field season. This expedition took place from 15 January to 6 February 2020 within the area defined as "C" of the Nansen Ice Fields (S72°38'–72°48'S, 24°35'–25°06'E). The expedition team consisted of four scientists and two field guides, who systematically searched the ice field area and collected 66 meteorites. The total weight of the meteorites was determined to be ～8 kg. In addition to meteorites, blue ice samples, volcanic ash layers, and wind-blown terrestrial rock fragments were collected from the area to study in detail the nature of the mechanisms concentrating meteorites on the Nansen Ice Fields. The recovered meteorites were transported in a frozen state to the National Institute of Polar Research, Japan for dry-thawing and subsequent classification.

[1] ブリュッセル自由大学．Analytical-, Environmental-, and Geo-Chemistry, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium.
[2] クルクラーレリ大学．Faculty of Aeronautics and Space Sciences, Kirklareli University, Kirklareli, Turkey 39100.
[3] ブリュッセル自由大学．Laboratoire G-Time, Université Libre de Bruxelles, CP 160/02, 50, Av. F.D. Roosevelt, 1050 Brussels, Belgium.
[4] 東京都立大学理学研究科化学専攻．Department of Chemistry, Tokyo Metropolitan University, 1-1 Minamiosawa, 19 Hachioji, Tokyo 192-0397.
[5] 国際極地基金．International Polar Foundation, Rue des vétérinaires, 42c/1 1070, Brussels, 21 Belgium.
[6] 国立極地研究所．National Institute of Polar Research, 10-3 Midoricho, Tachikawa, Tokyo 190-8518.
* Corresponding author. E-mail: shirai-naoki@tmu.ac.jp

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The newly collected meteorites will be presented to the Meteorite Nomenclature Committee of the Meteoritical Society for approval, after which their classification will be published in the Meteorite Newsletter.

Keywords: Meteorite search, Antarctic meteorite, Nansen Ice Field

1. Introduction

The Sør Rondane Mountains and blue ice fields surrounding these mountains in East Antarctica have previously been visited by research expedition teams to collect meteorites. One of the first expeditions to East Antarctica was JARE-10, the 10th Japanese Antarctic Research Expedition, which recovered 9 meteorites from the ice fields surrounding the Yamato Mountains (Yoshida *et al*., 1971). The meteorites collected around the Sør Rondane Mountains (mainly from the Nansen and Balchen Ice Fields) are called Asuka meteorites. The first Asuka meteorites were found by accident in 1986 by a glaciological party of JARE-27 on bare ice fields near Mt. Balchen (Nishio *et al*., 1987). During the 1987–1988 and 1988–1989 field seasons, JARE-29 and JARE-30 team members visited the Nansen and Balchen Ice Fields and recovered nearly 2000 meteorites (Naraoka *et al*., 1990; Yanai, 1993). Following this expedition, the nomenclature committee of the Meteoritical Society designated this region as an official meteorite dense collecting area (DCA), designated Asuka after the former Japanese research station in this area. All collected meteorites from this DCA are defined by the name Asuka (abbreviated as A), followed by the year of discovery and a number (e.g., A 87251). During the JARE-51 in the 2009–2010 field season with the participation of a Belgian researcher and logistical support from the Belgian Princess Elisabeth Antarctica (PEA) station, a total of 635 meteorites were recovered from the Mt. Balchen area (Kaiden *et al*., 2010). By systematically searching various sections of Nansen Ice Fields, the JARE and Belgian Antarctic Expedition (BELARE) joint expeditions recovered a total of 908 Asuka meteorites in the 2010–2011 and 2011–2012 seasons (Goderis *et al*., 2011; Tsuchiya *et al*., 2012; Imae *et al*., 2015). The Asuka meteorites include several large specimens such as A 87251 (46 kg) and A 12389 (18 kg), rare meteorites such as angrites (A 881371, A 12209), a lunar meteorite (A 881757), a shergottite (A 12325), unique carbonaceous chondrites (CH3: A 881020, A 881541, A 881691), a Rumuruti chondrite (A 881988), mesosiderites (A 87106, A 881154, and A 882023), 19 diogenites, 11 ureilites, 2 acapulcoites, and 2 ungrouped carbonaceous chondrites. During the 2018–2019 Antarctic season, 3 meteorites (A 18001, A 18002, and A 18003), classified as ordinary chondrites, were recovered from the area A of Nansen Ice Field by MY, as part of the 3rd Turkish Antarctic Expedition (TAE-III) (Yesiltas *et al*., 2019). All meteorite search expeditions in the vicinity of the Sør Rondane Mountains as well as the current repositories for the recovered meteorites are summarized in Table 1.

In this report, we report in detail on the BELARE 2019–2020 meteorite search and recovery expedition (BELAM), which took place between the 15 January and the 6 February 2020 within the area C of Nansen Ice Field and in which a Turkish scientist participated as part of the TAE-IV. The expedition team recovered 66 meteorites, totaling ～8 kg. The collected meteorites include carbonaceous chondrites, ordinary chondrites, and

Table 1. Previous and current meteorite search expeditions in the vicinity of the Sør Rondane Mountains and repositories.

Expedition*	Search Location	Field Season	Number and Weight of Recovered Meteorites	Current Repository+	Literature
JARE-27	Mt. Balchen	1986-1987	3 - 2.2 kg	NIPR	Nishio *et al.* (1987)
JARE-29	Mt. Balchen & Nansen	1987-1989	1897 - 375 kg	NIPR	Naraoka *et al.* (1990)
JARE-31	Mt. Balchen	1990-1991	48 - 10.6 kg	NIPR	Yanai *et al.* (1994)
JARE-51/BELARE-SAMBA	Mt. Balchen	2009-2010	635 - 13 kg	NIPR	Kaiden *et al.* (2010)
BELARE-SAMBA	Nansen A	2010-2011	218 - 6 kg	NIPR & RBINS	Goderis *et al.* (2011)
JARE-54/BELARE-SAMBA	Nansen B	2012-2013	424 - 70 kg	NIPR & RBINS	Imae *et al.* (2015)
TAE-III	Nansen A	2018-2019	3 - 64.4 kg	KirkU	Yesiltas *et al.* (2019)
BELARE-BELAM/TAE-IV	Nansen C	2019-2020	66 - 8.3 kg	NIPR & RBINS	

*JARE, Japanese Antarctic Research Expedition; BELARE, Belgian Antarctic Expedition; SAMBA, Search for Antarctic Meteorites, Belgian Activities; TAE, Turkish Antarctic Expedition; BELAM, Belgian Antarctic Meteorites.

+NIPR, National Institute of Polar Research; RBINS, Royal Belgian Institute of Natural Sciences; KirkU, Kirklareli Univeristy.

achondrites (notably HED meteorites), as identified in the field. These meteorites will be referred to as Asuka 19 meteorites. The average weight of each meteorite is ~120 g. The collected meteorites were securely packaged and transported in a frozen state to the National Institute of Polar Research (NIPR) in Tokyo, Japan. At the NIPR, the meteorites are dry-thawed in a controlled environment in order to avoid any contamination due to melting of ice/snow. Following the thawing process, each meteorite will be shared between Japan and Belgium. In addition, the expedition team members have priority access to the recovered meteorites for scientific research, as specified in the Memorandum of Understanding (MoU) signed by all parties involved.

2. Expedition members and their roles

The BELAM 2019–2020 expedition team consisted of four researchers in the fields of meteoritics, planetary sciences, or cosmochemistry, and two field guides, trained as medical doctor or paramedic. All six BELAM 2019–2020 team members and their roles are listed in Table 2.

3. Preparation for the expedition

3. 1. Pre-expedition meetings in Brussels and Cape Town

On 8 May 2019, BELARE 2019–2020 members (including MY, VD, and SG) met for the first time in Brussels at the headquarters of the International Polar Foundation (IPF) with the scientists and logistics staff to receive and exchange general information on BELARE 2019–2020, including the number of scientific teams, field guides, preliminary traveling dates, and the registration process for participation in the expedition. With regard to the BELAM 2019–2020 campaign, the length of the expedition to the Nansen Ice Field and the logistical support required were first discussed elaborately. This general meeting was preceded by shorter meetings between MY, SG, VD, and PC on 7 May in 2020 at both the Vrije Universiteit Brussel (VUB) and Université Libre de Bruxelles (ULB).

A second BELARE 2019–2020 meeting was organized at the IPF on 20 September 2019 (attended by HP and SG), with more detailed information regarding the various scientific projects, field guides, and cargo shipping. Particular attention was paid to the BELAM program and logistics, which included a detailed discussion with Alain Hubert of the IPF on the targeted search area on the blue ice fields.

The first BELAM 2019–2020 team meeting was organized in Cape Town, South Africa on 6 January 2020, after the arrival of all the scientific team members on 5 January. During various meetings in the following days, the schedule of the expedition was discussed after studying the targeted blue ice area of Nansen C (Figure 1-d) and considering the details presented by Imae *et al*. (2015). The main objective of recovering meteorites and sampling blue ice to better constrain the meteorite concentration mechanisms of the Nansen Ice Fields as a whole was discussed in great detail.

Table 2. *BELAM 2019–2020 joint meteorite search expedition team members, their affiliation and previous Antarctic experience.*

Team member	Nationality	Affiliation	Antarctic Experience	Responsibility
Steven Goderis (SG)	Belgium	Vrije Universiteit Brussel	Total of 5 expeditions	Team leader, planning, ice sampling, packaging.
Hamed Pourkhorsandi (HP)	Iran	Université Libre de Bruxelles	1st expedition	Samples, magnetic susceptibility measurements.
Mehmet Yesiltas (MY)	Turkey	Kirklareli University	Total of 2 expeditions	Weather observation, daily logs, packaging.
Naoki Shirai (NS)	Japan	Tokyo Metropolitan University	1st expedition	GPS, transportation.
Manu Poudelet (MP)	France	International Polar Foundation	Total of 2 expeditions	Logistics, communications.
Martin Leitl (ML)	Germany	International Polar Foundation	Total of 2 expeditions	Logistics, medical, mechanical problems.

3. 2. Dronning Maud Land Air Network (DROMLAN) flights

The Belgian, Japanese, and Turkish team members flew to Cape Town, South Africa independently using commercial airlines, from where DROMLAN operates flights to and from Antarctica. The flight schedules for outgoing (and return) flights from Cape Town to the Novolazarevskaya (Novo) Air Base (using a Boeing 757) and then to PEA Station (using a Basler Turbo) were arranged by the IPF staff members. The Antarctic Logistics Centre International (ALCI) briefing was organized on 8 January at 10:00 (UTC+2) to inform on general flight procedures, cargo requirements, polar clothing, and the general infrastructure at Novo.

3. 3. Itinerary

While the first departure on the Boeing 757 took place on 9 January (UTC+2), the airplane returned to Cape Town after approximately 3.5h of flight (reaching the point-of-no-return) due to (suddenly developed) poor weather conditions at Novo (total of 7 hours flight). The next and successful departure took place from Cape Town on 13 January at 10:00 (UTC+2) on an Ilyushin-76 airplane. After two hours of layover at Novo, the consecutive flight to PEA took place using a Basler Turbo airplane, which arrived at PEA on 13 January at 19:00 (UTC+1). A general discussion of the BELARE 2019–2020 scientific activities during the second part of the Antarctic season was organized on 14 January at 9:00 (UTC+1), led by Alain Hubert and other members of the IPF scientific and logistics staff. Details of the meteorite search and recovery expedition were further discussed during this meeting to ensure a safe and successful field campaign.

3. 4. Safety training

After arrival from Novo and before departure to the Nansen Ice Field, the pre-expedition safety training for the BELAM 2019–2020 team members took place near PEA. On 14 January, all team members participated in crevasse rescue training, by descending into a well-studied crevasse near PEA (S71.9170°, E23.5885°) and constructing a pulley-string system to extract each team member out of the crevasse in rotation. Before and after this crevasse rescue training technical details regarding the use of crampons as well as snowmobile driving and maintenance were reviewed. The team participated during the following afternoon and evening in presentation sessions on medical issues related to the cold Antarctic environment and high altitude (including first aid, rescue training, hypothermia, frostbite, and altitude sickness). Additional training and explanations were provided by the field guides once the team arrived at the base camp (area C of Nansen Ice Field).

3. 5. Logistics in Antarctica

At the PEA station, most of the expedition necessities had already been prepared by ML (fuel, containers, snowmobile, and communication devices) and MP (food, general equipment, and medical kits) between 5 and 10 January 2020. As a result, BELAM 2019–2020 team members and the IPF support team (Alain Hubert, Gigi Johnson-Amin, Louis Greindl, Pierre Dumont) were able to leave PEA for the Nansen Ice Field on 15 January 2020 at 9:30 (UTC+1). After 13 hours of travel, the convoy of two large snow vehicles (Prinoth snow tractors), each pulling 3 Lehmann sledges carrying living modules, fuel, food, and extra snowmobiles (Ski-Doo, BRP), arrived on the Nansen C Ice Field (at 22:30, UTC+1). Upon arrival, the "Nansen C" base camp (BC) was set up (S72.79754°, E24.86002°; elevation 3100 m) and the IPF support team returned to PEA with the two Prinoth snow tractors, one living module and an empty Lehmann sledge on 17 January. The team planned to spend approximately 3 weeks at the BC to search for meteorites within area C, based on the considered search area (Figure 1-d). After completion of the meteorite recovery mission, the return journey to PEA took place on the 6th of February. Upon returning to PEA, the team prepared to travel outbound, for which they first moved to the Perseus landing and departure airstrip near Romnœsfjellet. The flight to Cape Town took place on the 13th of February. The full BELAM 2019–2020 team arrived at their home countries in the period of 16 to 18 February 2020.

3. 6. Clothing

Outer clothes used during the meteorite search (snowmobile suits, snow boots, helmets, and crampons) were borrowed from the IPF, from the stock kept either at Cape Town or PEA. Other items such as base layer clothing, goggles, gloves, and balaclavas were prepared by the individual team members.

3. 7. Snowmobiles

The fuel requirement for snowmobiles was estimated based on the following assumptions: 6 snowmobiles traveling 50 km/day during 20 days with a fuel consumption of 3.5 km/liter/snowmobile requires ～1715 liters of fuel. The expedition foresaw a total of 1880 liters of fuel for the field work. The snowmobiles also require engine oil to operate. Oil consumption was estimated to be ～20 liters/snowmobile during the period of 20 days, for which a total of ～440 liters of engine oil was stored for use throughout the expedition.

3. 8. Heater

A total of 280 liters of JET-A1 fuel was brought to the base camp for the heating system (Webasto).

3. 9. Food

Twenty loaves of bread was estimated for 20 days to be consumed at breakfast. For lunch, 120 packs of instant soups and noodles, and 360 chocolate bars were brought. One hundred and twenty frozen meals for dinner were prepared at PEA. These numbers were estimated as for 6 persons per day during 20 expedition days. Plenty of fresh and dried fruits, vegetables, snacks, and nuts were also brought to the base camp.

4. Scientific matters

4. 1. Definition, division, and subdivision of search areas

Following previous expeditions to the Nansen Ice Field, three areas have been defined for meteorite searches on the Nansen Ice Field: areas A, B, and C (Figure 1-d). Areas A and B were previously searched by JARE-29 in 1987–1988 and 1988–1989 as well as BELARE 2010–2011 and JARE-54/BELARE 2012–2013 expeditions. Area C had been previously searched during JARE-29, while only the northern part had been covered by JARE-54/

BELARE 2012–2013. The remaining southern part of Nansen area C had thus not been searched in over 30 years. During this expedition, 3 weeks were dedicated to Nansen area C to cover the entire field for searching meteorites and collecting blue ice samples. A short excursion to Nansen area B also took place at the end of the 3 weeks to search for meteorites and terrestrial rocks in a previously encountered moraine. Another day trip allowed to collect additional ice samples from area A, which will be used to extend (or not) previously observed spatial patterns in the H and O isotopic compositions of Nansen area B across the entire Nansen Ice Field (Zekollari *et al*., 2019).

4. 2. Expected number of meteorite finds

The expedition 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; Imae *et al*., 2012). During the BELARE 2010–2011, 218 meteorites were collected from area A (Goderis *et al*., 2011), while 368 meteorites were recovered from area B and 56 from area C during JARE-54/BELARE 2012–2013 (Debaille *et al*., 2013; Imae *et al*., 2015). Assuming similar blue ice conditions and extraction efficiencies for each expedition, an approximate number of meteorites to be recovered was estimated based on the following ratios between the different areas and expeditions (i.e., 573:698:311 = 218:368:x), where x was the expected number of meteorites to be recovered from area C during the 2019–2020 season. Therefore, the expected number of meteorites for area C ranged from 118 to 164. Taking into account the number of meteorites that had already been recovered from the northern part of area C during JARE-54/BELARE 2012–2013, the expected number of meteorites for the remaining part of Nansen C ranged from 62 to 108.

5. Expedition log

A typical daily schedule on the Nansen Ice Field is summarized in Table 3. The duration of the BELAM 2019–2020 expedition was 31 days (Table 4). Of the 31 days in Antarctica, 9 days were spent at PEA (13 to 14 January and 6 to 13 February), and 22 days were spent on the Nansen Ice Field (15 January to 6 February, Table 4). Following the expedition, the BELAM 2019–2020 team left PEA at 8:00 UTC+1 on 12 February 2020, departed from Perseus on an Ilyushin-76 airplane, and arrived at Cape Town at 15:00 UTC+2 on 13 February 2020 after spending a single night at Novo.

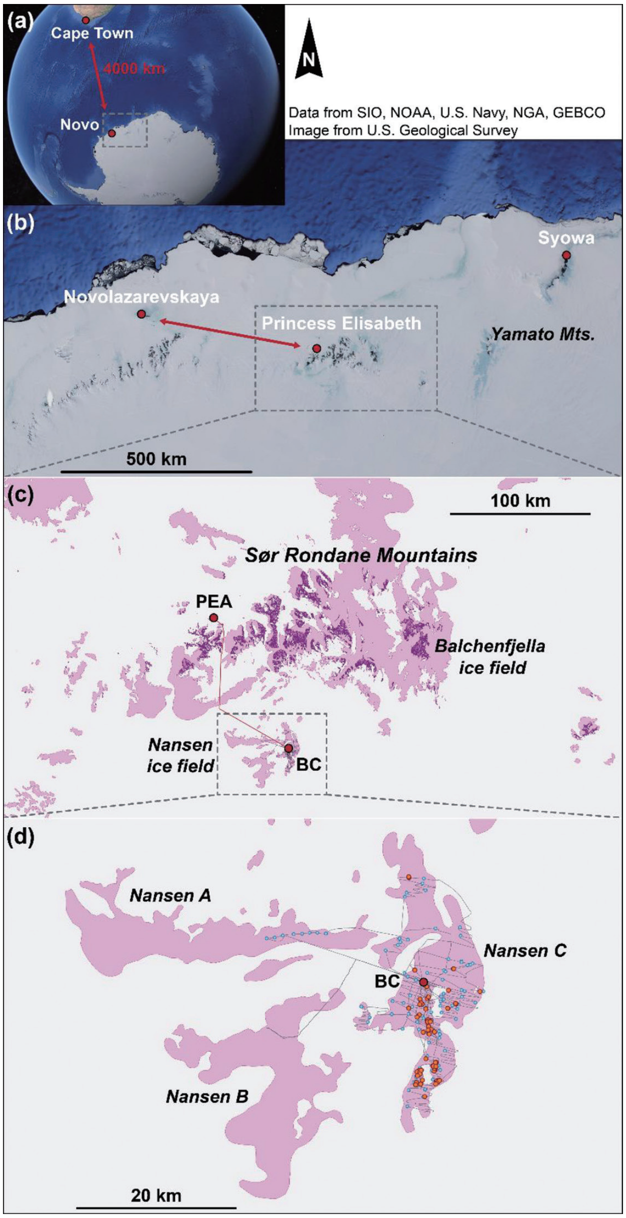

Fig. 1. Maps outlining the route of this expedition, from Cape Town to the Nansen Ice Field. (a) Cape Town to Novolazarevskaya Air Base (Novo). The area within the rectangle is enlarged in (b). (b) Novo to Princess Elisabeth Antarctica station (PEA). The area within the rectangle is enlarged in (c). (c) Sør Rondane Mountains and the Nansen Ice Field. "BC" denotes the basecamp setup in the Nansen Ice Field. The area within the rectangle is enlarged in (d). (d) Divisions of the Nansen Ice Field. Red and blue dots denote locations of meteorites and blue ice samples collected during the expedition, respectively. Solid grey lines highlight routes and tracks.

Table 3. Typical daily schedule at the Base Camp.

Time	Item
7:20	Weather observation (MY)
7:30 - 8:30	Breakfast (all members)
8:30	Weather observation (MY)
8:30 - 9:00	Briefing (all members)
9:00 - 10:00	Preparation for departure (all members)
10:00	Departure for meteorite search (all members)
10:00-17:00	Meteorite search (all members)
17:00 - 19:30	Daily tasks (all members)
19:30 - 20:30	Dinner (all members)
20:30	Weather observation (MY)
20:30 - 21:00	Briefing (all members)
21:00 -	Personal tasks and sleep (all members)

6. Nansen Ice Field

6. 1. Base camp

The location of our base camp (S72.79754°, E24.86002°) was determined by Alain Hubert during his reconnaissance trip. The living quarters were arranged in a straight line so that each solar panel mounted on the living quarters faced the sun. The arrangement of the three living quarters is shown in Figure 2. Snowmobiles were parked about 20 m north of the living quarters. Snow drift that developed at the camp site is clearly visible in Figure 2.

6. 2. Evening briefings

Every evening, activities performed during the day were reviewed by the team members. Magnetic susceptibility of the newly collected meteorites was determined. All meteorite images, track lines, and coordinates were gathered. These geographical data were imported in the QGIS-Quantarctica (Matsuoka *et al*., 2008) and Garmin Base Camp software packages, and maps of the visited regions were produced. The weather forecast for the next few days was also discussed (Section 6.3.). Then, the next day was planned based on discussions between all team members.

Table 4. Daily log of the 2019–2020 meteorite search expedition.

Date (2020)	Location	Recovered meteorites	Distance driven by snowmobile (km)	Comments
12 Jan	Cape Town			Meeting of expedition members
13 Jan	Cape Town			Departure, D10 flight
13 Jan	Novo Airbase			Arrival, Novo Airbase
13 Jan	Novo Airbase			Departure, Novo Airbase
13 Jan	PEA station			Arrival, PEA station
14 Jan	PEA station			Preparation at PEA station
15 Jan	Nansen Ice Field			Arrival, Base Camp (BC)
16 Jan	Nansen Ice Field			Preliminary search
17 Jan	Nansen Ice Field		7.6	Reconnaissance trip
18 Jan	Nansen Ice Field	6	51.4	Field work
19 Jan	Nansen Ice Field	1	26.4	Field work
20 Jan	Nansen Ice Field	2	55.3	Field work
21 Jan	Nansen Ice Field	9	51.2	Field work
22 Jan	Nansen Ice Field	16	37.8	Field work
23 Jan	Nansen Ice Field	12	67.4	Field work
24 Jan	Nansen Ice Field			Poor weather. No field work
25 Jan	Nansen Ice Field			Poor weather. No field work
26 Jan	Nansen Ice Field	2	72.2	
27 Jan	Nansen Ice Field	18	73.0	
28 Jan	Nansen Ice Field			Poor weather. No field work
29 Jan	Nansen Ice Field			Poor weather. No field work
30 Jan	Nansen Ice Field		39.0	Half day field work
31 Jan	Nansen Ice Field			Poor weather. No field work
1 Feb	Nansen Ice Field		56.8	Half day field work
2 Feb	Nansen Ice Field		52.7	Visit to Nansen B
3 Feb	Nansen Ice Field			Poor weather. No field work
4 Feb	Nansen Ice Field			Poor weather. No field work
5 Feb	Nansen Ice Field			Poor weather. No field work
6 Feb	Nansen Ice Field			Departure from base camp
7 Feb	PEA station			Arrival, PEA station
8 Feb	PEA station			Unloading containers
9 Feb	PEA station			Unloading containers
10 Feb	PEA station			Weighing meteorites
11 Feb	PEA station			Packaging meteorites/cargo
12 Feb	PEA station			Departure, PEA station
12 Feb	Novo Airbase			Arrival, Novo Airbase
13 Feb	Cape Town			Arrival, Cape Town, D13 flight
Total		66	301.6	

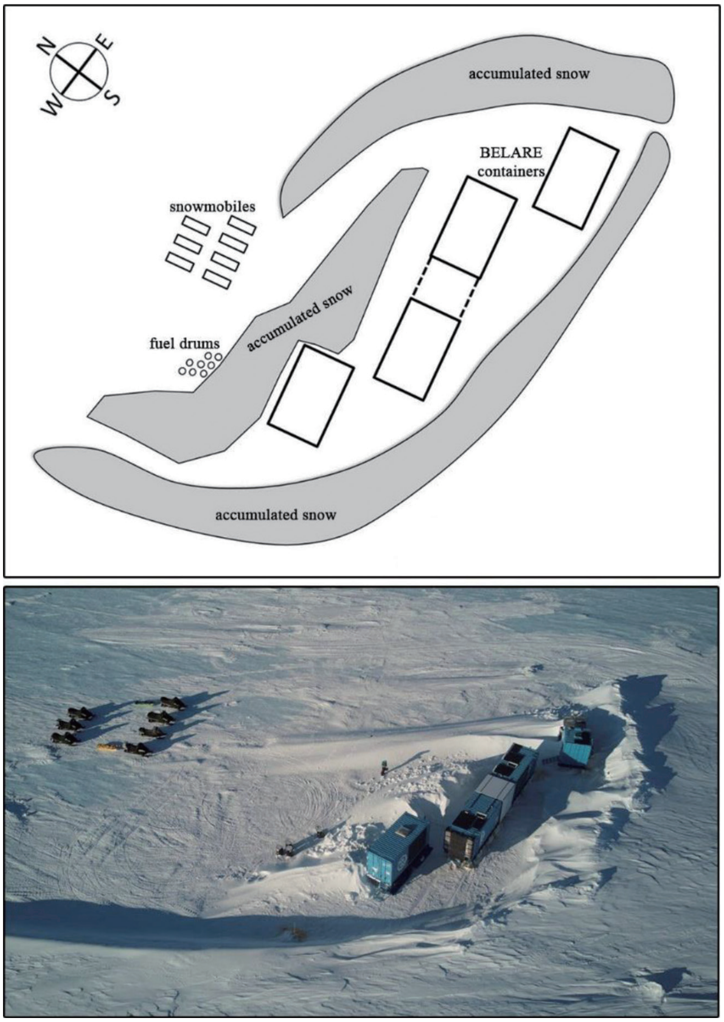

Fig. 2. Base camp on the Nansen Ice Field at S72.79754°, E24.86002°.

6. 3. Weather observations

Weather conditions in the Nansen Ice Field were measured three times a day using a handheld weather station (Kestrel-4500), before and after the breakfast (at 7:30 and 9:00 UTC+1, respectively) as well as in the evening (at 21:30 UTC+1). Temperature with and without the windchill effect, wind speed, humidity, and pressure was recorded. Based on the collected weather data, we observed that absolute temperature varied between −26.5℃ and −18.6℃, which corresponds to −47.1℃ and −31.8℃ when the windchill effect is taken into account (Figure 3, Table 5). Generally, wind and snow drift were experienced every day. Wind speeds ranged between 5.5 and 13.4 m/s. The humidity level varied between 44.3 and 100%, while the atmospheric pressure ranged between 984.9 and 1009.5 hPa. The weather observation log is given in Table 5. Weather conditions were ideal for meteorite search for 12 days out of the 22 days spent on the Nansen Ice Field. During the other days, strong winds caused snow drifts, which reduced visibility and prevented any field work.

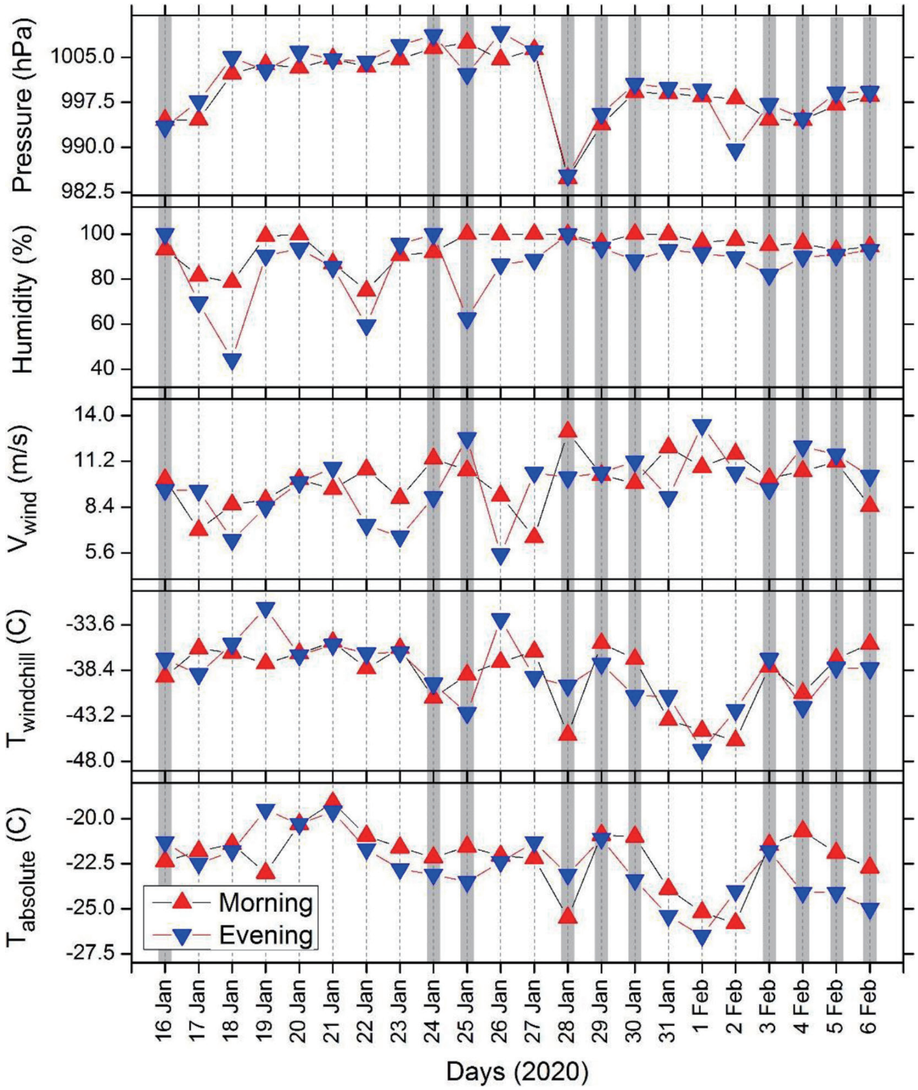

Fig. 3. Daily weather data for the Nansen Ice Field. Gray vertical lines indicate days with poor weather that prevented any field work. Morning data (red triangles) represent average of the two measurements that were done before and after breakfast.

6. 4. Meteorite search

Our search mostly focused on the Nansen Ice Field C (Figure 1-d). Therefore, our base camp was set up in this region. Every morning, after breakfast and the weather observation, the departure time for the field work was decided. In the case of good weather, the usual departure time was around 10:00. After each snowmobile was checked and prepared, the team members left the base camp following the guide (MP) in a straight line with an appropriate distance from each other that depended on the visibility. After arrival at the targeted search area, the team members took their designated position, forming a V-shaped orientation with each member in his fixed position and one field guide (MP) at the apex of

Table 5. Daily average weather observation log at the Base Camp in Nansen Ice Field.

Day (2020)	Temperature (°C)*	Wind speed (m/s)	Temperature (°C)+	Humidity (%)	Pressure (hPa)
16 Jan	-22.0	9.9	-38.4	95.5	994.2
17 Jan	-22.0	7.8	-37.0	77.5	995.6
18 Jan	-21.5	7.8	-36.2	67.1	1003.2
19 Jan	-21.8	8.7	-35.7	96.2	1003.5
20 Jan	-20.3	10.0	-36.7	97.7	1004.1
21 Jan	-19.3	9.9	-35.5	86.4	1004.8
22 Jan	-21.2	9.6	-37.7	69.7	1003.7
23 Jan	-22.0	8.2	-36.2	92.2	1005.5
24 Jan	-22.5	10.6	-40.8	94.6	1007.3
25 Jan	-22.2	2.9	-40.2	87.5	1005.7
26 Jan	-22.2	7.9	-36.0	95.5	1006.2
27 Jan	-21.9	7.9	-37.3	96.2	1006.2
28 Jan	-24.7	12.1	-43.5	99.9	985.0
29 Jan	-21.0	10.4	-36.3	95.4	994.4
30 Jan	-21.8	10.3	-38.5	96.1	999.6
31 Jan	-24.4	11.0	-42.8	97.6	999.3
1 Feb	-25.6	11.7	-45.4	99.5	998.9
2 Feb	-25.2	11.3	-44.7	98.1	995.3
3 Feb	-21.6	9.9	-37.7	99.4	995.5
4 Feb	-21.8	11.1	-41.3	99.3	994.6
5 Feb	-22.6	11.3	-37.5	99.4	997.7
6 Feb	-23.5	9.1	-36.5	99.3	998.8

*Average absolute temperature. +Average temperature with the windchill effect.

the V-formation (Figure 4), while the other field guide (ML) was positioned at one end of the V-shape. The field guide then followed predetermined GPS tracks in a zigzag pattern. Following previous campaigns, working and searching in this pattern provides the highest

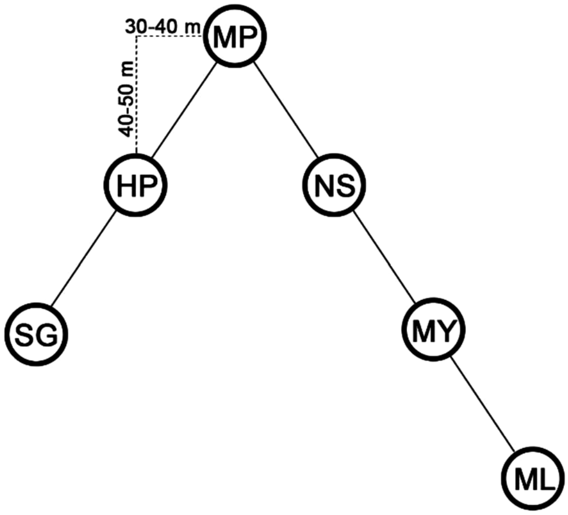

Fig. 4. Expedition members and their positions in the V-formation during the meteorite search. Initials inside the circles denote the names of the members (see Table 2), while circles denote the positions of the snowmobiles. One field guide (MP) was always at the apex of the V-formation during the search, while the other field guide (ML) was positioned at one end of the V-shape.

surface coverage as well as maximum safety.

When a meteorite was found, previously defined procedures were followed (Goderis *et al*., 2011; Imae *et al*., 2015). First, the find was reported to other members over the radio. Then, the field sample number consisting of the initial of the finder's last name, the year, month, day, and the number of the meteorite found on that day by the member (e.g., Y20012501) was written with a marker pen on the surrounding ice/snow near the meteorite and a scale was placed beside it. Pictures of the meteorite (with a scale) were taken from various angles (Figure 5). The meteorite was then picked up using zip lock polyethylene bags while avoiding any direct contact. In case carbonaceous chondrites were identified in the field, these meteorites were placed in Teflon bags instead of regular polyethylene zip lock bags due to possible contamination of organic compounds from polyethylene zip lock bags. After sealing the zip lock bag, it was placed in a larger field bag. Finally, the location of the recovered meteorite was recorded using a handheld GPS unit. In order to save time, these steps were usually performed with the help of another member of the field campaign. Return time to the base camp was determined based on the weather conditions. In good conditions, this typically was around 17:00 (UTC+1). After 17:00 (UTC+1), even during good weather conditions, the angle of the sunlight and its reflectance from the surface of the blue ice made the search strenuous, lowering the effectiveness of the systematic searches.

6. 5. Mass distribution

All recovered meteorites (n = 66) were weighted upon returning to the PEA station. Although the samples were weighted within their bags, the weight of empty bags was later subtracted from the initial measurements. The total mass of the collected meteorites was

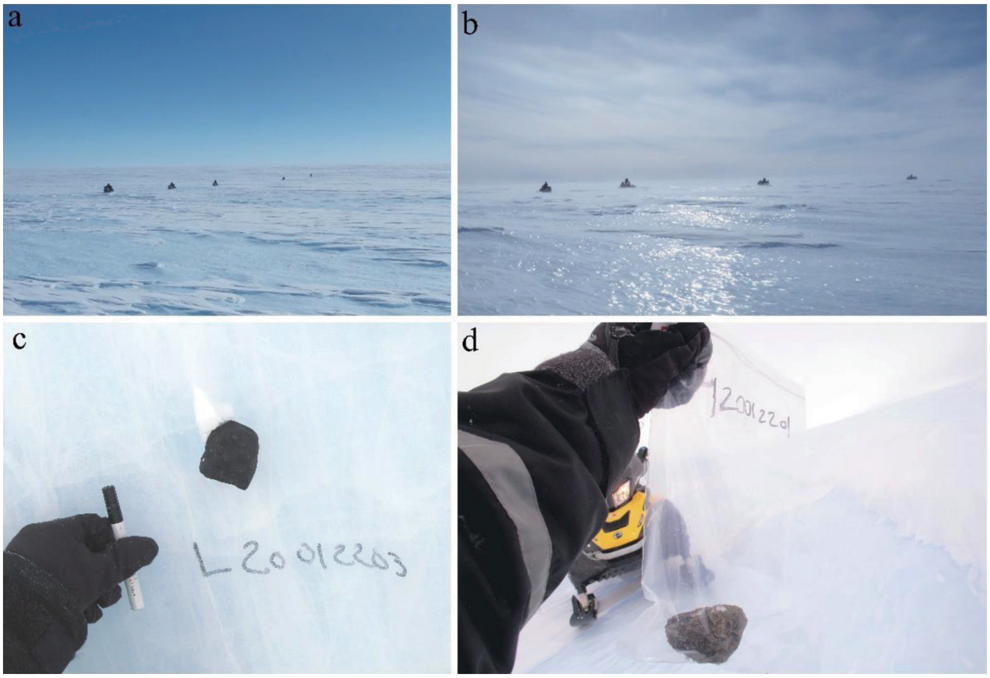

Fig. 5. (a) Picture of the team members leaving the base camp in a line with an appropriate distance from each other until the search location is reached, (b) the V-formation of the team while searching for meteorites in the field, (c) the field name of the meteorite was written on blue ice and its picture was taken with a scale for documentation, (d) the meteorite was placed in a zip lock bag (Section 6.3.) without touching the sample, and the meteorite field name was written on the bag. C-type meteorites were placed in Teflon bags instead of regular polyethylene zip lock bags.

calculated to be ～8280 g, with individual specimens range from 1 to 889 g. The average, median, and mode weights were ～125, 58, and 30 g, respectively. Figure 6-left summarizes the mass distribution of the collected samples. Meteorites with masses between 10 to 50 g exhibit the highest relative abundance (34.85%, n = 23), while those heavier than 500 g are the least common ones (4.55%, n = 3).

6. 6. Magnetic measurements

Magnetic susceptibilities of the recovered meteorites were measured on whole samples using a handheld A*METMET susceptibility meter developed at CEREGE (Aix-en-Provence) by Dr. M. Uehara and Dr. J. Gattacecca. Magnetic susceptibility is expressed as the decimal logarithm of χ in 10^{-9} m^3/kg in order to account for the five orders of magnitude variation in rocks. For strongly magnetic material ($\log \chi > 3$), χ is proportional to the amount of metal, magnetite, maghemite, cohenite, and schreibersite, i.e., minerals with practically equal specific χ. A combination of magnetic susceptibility data with microscopic observations is an effective way to classify ordinary chondrites and evaluate pairing (Pourkhorsandi *et al*., 2019). Comparison of in-situ magnetic susceptibility measurements data with the existing database (Folco *et al*., 2006, Rochette *et al*., 2003, 2008, 2009) can provide insights on the possible

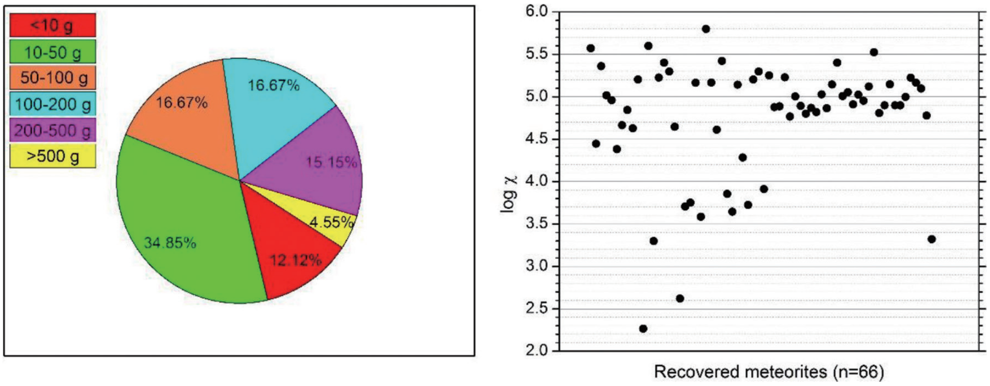

Fig. 6. Mass distribution (left) and log χ values (right) of the recovered meteorites in this expedition.

meteorite types. While detailed mineralogical and textural investigation as well as the approval of the meteorite Nomenclature Committee of the Meteoritical Society is needed to narrow down this preliminary classification, the log χ values of the meteorites collected on the Nansen area C Ice Field are presented in Figure 6-right. A more detailed classification of these samples will take place at the NIPR.

7. Problems encountered

7. 1. Snowmobiles

Two snowmobiles broke down during the course of the expedition. On the 26th of January, a JARE snowmobile (number 49-1) had to be towed back to the base camp by another snowmobile due to battery failure. Two days later, another snowmobile broke down due to engine failure during the meteorite search and was also towed back to the base camp by another snowmobile.

7. 2. Heaters and generators

Each living quarter had a diesel-fueled heater (Webasto heater-Air Top Evo 3900). The heater in the bedroom did not work for unknown reasons, instead an electric-powered heater was used in the bedroom. The day before the end of the expedition, the generator stopped working because of a low battery following the failure of the alternator of the generator. This issue was solved by using a power booster/jumper to start the generator.

7. 3. Medical issues

Some of the expedition team members suffered from the strong winds during meteorite searches. This resulted in colder than usual fingers and toes. Multiple instances of light frostbite (frostnip) on the face were experienced on windy days. However, severe frostbite did not occur due to the use of appropriate clothing, chemical warmers, and wind-protected helmets.

8. Post-expedition matters

8. 1. Retrieval of the base camp

On the evening of 5 February 2020, an IPF support team composed of Alain Hubert and Pierre Dumont arrived at the base camp location with two Prinoth snow tractors to retrieve the meteorite recovery team members and base camp. Prior to their arrival, the interiors of the living quarters and containers were cleaned and prepared by the field guides and the expedition team members for the return. Due to constant snow drift near the base camp, the containers accumulated significant amounts of snow on the leeward side. The accumulated snow had to be removed by hand and using the Prinoth vehicles to free the containers from accumulated and compacted snow. Next, all containers were disassembled and separated from each other. Subsequently, these containers were attached to the Prinoth trucks for the return trip. After departing from the Nansen Ice Field at 16:00 (UTC+1), all containers and equipment, along with the expedition team members, who travelled inside one of the living quarters, arrived at the PEA station at 4:00 (UTC+1) on 7 February 2020.

8. 2. Return of food supplies and equipment

The returned containers and living quarters were emptied by the field guides upon arrival to the PEA station. All remaining food and used equipment were returned to the PEA station.

8. 3. Storage and transportation of the meteorites

All individually packed meteorites were stored in larger zip lock and cotton bags, which were stored inside a cool box placed outside of the containers throughout the expedition (Figure 7). Although the NIPR was not directly involved in the field collection of meteorites in this expedition, the MoU defined during the previous expeditions since 2009–2010 was upheld and all collected meteorites were sent to NIPR in Tokyo, Japan for defrosting and classification before sharing with the Royal Belgian Natural History Museum (RBINS). As such, NIPR scientists prepared 0.08 mm-thick polyethylene zip lock sample bags of various sizes to store the collected meteorites, similar to what had been done during previous

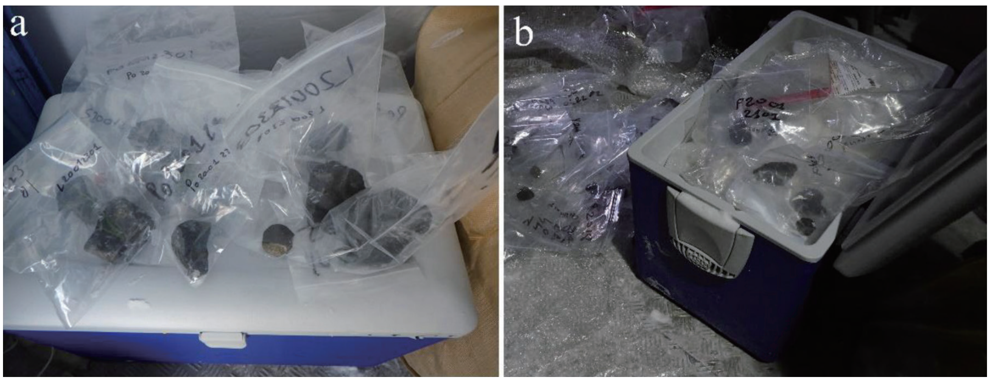

Fig. 7. (a) The recovered meteorites were placed in a cool box at the end of each field day. (b) All samples were appropriately packed and secured in the cool box before shipment to Cape Town.

joint expeditions (e.g., Imae *et al*., 2015): 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). In addition, 0.05-mm-thick powder-free polyethylene bags of 40 × 60 cm and 100 × 120 cm were used. Due to logistical issues and the outbreak of COVID-19, the collected meteorites were only transported at the beginning of June (departure date from Cape Town on 4 June). In continuously frozen state, the World Courier shipping company transported the meteorites from the Trade Universal storage facilities near the airport in Cape Town to the NIPR in Tokyo, where the package arrived on 11 June and was kept in the cold temperature (−30℃) room until the meteorites were processed.

9. Summary

During the 2019–2020 field season, an expedition team consisting of four scientists and two field guides conducted systematic meteorite recovery activities within the previously defined area C of the Nansen Ice Fields. Sixty-six meteorites with a combined mass of ∼8 kg were recovered. This number falls within the range of meteorites (62 to 108) estimated to be collected within Nansen C. These meteorites will be referred to as Asuka 19 meteorites and classified following controlled dry-thawing at the NIPR. Volcanic ash layers and wind-blown terrestrial rock samples as well as blue ice samples were also collected from the Nansen Ice Fields, which will improve our current understanding of the meteorite concentration mechanisms in this area.

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