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CAGE-22-2 Scientific Cruise Report

AKMA 2/Ocean Senses

Co-Chief scientist: Giuliana Panieri & Stefan Bünz

RV Kronprins Haakon, Capt. R/V: Johnny Peder Hansen

11-13 May 2022 Longyearbyen (NO) -Longyearbyen (NO)

Report prepared by: Giuliana Panieri & Stefan Bünz

With contributions by cruise participants: Alessandra Savini, André Jensen, Bjørn Løfquist, Bjorn Olsen, Ciara Willis, Claudio Argentino, Clément Bertin, Davide Oddone, Dimitri Kalenitchenko, Erling Rosnes, Fanny Cusset, Filip Maric, Fulvio Franchi, Jan Pawlowski, Jane Zimmermann, Jessica Eve Todd, Jørn Patrick Meyer, Kate Waghorn, Katrin Losleben, Margherita Poto, Mari Heggernes Eilertsen, Mathew Stiller-Reeve, Monica Clerici, Pierre Antoine Dessandier, Raphael Moncelon, Sofia Ramalho, Solmaz Mohadjer, Stig Vågenes, Vibeke Aune, Vibeke Os, Victor Poddevin, Villads Holm

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Table of Contents

1. Error! Reference source not found.

	Name	Affiliation	Role	Discipline
1	Giuliana Panieri	CAGE UIT	PI	Chief Scientist, PI AKMA, micropaleontology
2	Stefan Buenz	CAGE UIT	co-PI	Co-chief, geophysics
3	Bjorn Ølsen	UIT	UiT Engineer	
4	Stig Vågenes	IMR	ROV Engineer	
5	Jørn Patrick Meyer	IMR	ROV Engineer	
6	Bjørn Løfquist	IMR	ROV Engineer	
7	Claudio Argentino	CAGE UIT	researcher	Geochemistry, carbonates
8	Kate Waghorn	CAGE UIT	researcher	Geophysics and outreach
9	Dimitri Kalenitchenko	La Rochelle Univ.	researcher	Microbiology
10	Alessandra Savini	UniMIB, IT	researcher	Seafloor and habitat mapping
11	Sofia Ramalho	Aveiro Uni, PT	researcher	Marine biology
12	Fulvio Franchi	BIUST	researcher	Geology
13	Jan Pawlowski	IOPAN, PL	researcher	Micropaleontology
14	Mari Heggernes Eilertsen	UiB, NO	researcher	Marine biology
15	Pierre Antoine Dessandier	IFREMER, FR	researcher	Micropaleontology
16	André Jensen	NPD, NO	geologist	Geology
17	Katrin Losleben	UiT, NO	musicologist	Gender studies
18	Margherita Poto	UiT, NO	Research professor in law	Law
19	Jane Zimmermann	UiT, NO	graphic designer	Illustration
20	Filip Maric	UiT, NO	researcher/education	Education
21	Solmaz Mohadjer	Tubingen Univ., DE	researcher	Education
22	MathewStiller-Reeve	Bergen, NO	researcher/education	Education
23	Erling Rosnes	Bergen, NO	high-school teacher	Education
24	Vibeke Os	UiT, NO	Chemist	Education
25	Davide Oddone	Torino, IT	Documentarist	Filming and video reporting
26	Victor Poddevin	La Rochelle, FR	high-school teacher	Education

27	Vibeke Aune	Kongsbakken Skole, Tromsø, NO	high-school teacher	Education
28	Villads Holm	UiT, NO	master student	Micropaleontology
29	Ciara Willis	WHOI-MIT US	PhD student	Marine biology
30	Jessica Eve Todd	WHOI-MIT US	PhD student	Technological development
31	Raphael Moncelon	La Rochelle Univ., FR	PhD student	Biogeochemistry
32	Fanny Cusset	La Rochelle Univ., FR	PhD student	Biology
33	Clément Bertin	La Rochelle Univ., FR	PhD student	Modelling
34	Monica Clerici	UniMIB, IT	PhD student	Psychology

Participants Institution:

CAGE – UiT CAGE - Centre for Arctic Gas Hydrate, Environment and Climate,
Department of Geosciences
UiT The Arctic University of Norway

WHOI Woods Hole Oceanographic Institution, USA

MIT Massachusetts Institute of Technology, USA

IMR Institute of Marine Research, Norway

La Rochelle Université, France

Botswana International University of Science and Technology (BIUST), Africa

UniMIB, Università degli Studi di Milano-Bicocca, Italy

Universidade de Aveiro, Portugal

IOPAN Poland Academy of Sciences, Poland

Centre for Deep Sea Research, University of Bergen, UiB, Norway


Erling Rosnes
Teacher


Jan Pawlowski
Biologist


Sofia Ramalho
Biologist


Mari Heggernes Eilertsen
Biologist


Filip Maric
Environment health philosophy


Alessandra Savini
Geomorphologist


Fulvio Franchi
Planetary geologist


André Jensen
Geologist


Katrin Losleben
Feminist theory/sound studies


Vibeke Os
Manager, skolelaboratoriet


Margherita Poto
Lawyer


Jane Zimmermann
Artist


Matthew Stiller Reeve
Educator/project manager


Solmaz Mohadjer
Geoscientist/communicator


Vibeke Aune
Teacher


Fanny Cusset
PhD student


Clément Bertin
PhD student


Raphael Moncelon
PhD student


Ciara Willis
PhD student


Dimitri Kalenitchenko
Microbiologist


Pierre Antoine Dessandier
Benthic ecologist


Victor Poddevin
Teacher


Claudio Argentino
Geochemist


Kate Waghorn
Geophysicist


Stefan Buenz
Co-chief


Jessica Eve Todd
PhD student


Giuliana Panieri
Chief


Davide Odonne
Videographer


Monica Clerici
PhD student


Bjørn Olsen
Engineer


Villads Dyrved Holm
MSc student

2. Introduction and objectives

AKMA-OceanSenses Research Expedition (11-23 May 2022) aboard the research vessel Kronprins Haakon to the Arctic Ocean is under the umbrella of the project AKMA, Advancing Knowledge of Methane in the Arctic, funded by NFR, and it is focused on both science and education. Our science focuses on extreme environments such as “cold seeps”, places on the seafloor where methane and oil are emitted at the seafloor naturally and areas characterized by gas hydrate. In seep sites environmental stressors, such as chemistry of the emitting fluids and anoxic conditions at the seafloor, affect biological communities and produce peculiar seafloor features. Combining newly acquired data with the data already available to us we will increase our ability to understand the present and predict the future of these delicate and remote areas in the deep sea.

During the expedition, scientists and educators will develop learning tools to experience the ocean using all our senses (touch, sight, smell, hearing, and taste). Schools and scientists from Norway, Italy, France, Kazakhstan, Portugal, Brazil, Tanzania, and Botswana will work on the vessel, or remotely, to perform science and develop education materials. During the expedition, scientists, and teachers on-board have connected with colleagues, school classes, and to the public through online seminars. We have also developed a series of educational video recordings of the work done in the onboard laboratories.

This expedition has received endorsement from the UN Decade of Ocean Science for Sustainable Development, and a number of our objectives and goals aboard relate to the UN Sustainable Development Goals (SDGs) calling for action across all nations and all sectors of society to *‘improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests’.* The AKMA-OceanSenses Research Expedition has also received endorsement from the Challenger 150 programme, an Ocean Decade cooperative action for deep-sea biological research.

The objectives of this expedition are:

- Investigate cold seeps (methane, gas hydrate and oil) from five sites in the Arctic Ocean (Fram strait) to study: the origin of fluids, micro-meio-macro-biology, environmental DNA, ice biogeochemistry.
- Develop learning tools to experience the ocean using all our senses (touch, sight, smell, hearing, and taste)

3. Deviations from the intended cruise schedule

The cruise visited followed the intended cruise schedule as planned.

4. Geological setting of the working areas

4.1 Southern Yermak Plateau (super station SS1)

On the far NW Svalbard shelf, bordering the Yermak Plateau to the north, several gas flares (indication of gas ebullition in the water column), have been discovered along the edge of a Mareano multibeam survey (Figure 1). The flares are concentrated in a small area of the survey. This site is often covered by ice and is close to the Svalbard shoreline, which makes it difficult to map out. But it is believed that these flares continue into unmapped areas.

The flares mapped by the Mareano Project appear to be structurally controlled as they are aligned with major fault complexes striking N-S along the coast of Svalbard. IODP drill sites nearby provide age control for the underlying sedimentary sequences (Mattingsdal et al., 2013), however, the origin of methane is not clear. Indications of gas hydrates exist in seismic data further north on the Yermak Plateau (Jokat et al., 2008) and further west towards the slope. However, the flare location here is likely too shallow to be inside the gas hydrate stability zone. The area is highly influenced by glaciation/deglaciation cycles, with obvious seafloor features like trough mouth fans and plough marks indicating the glacial erosion and redeposition of the West Svalbard shelf.

4.2 West-Svalbard continental slope, Vestnesa Ridge (super station SS3)

The West-Svalbard continental slope represents one of the northernmost gas hydrate provinces in the world. It is located on the western Svalbard margin in the eastern Fram Strait at ~79°N, north of the Knipovich Ridge (KR) and Molloy transform fault (MTF) situated on hot (>115 mW/m^2) and relatively young oceanic crust (Engen et al., 2008)(Figure 1). In the Early Miocene, sea floor spreading connected the North Atlantic mid-ocean ridge system (Mohns Ridge – Knipovich Ridge) with the Arctic Gakkel Ridge, causing the opening of the Fram Strait (Ritzmann and Jokat, 2003). The Fram Strait represents the final opening of the Atlantic-Arctic gateway, as a part of the non-glacial uplift and subsidence (Knies et al., 2014).

The margins along the eastern flank of the Fram Strait were dominated by contourites during the late Miocene-Pleistocene (Mattingsdal et al., 2013). ODP sites at the Yermak Plateau showed that a major increase in sedimentation-rate occurred at ~2.7 Ma, which is attributed to the increase in glacial erosion at that time. Contour currents along the slope lead erosional sediments from the Barents Sea and Svalbard shelves along the slope and deposit them in sediment drifts e.g. the Vestnesa Ridge (Fohrmann et al., 2001). This sediment drift grows due to bottom-current controlled sediment dynamics (Eiken and Hinz, 1993). Several hundred meters of sediments are lying in close distance (40 km) to the 20 Ma young W-Svalbard margin, where the relatively warm and northward directed W-Spitsbergen current is shaping the morphology of the Vestnesa Ridge.

The Vestnesa Ridge is a 100 km long submarine sediment drift that extends from the continental slope and elongates in a SE-NW (eastern segment) to EW (western segment)-bending direction, where the crest of the ridge lies at 1200-1300 m water depth (Bünz et al., 2012; Plaza-Faverola et al., 2015). The presence of a prominent gas-hydrate related bottom simulating reflector (BSR) was revealed on seismic profiles in several seismic studies (e.g. Eiken and Hinz, 1993; Posewang and Mienert, 1999; Vanneste et al., 2005), which indicates that gas hydrates and gas accumulations are common in the area. The BSR covers the whole of the Vestnesa Ridge and most of the western Svalbard continental slope north of the MTF (Sakar et a., 2012; Bünz et al., 2012). Faults are identified on seismic profiles, stretching from the seafloor and through the BSR and control the ascend of fluids and the distribution of chimneys on the Vestnesa Ridge (Vanneste et al., 2005; Plaza-Faverola et al., 2015). In this setting, very close to the mid-oceanic ridge, the fluid flow system is strongly influenced by the young and hot oceanic crust. Geothermal gradients increase gradually from 70 to 115 °C/km towards the MTF. A plume of gas bubbles from a pockmark on the Vestnesa Ridge was first observed in 2008 from RRS James Clark Ross cruise JR211 (reported in Hustoft et al., 2009, together with later observations).

The site of Superstation 3, a cluster of 5 pockmarks lies at the southernmost extent of the Vestnesa Ridge, on the Svalbard continental slope, only 12 km north of the MTF in 1400 m water depth. Fluid leakage structures including indications for leakage along faults have been first recognized here in 2001 (Vanneste et al., 2005; Westbrook et al., 2008). However, hydroacoustic evidence for active gas seepage was absent until 2021 albeit several CAGE cruises regularly crossing this area. Hence, the pockmark cluster received much less attention than their counterparts on the Vestnesa Ridge crest. In October 2021, CAGE21-5 cruise was the first to detect an acoustic flare from the easternmost pockmark. This is the deepest actively gas-seeping structure yet discovered on this margin and was therefore chosen as target site for the AKMA2 (CAGE22-2) cruise.

4.3 Svyatogor Ridge (super station SS4)

The Svyatogor Ridge is a sediment drift atop the inside corner high of the Knipovich Ridge – Molloy Transform Fault intersection (RTI) (Figure 1). The RTI inside corner high is underlain by a detachment fault accommodating spreading on the Knipovich Ridge. In this area, Johnson et al., 2015 and Waghorn et al., 2018, 2020 hypothesize a contribution from abiotic methane to the gas hydrate system. South of the Svyatogor Ridge is a paleo-transform fault that, during its period of activity, contributed to tectonic deformation of the crust and overlying sedimentary sequences at the southern end of the Svyatogor Ridge (Crane et al., 1991). Areas with exhumed mantle are of interest as the hydration of olivine produces H_2, which may in turn react with CO_2 on a metallic catalytic surface to produce abiotic methane (Etiope and Sherwood-Lollar, 2013). Inside corners of mid-ocean ridge-transform fault intersections are the predominant oceanic setting where abiotic methane is recognized (i.e. Lost City Hydrothermal Field, Mid-Atlantic; Kelley et al., 2005). During CAGE expeditions in 2018, seismic data showed that two ridges southwest of the Svyatogor Ridge had oceanic crust subcropping and one of the ridges had a

BSR reflection in the sedimentary sequence above the crust subcrop (Waghorn et al., 2020). During CAGE21-1, we explored these two ridges in order to understand fluid cycling associated with Oceanic Transform Faults.

4.4 Prins Karls Forland (super station SS5)

Prins Karls Foreland is a small and elongated island on the western flank of the Svalbard archipelago (Figure 1). The island and its western submersed bank areas belongs to the West Spitsbergen fold-and-thrust belt, a system of complex horst and graben structures, which are comprised of a late-Tertiary wedge of sediments. It formed along the transform plate boundary between Greenland and the western Barents Sea during Paleocene-Eocene breakup in the northern North Atlantic. The Hornsund fault zone forms the western termination of the fold and thrust belt. This fault zone runs along the whole western Svalbard margin and has been associated with numerous active gas seepage areas. One of CAGE's major study sites is located just west of Prins Karls Foreland in 80-100 m water depth. Intense gas flaring has been observed over multiple years. More recently, satellite images revealed the presence of oil slicks on the sea surface at this location. The first AKMA cruise (CAGE21-1) discovered and sampled oil seep sites at the seafloor.

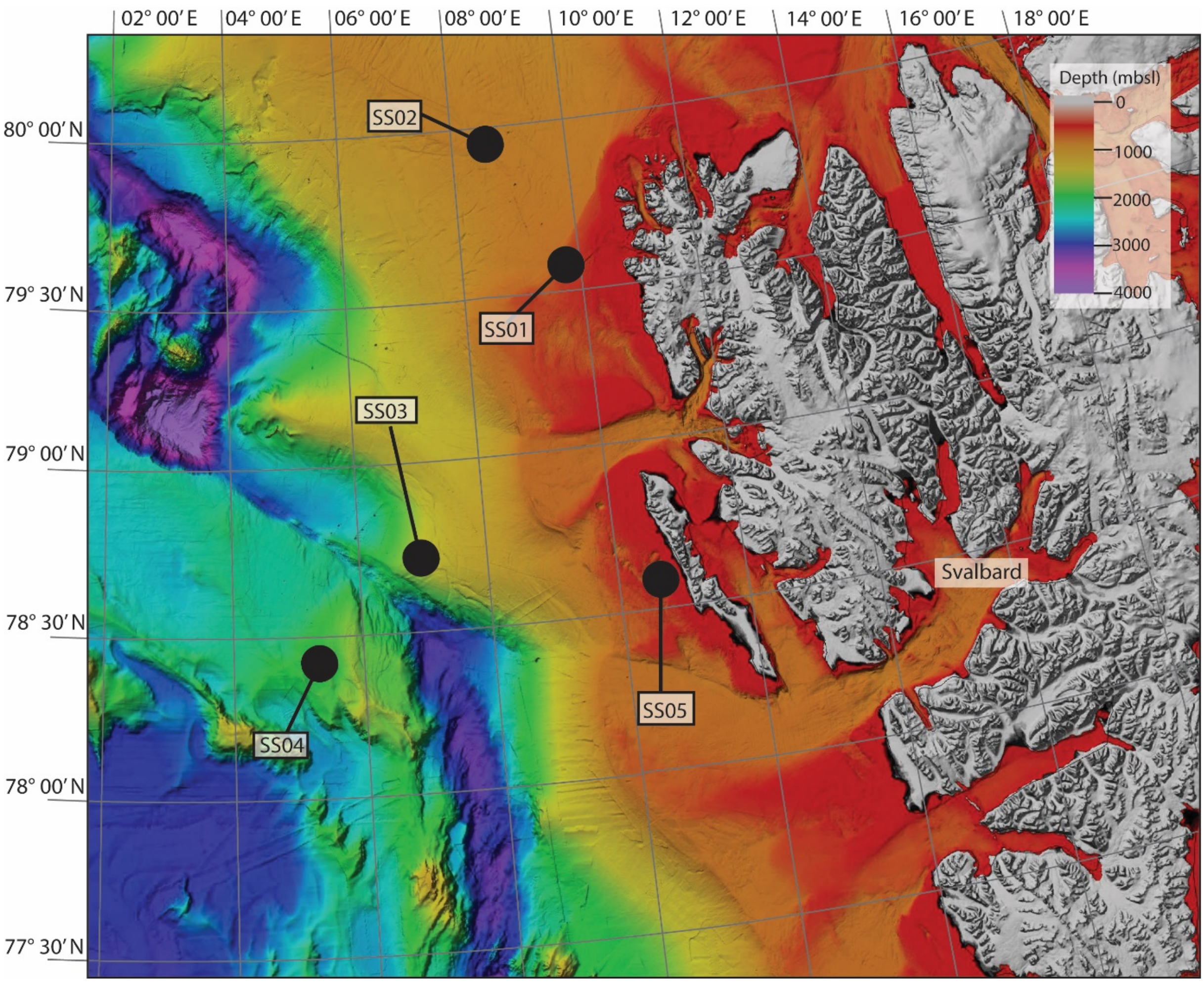

Figure 1. Study sites during the AKMA2-OceanSenses expedition.

5. Scientific narrative of the expedition

Note: Given times in the narrative are local time while the log sheets are in UTC.

Wednesday 11th May DAY1

The scientific team arrived at the RV Kronprins Haakon during the day. The ROV team has started the mobilization on the Ægir ROV. There is still much left to do, and the mobilization will be finished tomorrow. During the morning we received a visit from a delegation from Singapore: Prof. Benjamin P. Horton - the director of the Earth Observatory of Singapore, a few students from the Nanyang Technology University, and Per Christer Lund - Science & Technology Counsellor at the Royal Norwegian Embassy in Singapore. The purpose of their visit in Norway was focused on strengthening the relations between Norwegian and Singapore universities and research organisations, Nanayang Technological University and UiT. The visit also aimed to motivate and inspire young researchers and PhD students to work on climate change challenges – connecting the arctic and tropics.

At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Thursday 12th May DAY2

The mobilization of the ROV continued during the day. The scientific crew received a safety briefing at 08:00. The Ocean Senses project started officially at 10:00. At 20:30 the RV Kronprins Haakon began heading to the first study site of the expedition: the southern Yermak Plateau, Superstation 1 (SS1). During the transit to the station, multibeam data were collected across the Prins Karls Foreland oil site discovered during the AKMA cruise in 2021. This year we also spotted oil bubbling at the sea surface.

At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Friday 13th May DAY3

At 9:30 we had a meeting to plan the ice station happening later today. We arrived at SS1 at 11:15 and after a CTD to determine sound velocity we started a multibeam survey of the area. Between 14:00 and 14:30 we stopped the multibeam survey. The survey then continued until 17:30, by which time the ROV was ready for Dive 1. The ROV had some issues, and it did not record all the videos. At 20:00 the ROV came up and we started our transit to the ice station.

At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Saturday 14th May DAY4

It took a few hours to find thick ice that let us do an ice station. The vessel reached ice on the evening of the 14th of May at the coordinates N79° 56.92’ – E 008° 05.96’. The coring operations were conducted between 01:45 and 2:20 UTM+2. Four cores were collected at the corners of a 20x20m square. The length of the cores was between 1.16 and 1.33 m that corresponds to the thickness of the ice pack in this area (Table 1). Samples of water were collected from the drill holes of cores 1 and 4 by means of a 500ml glass bottle (Table 1). At the SS2 Ice station we recovered 4 ice cores, 2 water samples in core holes, and hydrophone

recording under ice. The vessel reached ice on the evening of the 14th of May at the coordinates N79° 56.92 – E 008° 0.5.96. The coring operations were conducted between 01:45 and 2:20 UTM+2. Four cores were collected at the corners of a 20x20m square. The length of the cores was between 1.16 and 1.33 m that corresponds to the thickness of the ice pack in this area (Table 1). Samples of water were collected from the drill holes of cores 1 and 4 by means of a 500ml glass bottle (Table 1).
At 04:30 we started steaming towards Vestnesa (SS3; north of the Knipovich Ridge), arriving at 13:22. This station is a pockmark of ca 500 m in diameter characterized by gas hydrate and seepage system identified and first surveyed during SEAMSTRESS expedition CAGE21-5 (https://cage.uit.no/cruise/cage21-5-seamstress-cruise/) and a more recent ROV-aided instrument recovery operation (April 2022). The SEAMSTRESS project is supported by starting grants from the Tromsø Research Foundation (TFS) and the Research Council of Norway (grant 287865) awarded to Andreia Plaza-Faverola. At this station we did 3 Multicorer deployments from a reference area 1 mile north from the pockmark (total recovery 10 cores): CAGE22-2-KH-03-MC-01, CAGE22-2-KH-03-MC-02 and CAGE22-2-KH-03-MC-03. The ROV Dive 2 was for the deployment of a hydrophone rigged on a frame at the seafloor. The hydrophone was deployed close to a bacterial mat. Since the ROV was leaking oil, we terminated the dive immediately after the deployment of the hydrophone.
At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Sunday 15th May DAY5
We are still at SS3. During the night, we did 2 gravity cores (CAGE22-2-KH-03-GC-01, CAGE22-2-KH-03-GC-02) from the exact same location (1 sampled for pore water and the second stored at -20C) that penetrated ca 1 m because of gas hydrate occurrence in the sediment, and 2 heat flow along a transect E-W across the pockmark. At 8:30 we started ROV Dive 3 which focused on surveying, photomosaic and multibeam in an area characterized by patches of bacterial mats and tubeworms. We do not have high resolution bathymetry from this area, so we have been guided by the presence of flares detected from the echosounder. During the dive, the methane sensor on the ROV recorded a slight increase in methane in the water. We recorded video with the 4K camera. At the end of Dive 3 we recovered the hydrophone deployed the previous night. At 13:00, the ROV came onboard to change the setting to sampling configuration. At 14:30 we did a CTD on top of this area with bacterial mats and we collected 3 Niskin bottles from bottom water.
In the afternoon, we did a few dive attempts with the ROV but there were some issues with oil leaking and a filter; that was supposed to be Dive 4 that has been logged as "aborted".
At 19:43 we did a multicorer tow cam dive that ended with sampling in a tube worm area (CAGE22-2-KH-03-Dive-04; 3 full cores). During the dive, we noticed the track at the seafloor left by the gravity core the previous night.
At 21:00 we did a gravity core (CAGE22-2-KH-03-GC-03) and collected gas hydrate. During the night we completed a transect of 5 Heat flows and surveyed the area with multibeam.
At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Monday 16th May DAY6

Early in the morning we ended the multibeam survey and at 09:30 we started ROV Dive 5. Dive 5 targeted a tubeworm area inside the pockmark. We deployed a thermometer close to bacterial mats and tube worms and we collected 1 push core (1 failed) CAGE22-2-KH-03-PusC-01, 1 blade corer (CAGE22-2-KH-03-BlaC-01), a scoop (CAGE22-2-KH-03-Scoo-01) and did suction sampling (CAGE22-2-KH-03-SuSa-01). This dive was very successful. Dive 6 started at 14:30 with the aim of collecting samples from bacterial mats. We collected samples from three different bacterial mats; the first two were inside the depression we surveyed yesterday during Dive 3, and we took 2 push cores in each (targeting gastropods grazing on mats and bacterial mats). The third mats were inside another small pit NW of the previous one. At the end of the Dive, we collected 5 push cores and one blade corer. Samples collected are CAGE22-2-KH-03-PusC-02, 03, 04, 05, 06, CAGE22-2-KH-03-BlaC-02 and 03. Through the end of the dive, we reached a relatively small depression (from now on named ‘pit’), surrounded by a steeply dipping rim where seeping gas and gas hydrate were clearly visible. There were isolated, massive carbonate blocks scattered around and one big block inside the small depression. We collected a piece of this carbonate within the pit (CAGE22-2-KH-03-CarC-01). During the ascend at ca 500 m water depth, the carbonate block started to release methane. During this dive we recorded 4K videos and took 4K images. Once on deck, one of the cores was lost in the drawer. Today at 13:00 there was a HMS meeting among G.Panieri and the crew.
At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Tuesday 17th May DAY7

During the night we completed 4 heat flow measurements. At 9:30 we the ROV descended for Dive 7 in a sampling configuration: 5 push cores, 2 blade corers, the suction sampler, and the gas sampler with three bottles. We took 5 push cores (CAGE22-2-KH-03-PusC-07, 08, 09, 10, 11) from an area without mats of tube worm that could be considered as a “background” within the pockmark we are investigating, and 1 blade corer in tubeworm (CAGE22-2-KH-03-BlaC-05). The suction sampler collected epifauna (CAGE22-2-KH-03-SuSa-03) and two carbonate crusts (ca 30-50 cm in diameter) (CAGE22-2-KH-03-CarC-02, 03). The gas sampler collected one bottle of gas in the small depression with gas hydrate we observed yesterday. When we attempted to place the holder with the blade corers on the seafloor at this location (to take one piece of gas hydrate), it flipped. This sample was subsequently used for food web analyses and not foraminifera as previously planned. In the second blade corer we collected gas hydrate.
In the evening we did a CTD for water samples and sound recording.
This morning at 10:00 we did a parade on-board for celebrating May 17th. Our video from the Ægir ROV holding the Norwegian flag and all of us on the helideck was broadcast on NRK1.
At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Wednesday 18th May DAY8

During the night we did a few more heat flow stations. At 10:00 ROV Dive 8 started. The configuration had been changed from sampling to photomosaic and multibeam. The multibeam survey of the entire pockmark has been completed, as has the photomosaic on the main pit sampled during the expedition. At the end of the dive, one blade corer was taken from an area in transition between tubeworm and normal seafloor (CAGE22-2-KH-03-BlaC-06). At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Thursday 19th May DAY9

During the night we completed heat flow stations then we moved to the Svyatogor Ridge, SS4. At 5:00 we collected a multicorer as a reference (CAGE22-2-KH-04-MC-01) from this area at 2 miles away from the active site at Svyatogor Ridge that was reached at 8:00. At 9:00 the ROV ascended to an active area discovered during the AKMA 1 cruise. Here we completed Dive 9 that recovered 5 push cores (CAGE22-2-KH-04-PusC-01, 02, 03, 04, 05) and 2 blade cores (CAGE22-2-KH-04-BlaC-01, 02) from bacterial mats. One of the blade corer tilted and was subsequently sampled for food web analyses. The following Dive 10 was dedicated to biology and scoops (CAGE22-2-KH-04-Scoo-01) and suction sampling (CAGE22-2-KH-04-SuSa-01) were done. At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Friday 20th May DAY10

During the night few more heat flow stations were performed. At 9:00 we started the ROV Dive 11 that targeted tube worms and reference area in between tube worm and bacterial mats. We identified a good area where 2 push cores (CAGE22-2-KH-04-PusC-06, 07) and 2 blade cores (CAGE22-2-KH-04-BlaC-03, 04) were taken from tube worms. One of the blade cores was from the transition between tubeworms and normal sediment. We also collected 3 push cores from normal sediments between worms and bacteria mats (CAGE22-2-KH-04-PusC-08, 09, 10). The wind speed increased towards the evening and no operations at sea were permitted. The team secured all the equipment in the different labs and during the night we moved back to SS3 Vestnesa Ridge. At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Saturday 21st May Day 11

During the day the weather has been a bit calmer than last night, and we completed two ROV Dives, 13 and 14. The Dive 13 focused on exploring all the pits within the pockmark in SS3 we have sampled in the previous days while the Dive 14 focused on looking for features related to methane in other pockmarks west of the main, we investigated. During Dive 13 we collected 5 push cores (CAGE22-2-KH-03-PusC-12,13,14,15,16) and one suction sample (CAGE22-2-KH-04-SuSa-04). Dive 14 collected 2 blade corers (07 and 08). During the evening the wind was still too strong and there were no more operations. At 22:00 we started to sail towards Prins Karls Forland. At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Sunday 22nd May Day 12

During the night we reached the oil seep located west offshore of Prins Karls Forland, that was discovered last year during the CAGE21_1 AKMA expedition. At 8:00 in the morning we deployed the ROV for Dive 15 during which we explored the area looking for evidence of oil emission from the seafloor. During Dive 15 we collected 5 push cores (CAGE22-2-KH-05-PusC-01, 02, 03, 04, 05), and 2 blade cores (CAGE22-2-KH-05-BlaC-01, 02). Among the samples taken only one push core and one blade core showed evidenced of oil. Oil was samples for NPD. The following Dive 16 followed the alignment of bacterial mats (ca 50 meters) identified in the previous dive. During this dive we collected samples from 2 bacterial mats seeping oil and gas (CAGE22-2-KH-05-PusC-06, 07). We collected 2 push cores. The Dive 17 and 18 were for exploration of the area and did not collect any samples. At 18:00 we started the transit to Longyearbyen. At 18:30 we had the daily science meeting and other seminars as indicated in Chapter 7.

Monday 23rd May, DAY 13

We arrived in Longyearbyen at ca 00:45 and in the morning the AKMA2/Ocean Senses expedition ended.

6. Scientific Equipment

6.1 Hydroacoustic systems

The hydroacoustic systems on-board RV Kronprins Haakon can be operated simultaneously, where a dedicated software intelligently manages transducer pings to avoid interferences. In-ice operations only allow using acoustic systems that are mounted in the so-called Arctic tank, an ice window in the hull of the ship, where sea ice can slide along without damaging any transducers during ice breaking. However, ice operations make data acquisition more prone to noise.

Among the hydroacoustic systems, the following were used extensively during the CAGE 22-2 cruise:

- Simrad Kongsberg EK 80 single beam echosounder
- Simrad Kongsberg EM 710 multibeam echosounder
- Simrad Kongsberg EM 302 multibeam echosounder and SBP 300 Sub-Bottom Profiler

6.1.1 Simrad Kongsberg EK 80 single beam echosounder

The EK 80 single beam echosounder operates up to four high power transceivers simultaneously. Available frequencies span from 12 to 710 kHz. A variety of highly efficient transducers is available to suit all your operational needs from extreme shallow water to a depth of 11.000 meters. Major applications of this echosounder are to identify the depth and finding high-reflective objects in the water column, e.g. gas bubbles.

6.1.2 Simrad Kongsberg EM 710 multibeam echosounder

The EM710 multibeam echosounder is a high to very high resolution seabed mapping system which operates at sonar frequencies in the 70-100 kHz range. The system is mounted on the port drop keel of Kronprins Haakon and is particularly suited for swath bathymetry surveys up to 800 m water depth. The system sends out 400 beams at an angle of up to 700 on each side (1400 coverage in total). To achieve a high-density of beams the system was used at an angle of 600 on each side. There are options to adjust the beam spacing, either equiangular or equidistant. There is an additional high-density mode to achieve higher sounding density by reducing the acoustic footprint. During the CAGE21-1 cruise, the system was run on high-density equidistant mode. In addition, EM710 also allows the recording of water column backscatter data. This is particularly useful in identifying gas bubbles in the water column. New CTD data were acquired at each study area to update the water velocity used by the EM710 system.

6.1.3 Simrad Kongsberg EM 302 multibeam echosounder and SBP 300

The EM 302 multibeam echo sounder has an operating frequency of 30 kHz and is designed to perform seabed mapping with high resolution and accuracy to a maximum depth of more than 7000 m. Beam focusing is applied both during reception and transmission. EM 302 is equipped with a function to reduce the transmission power to avoid hurting mammals if they are close by. The system has up to 432 soundings per swath with pointing angles automatically adjusted according to achievable coverage or operator defined limits. With dual swath (two swaths per ping) the transmit fan is duplicated and transmitted with a small difference in along-track tilt. The applied tilt considers depth, coverage and vessel speed to give a constant sounding separation along track. In dual swath mode, 2 swaths are generated per ping cycle, with up to 864 soundings. The beam spacing is equidistant or equiangular. The transmit fan is split into several individual sectors with independent active steering. This allows stabilization, which compensates for the vessel movements: yaw, pitch, and roll. Each transmit sector has individual beam focusing.

In conjunction with a separate low frequency transmit transducer, the EM 302 may optionally be able to deliver sub-bottom profiling capabilities with a very narrow beamwidth. This system is known as the SBP 300 sub-bottom profiler. During this cruise, the SBP was operated constantly with a chirp pulse of 50 ms and frequency bandwidth of 2.5 – 6.5 kHz.

The EM 302 (including the SBP 300) is mounted in the ice window in the bottom hull of the vessel. During ice breaking, ice sliding beneath and along the ice window significantly affect the acquisition leading to high noise levels and false measurements.

6.2 Attributed sensors

6.2.1 GPS/Navigations, motion reference unit

RV Kronprins Haakon uses a Kongsberg Seapath 330-5 system, an integrated global navigation satellite system (GNSS), using the GPS, GLONASS, Galileo or Beidou signals and inertial measurements to provide high quality results for applications including hydrographic surveying, dredging, oceanographic research, seismic work etc. This Seapath system includes a 5th generation MRU motion sensor package, providing up to 0.008° RMS roll and pitch accuracy. This accuracy is achieved using accurate linear accelerometers and unique MEMS type angular rate gyros.

6.2.2 USBL HiPap

RV Kronprins Haakon is equipped with a HIPAP 501 Acoustic Underwater Positioning and Navigation System. ROV, tow-cam, heat flow probe and partly also coring equipment were outfitted with a HiPaP beacon for exact positioning information on the seafloor. The HiPAP 501 system operates with the transducer mounted on the hull to allow the transducer to be lowered some meters below the hull of the vessel. A transceiver unit containing transmitter, preamplifiers and beam forming electronics is mounted close to the hull unit. The HiPAP 501 system has a spherical transducer with several hundred elements covering the whole sphere under the vessel. The system will dynamically control the beam, so it is always pointing towards the transponder. The transponder may be moving, and roll, pitch and yaw affect the vessel itself. Data from roll/pitch sensors are used to roll and pitch compensate the position.

The Super Short Base Line (SSBL) principle has the obvious advantage that it only requires installation of one hull mounted transducer and one subsea transponder to establish a three-dimensional position of the transponder. An SSBL system is measuring the horizontal and vertical angles together with the range to the transponder. An error in the angle measurement causes the position error to be a function of the range to the transponder. To obtain better position accuracy in deep water with an SSBL system it is necessary to increase the angle measurement accuracy. The frequency band of the HiPaP 501 is 21 - 31 kHz and the operating range is 1 - 5000 m. The range detection accuracy is given as 0.02 m assuming free sight between transducer and transponder, no or very little noise in the water column and no error from heading/roll/pitch sensor. We recognized interference between HiPaP and multibeam EM 302 systems due to usage of similar frequency bands. For most operations at the seafloor, EM 302 acquisition was stopped, leading to more stable positioning of the USBL transponder.

6.3 CTD (Conductivity, Temperature, Density)

Physical and chemical measurements are measured in the water column from a CTD/rosette. The CTD model is a Seabird SBE 911 plus mounted on a 12 10-liters Niskin bottles carousel. The CTD (conductivity, temperature, depth) sensor records physical (conductivity, temperature, P-wave velocity, pressure for depth calculation) and chemical properties (fluorescence/chlorophyll, O2 concentration, turbidity) vertically through the water column.

One CTD profile was realized from 10 to 1400 m depth at station CAGE 22-2-KH03-CTD-78. Water samples were collected at 10, 50, 100, 200, 300, 400, 500, 600, 700, 800, 1000 and 1400m depth with Niskin bottles. 15 mL of each sample was conserved at -20 °C for nutrients analyses (nitrates (NO_3^-), nitrites (NO_2^-), soluble reactive phosphorus (SRP), ammonium ($\sum NH_3$) and an aliquot was conserved at 5°C for silica (Si) analysis in both bottom and pore waters.

Aliquots were immediately HNO_3 acidified (0.01 mol L^{-1}; Suprapur Merck) for metal (dissolved iron (Fe_d), manganese (Mn_d) and sulphur (S_d) analysis.

6.4 Sediment sampling and measurements

6.4.1 Gravity corer

The gravity corer is one of the most useful tools for the collection of marine sediment (Figure 2). The gravity corer consists of a 6m long iron barrel with iron weights attached on top of it. The whole apparatus weighs ~ 2 tons. A plastic liner with outer diameter of 11 cm and inner diameter of 10 cm is inserted into the steel barrel. Prior to the coring operation, a core catcher and core cutter are attached to the lower end of the gravity corer. Core catcher keeps the sediments from falling out of the core, whereas core cutter helps the penetration of the core into the sediments.

The gravity corer lies on deck and during operation is lifted vertically with a winch and the gravity corer is lowered to around 20 m away from the seabed. When at the chosen core location, the gravity corer is dropped. When the gravity corer is lifted from the seabed and is brought to deck, the core catcher and core cutter are sampled first, if there are sediments present in them. Then, the plastic liner is taken out, cleaned, cut to 1meter sections, and labeled. Cores are then sectioned and immediately sampled for pore water and gas onboard, whereas the geochemical, microbiological, and micropaleontological investigations will be conducted onshore.

Figure 2: Gravity corer deploying from RV Kronprins Haakon (picture taken during the CAGE22-2 cruise)

6.4.2 Multicorer

The multicorer has been converted into a TowCam/Multicorer, TCM (Figure 3). The frame has been used to place a video camera. The multicore recovers six parallel 70 cm long tubes with a diameter of 10 cm from the same spot at the seafloor. The core tubes are loaded with open upper and lower ends. When the multi corer lands on the seafloor, the tubes are pushed into the soft sediment by lead weights and closed on both ends. Up to 70 cm of sediment and the immediate overlying water can be sampled. This allows the analysis of undisturbed faunal samples within their undisturbed environment. Once on board, the liners were carefully taken out of the sampling device, the ends were sealed, and the cores moved, in an upright position, in the wet laboratory. Once in the lab, in racket to keep them vertical, the sampling of pore water, microbiology, micropaleontology and macropaleontology start. Three extruders were used from the different groups that sampled contemporaneously. In the present cruise, we were able to use real-time imaging capability to precisely guide the sampling locations of the multicorer (MC) samples.

Figure 3. Multicorer deployment from RV Kronprins Haakon.

6.5 Heat flow probe

The heat flow probe is used to measure in situ thermal gradients and the thermal conductivity of the sediments. The Fielax Heat Flow Probe FLX-T015SM (Figure 4) consists of 22 thermistors (temperature sensors) distributed along a 6 m sensor string and a heating wire. The sensors are spaced 25 cm apart and is designed for a temperature range of -2 to 60°C, with a resolution of

1 mK and accuracy of 2mK after calibration. The probe weighs ~1100 kg and can penetrate up to 6 m of sediments, in water depths up to 6000 m. The head section of the probe contains a data acquisition and power supply unit. The data acquisition unit records the data from the sensor string and initiates the heat pulse of the probe. The unit also comprises a high-resolution pressure/temperature sensor (PT100) and can measure the tilt and vertical acceleration of the probe. The configuration of the probe involves definition of stability requirements prior to heat pulse generation, based on pressures recorded by PT100, the tilt and vertical acceleration of the probe. Temperatures recorded by PT100 are used to calibrate the thermistors on the sensor string. The thermal gradients are calculated based on temperatures measured by the thermistors, whereas in situ thermal conductivity is estimated based on temperature decay as a function of time following heat pulse generation. Quality control of the recorded data was done using the Fellow software from Fielax. Processing of this data will be done after the cruise.

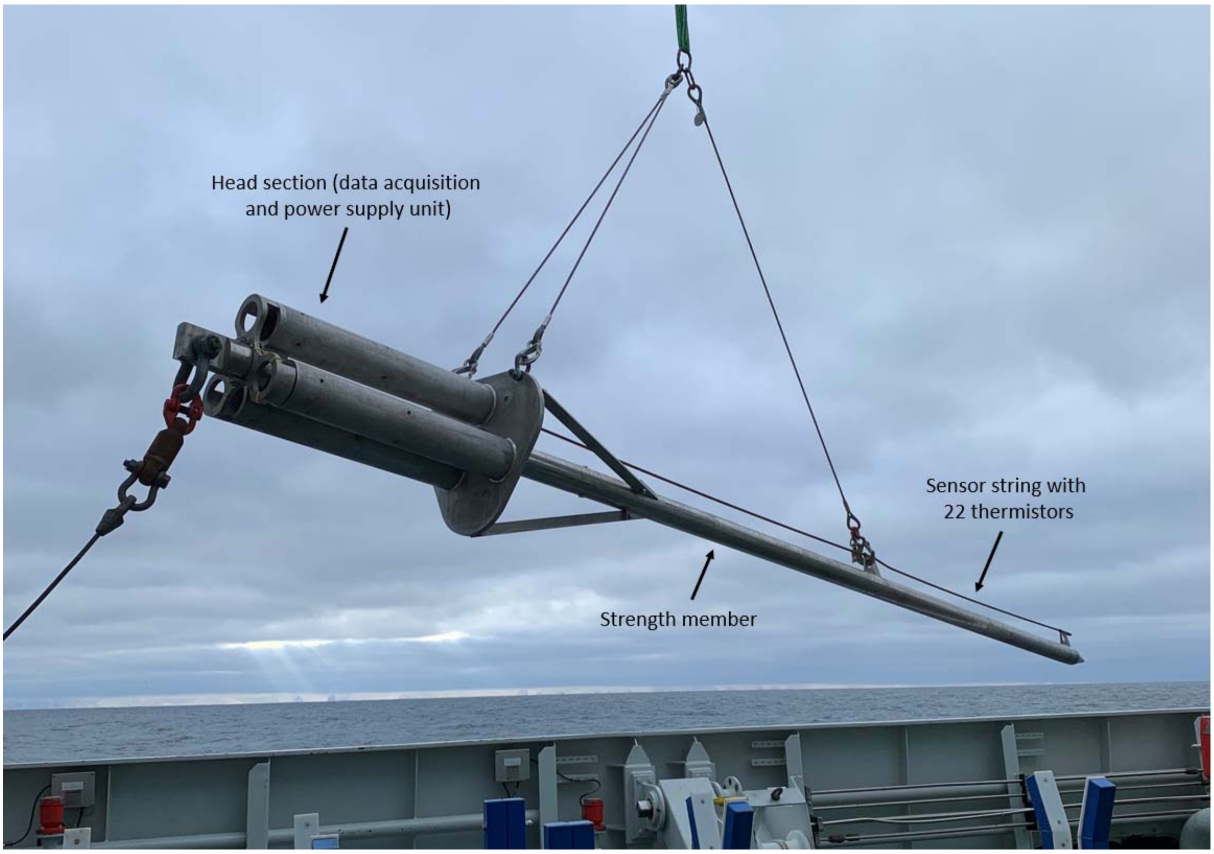

Figure 4. The Fielax heat flow probe being deployed from RV Kronprins Haakon (picture taken during the CAGE21-1 cruise)

6.6 Deep-Towed Camera System

The deep-tow camera system is a modification to the CAGE multicorer tool, that allows capture of images and videos from the multicorer during towing entire instrumentation behind the vessel (Error! Reference source not found.). It consists of a pair of "wings" that are extending out from the front ant the back of multicorer frame and allows for ample space for mounting the cameras, lights and batteries. The system was co-designed with Woods Hole Oceanographic Institute in the U.S.

Batteries are placed in a box and attached to a shelf on the front 'wing' (in a big orange box). Data-link box, providing communication with cameras and lights, is kept in in a black housing on the top of the back 'wing' structure. To improve hydrodynamic shape and positioning during towing, two 130 x 61 cm fins are attached to the sides of the back wing, giving it a better hydrodynamic shape for the towing.
In the front of the system, on the front "wing", live feed camera is mounted pointing at the bottom at 45-degree angle (**Error! Reference source not found.**). Two-point lights, located on the both sides of it, provide necessary light. Bottom-facing camera is held in a pressure housing (Figure 6), and it consists of off-the-shelf photo components (Nikon D810). Housing is in the middle of the front wing structure, pointing directly down. Two green lasers, separated by 20 cm are mounted on left and right side of the bottom-facing camera (one for each side). Strobe lights providing necessary illumination are mounted at the same wing, on both sides of the camera, a little further back. An additional light is mounted in front of the camera, at the leading edge of the entire frame. All data is transformed in the real time by fiber optic cable that is connected to system from the deck (using a winch). We can control status of the strobe lights, recording mode of the cameras and take photos using bottom-facing camera on command.

6.7 ROV Ægir 6000

The ROV ÆGIR6000 is a SUPPORTER 2-type ROV from Kystdesign in Aksdal, Norway (Figure 5). The ROV has a total combined power of 115 Kw, a depth rating of 6000 m and is maneuvered by 7 thrusters. Its dimensions are (LxBxH) 2,75 m x 1,7 m x 1,65 m and it weighs 3600 kg in air. The ROV can carry a payload of 400 kg and has two strong manipulator arms. 8 HD and composite video camera inputs provide full vision of operation and partly have zoom and focus capability. The video footages recorded by the ROV include the overlay (date, time, depth, coordinates, cruise name) in UTC time or in ship time (local time) when not differently indicated in the overlay. The lighting capacity includes ten dimmable lights and has a maximum total load of 2300W. The SUPPORTER 2 can accommodate up to 24 additional hydraulic tooling functions, up to 21 additional survey sensors and 8 camera connectors. All hydraulic functions are proportionally controlled, and all electrical power supplies are ground fault monitored. The ROV control system offers a variety of auto-functions like AutoPOS and AutoTRACK capabilities. The control pod and telemetry system for survey operations work via up to 6 fiber optic cables. The umbilical cable on RV Kronprins Haakon provides 4 fiber optic cables. In addition to the video feed, the system can support several additional communication channels both serial and Ethernet. The ROV is equipped with an EM 2040 multibeam echosounder for deep water multibeam mapping of the near bottom sounding environment in detail. The basic EM 2040 has a transmit transducer, a receive transducer, a processing unit, and a deck-side processing computer. The EM2040 operates at 200 - 400KHz, with 400 beams in single-swath mode offering 0.4 x 0.7 degree angular resolution. A swath angle of up to 140 degrees can be reached providing a maximum coverage of 4 to 5 times the water depth. During the cruise, the maximum swath width was varied between 50 and 70 degrees on either side in order to improve data quality and reduce the amount of noisy data at the outer beams. The ROV is equipped with a large drawer to store sample material during dives. Aside from the manipulator arms that provide the opportunity to take direct carbonate or rock samples, the ROV ÆGIR6000 also offers a number of sampling tools, most prominently the push coring device that can take up to 60 cm long sediment cores with a diameter of 8 cm (Figure 56). Another device is the blade corer; it is 32 cm long and can sample a volume of sediment with a larger rectangular area of approximately 25x10 cm (Figure 6). The push cores are of fiber glass, 60 cm long with a diameter of 8 cm (Figure 6). Push core and blade core liners are pre-drilled for pore water sampling with a resolution of 1-2 cm. The push cores are placed in the hull of the ROV during the entire dive, while the blade core container is held by one of the ROV arm during descent and ascent. When the ROV reaches the bottom, the blade cores container is placed on the seabed while the Dive is ongoing. The blade corer frame has an automatic closing mechanism at the bottom to avoid sample loss. The blade cores are manually winded up before hand, and when placed on the seafloor the ROV will push them into the sediment and release a pin that makes the blades closing. This trap the sediments in the core and the whole core becomes sealed.

Figure 5. Deployment of the ROV Ægir6000. ROV Ægir6000 is a Kystdesign Supporter ROV rated to 6000 m water depth.

Figure 6. Blade corers (left) (frame 25 x 10 x 32 cm) and push corer (right) (inner diameter 8 cm, lenght of 60 cm) used during visually-guided sediment sampling with the ROV (CAGE22-2).

Ægir6000 also has a METAS suction sampler with 5 chambers and a suction hose with a diameter of 8 cm. The suction sampler allows for targeted sampling of mobile fauna and fauna of small size, and the closed chambers keep the samples in good shape until they reach the vessel. Two ROV operated scoops were also used, one square and open which is effective for scraping hard surfaces and collecting pieces of rock and larger faunas. The second scoop is cylindrical with a lid, and enables collection of fauna in areas where coring is difficult because of crusted/rocky sediment.

7. Methods

7.1 Marine Geology

The complete list of all sediment samples collected during the expedition is reported in table "List of samples" with indication of the sampling gear, namely pushcorers and bladecorers operated by Ægir ROV, by gravity, by the multicorer, as well as indication of the target analyses.

7.1.1 Sedimentology

The type of seafloor sediment was assessed based on high-resolution ROV imagery of the seafloor (top layer) and visual inspection during push core and bladecore slicing. X-ray fluorescence (XRF) core-scanning, a convenient non-destructive tool to rapidly assess elemental variations in grain size analyses will be done once in the lab.

7.1.2 Pore water geochemistry - sulfate, DIC, Sr isotopes

We extracted pore water samples from different depths from push cores, blade cores and gravity cores upon retrieval. The push core and blade core liners were pre-drilled every 2 cm and sealed with tape prior to deployment. The pore water sampling was conducted in cold storage (4 °C). We collected the samples using 5 cm long pre-wetted rhizons (0.15 µm mesh) and 12 mL syringes (Figure 7). The pore water samples were split in three aliquots: 1) 1.5 mL subsamples were transferred into screw cap glass vials for dissolved inorganic carbon (DIC) analysis. We added 10 µL of mercuric chloride ($HgCl_2$) and stored DIC samples at 4 °C. 2) >1 mL was transferred into Eppendorf tubes and stored at -20 °C for sulfate analysis. 3) Samples for strontium isotope analysis (> 1 mL) were treated with 10 µl of ultrapure 65% nitric acid (HNO_3) to lower the pH to < 2 and stored at 4 °C.

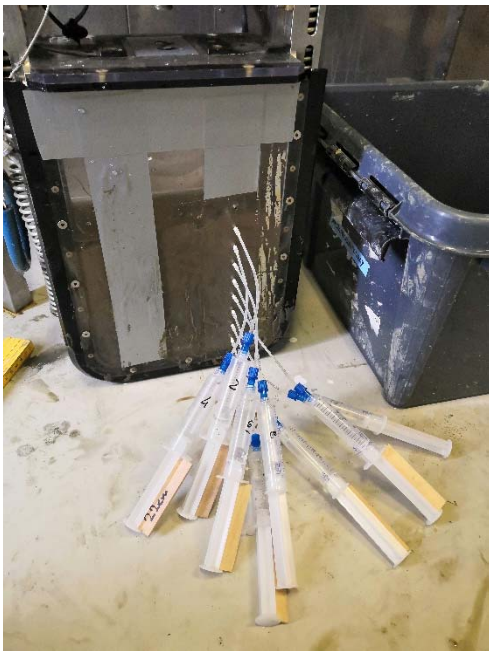

Figure 7. Pore water extraction from blade core CAGE22-2-KH-04-BlaC-01

7.1.3 Alkalinity

On each super-station, 4 cylindrical cores were collected with the ROV or with the multicorer. 2 from reference super-station site using multicore PVC tubes (10 cm diameter, 70 cm long) and 2 from bacterial mats using PVC tubes (7cm diameter, 50cm long). Cores were sliced every 5 mm step from 0 to 6 cm depth, 2 cm step from 6 to 14 cm depth and 4 cm step from 14 to 30 cm depth (i.e. 20 layers) under nitrogen atmosphere. Porewater was extracted from each sediment layer by centrifugation (15 minutes at 3000g) then filtered through 0.2 µm filters. Overlying and pore waters were conserved at -20 °C for nutrients analyses (nitrates (NO_3^-), nitrites (NO_2^-), soluble reactive phosphorus (SRP), ammonium ($\sum NH_3$)) and an aliquot was conserved at 5°C for silica (Si) analysis in both bottom and pore waters. Aliquots were immediately used for alkalinity measurement and HNO_3 acidification (0.01 mol L^{-1}; Suprapur Merck) for metal (dissolved iron (Fe_d), manganese (Mn_d)) and sulphur (S_d) analysis. Alkalinity was determined according to the colorimetric Sarazin et al., (1999) method. Absorbance measurements were carried out with a spectrophotomer (Schimadzu 1900) at 590 nm.

The remaining sediment (from centrifugation) was then frozen at -20°C. Samples will be freeze-dried and manually grounded for solid phase analyses (organic matter, metal oxides).

Alkalinity calibration range

Some alkalinity results (red line represent the sediment)

Alkalinity

Reference station

Bacterial mat station

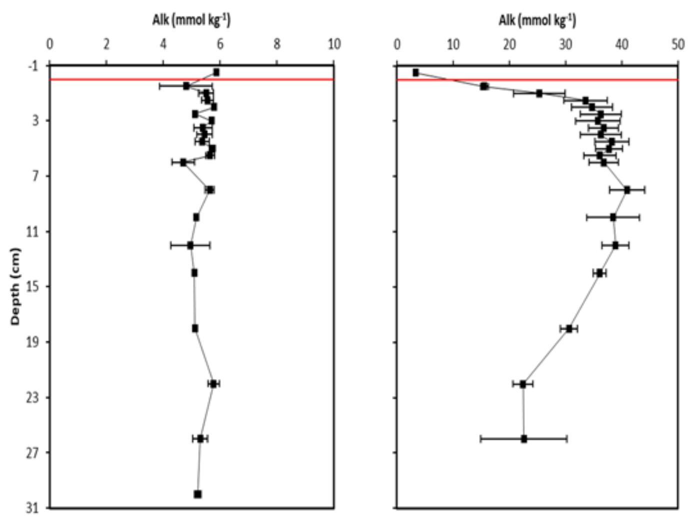

Figure 8. Alkalinity calibration rage and examples of alkalinity measured in reference and microbial mat station

Sample list for alkalinity measurements:

Super station	Location	Sample code	ROV Dive	Date	Recovery (cm)	Habitat
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-02_1	-	14.05.2022	30	Reference
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-02_4	-	14.05.2022	30	Reference
KH03	Vestnesa seep NW	CAGE22-2-KH-03-PusC-04	ROV06	16.05.2022	26	Mats
KH03	Vestnesa seep NW	CAGE22-2-KH-03-PusC-05	ROV06	16.05.2022	26	Mats
KH04	Svyatogor ridge	CAGE22-2-KH-04-MC-01_1	-	19.05.2022	30	Reference
KH04	Svyatogor ridge	CAGE22-2-KH-04-MC-01_2	-	19.05.2022	30	Reference
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-03	ROV09	19.05.2022	30	Mats
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-04	ROV09	19.05.2022	26	Mats
KH05	PKF oil seep	CAGE22-2-KH-05-PusC04	ROV15	22.05.2022	30	Mats
KH05	PKF oil seep	CAGE22-2-KH-05-PusC07	ROV16	22.05.2022	30	Mats

7.1.4 Oxygen penetration depth

The oxygen penetration depth of all cores collected for microbiology and infauna ecology (push and multicorer) was assessed using a Clarck microelectrode that reacts to oxygen (Unisense, Aarhus, Denmark). Then, we sliced the core every cm for the first 10 cm and then every 4 cm until the bottom of the core. Each of the core sampled for microbiology has a sister core were porewater composition and methane concentration will be measured. All samples were frozen after collection (-80ºC)

7.1.5 Gas in sediment

Bulk sediment samples (5 mL) were extracted at 5 cm and 15 cm depth in blade cores and push cores using a cut-off syringe. The samples were transferred into glass vials prepared with 5 mL of NaOH (1 M) to stop microbial activity (Figure 8), plugged with a rubber septum, sealed with aluminum crimp caps and shaken, then stored upside-down at 4 °C.

Figure 9. Bulk sediment sample in a glass vial prepared with NaOH. The headspace will be analyzed for gas composition.

6.1.6 Gas from hydrate sampling

Gas hydrates were found at the bottom of the gravity corer, in the core catcher. Small fragments of gas hydrates were placed into a bucket full of water and the gas generated during the degassing collected into a glass bottle filled with water. The gas bubbling gradually substituted the water in the glass bottles to avoid overpressure (Figure 10; Table ICE). The bottles were then sealed with rubber stoppers and caps and stored in the -20 °C cold room.

Figure 10. Samples of bottom water were collected with the CTD at ca. 10 m from the seafloor (seafloor depth 1382 m) at a measured pressure of 1405 Pascals.

7.1.7 Rock sampling

Rock (carbonates and non-carbonates) samples noticed at the seafloor during the ROV Dives that were of particular interest have been collected from the seafloor using the ROV manipulator arm. Rocks were washed with freshwater to remove any salt residue and left on deck to dry out. On some occasions the biologist removed epiphytic organisms attached to the rocks.

7.1.8 Oil Sampling

The oil from Prins Karls Foreland sediment was sampled from the overlay water inside one of the blade cores recovered from the ROV Ægir. The oil has been removed with a syringe and put into a vial for further measurements. The sample will be kept by NPD, Norway.

7.1.9 Heat flow measurements

During the CAGE22-2 cruise, in situ temperatures were measured at 13 stations, with a total of 31 successful penetrations (Figure in chapter “maps and sampling”). The main objective of the heat flow survey was to obtain high-resolution heat flow measurements across faults and pockmarks on the western Svalbard continental slope just north of the MTF, and across crustal highs in the Svyatogor Ridge area.

Previous studies in the area have revealed areas with anomalous thermal gradients and low thermal conductivities coinciding with fluid flow indications in seismic data, possibly indicating the presence of gas and active fluid flow. The heat flow probe was deployed after configuration, and lowered to the seafloor with a winch speed of ~1.2 m/s. The probe was stabilized 50 m above seafloor before penetration. After penetration it was kept stable in the sediments for 10 min, allowing stabilization of temperatures after temperature increase due to frictional heating during penetration. A heat pulse was then generated for about a 3rd of all measurements, and the probe kept in the sediments for another 15-20 minutes to allow temperature decay following heating. The probe was then pulled out of the sediments with a winch speed of ~0.2 m/s. Several transects of heat flow measurements were conducted using the 'Pogostyle' method, in which the probe was lifted ~100 m above the seafloor, initiating a new cycle, and moved to a nearby location between 150 to 500 m away for new heat flow measurements. During all measurements, the heat pulse (duration of 20 s) was set to release if the probe remained stable for 15 minutes, and the tilt was within 10° with fluctuations within 0.5°, and acceleration fluctuations within 0.01 g. The vertical distance limit for activating the second heat pulse was set to 100 dbar. Figure XYZbelow shows an example and quality control of heat flow station HF9 with two penetrations. A heat pulse was triggered only for the first measurement.

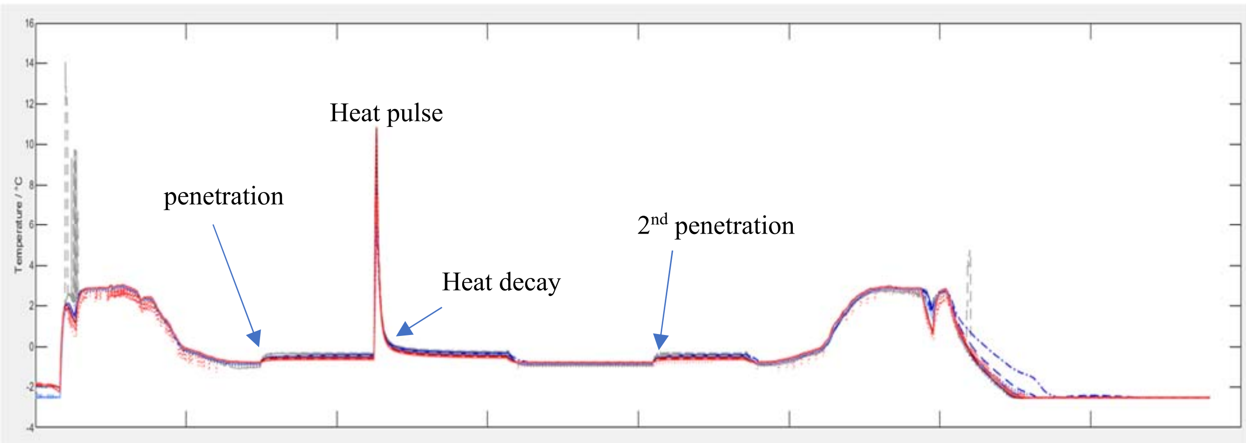

Figure 11. Quality control of heat flow station HF9 with two penetrations from launching to recovery of the heat flow probe.

7.2 Marine Biology

7.2.1 Microbiology

Cold seeps environments are characterized by methane fluxes from reservoirs below the seabed to the water column. This source of carbon can be converted by bacterial/archaeal consortium into hydrogen sulfide. Thereafter, hydrogen sulfide become a source of energy for free living or symbiotic bacteria. For this cruise, we investigate the microbial community that occurs at the bacterial mats. We combined sediment sampling using push corers deployed by the ROV and Multicorer, deployed from the ship. All samples collected are listed in table below:

Sample list for microbiology:

SS	Location	Sample code	Micro-habitat	O2 Pen (mm)	Microbio
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-03_3	Reference	31 (0%Sat)	X
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-04_1	Tubeworms	19 (0%Sat)	
KH03	Vestnesa seep NW	CAGE22-2-KH-03-PusC-01	Mat	1.5 (0%Sat)	X
KH03	Vestnesa seep NW	CAGE22-1-03-PusC-07	Ref (within seep)	1.7 (0%Sat)	
KH04	Svyatogor ridge	CAGE22-2-KH-04-MC-01_5	Reference	30 (30%Sat)	X
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-01	Mat	1.2 (0%Sat)	X
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-07	Tubeworms	23 (0%Sat)	
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-09	Ref (within seep)	7 (0%Sat)	
KH05	PKF oil seep	CAGE22-2-KH05-PusC-06	Mat	2 (0%Sat)	X

Future work

We will extract the DNA and the RNA from 2 grammes of each of the 162 samples collected. Nucleic acids will then be sequenced using specific primers targeting Bacteria and Archaea to reveal the microbial community diversity in the sediment surrounding the flare and within the gas.

7.2.2 Micropaleontology and meiofauna diversity

Sediments and the overlaying bottom water were collected from all seep areas investigated using either the ROV-guided push cores (Ø 8cm) or the blade cores (32x25x10cm) deployed with the ROV Ægir6000 (see summary sample list in table below). The coring inside the seep sites targeted the following micro-habitats: bacterial mats, tubeworm patches and sediments in the vicinity of the seep. Additionally, replicate cores were collected by means of the multi-corer (Ø 10cm) in areas outside the central active seepage locations, as a reference. This sampling aimed to investigate the infauna biodiversity of the studied micro-habitats in these seep sites, namely from the >32 µm fraction of the sediments, including both the metazoans and foraminifera. Additionally, surface sediment samples were also collected for subsequent molecular analyses of foraminifera (ID-Gene, Switzerland). These analyses will be conducted at UiT (Norway), Ifremer (France) and U. Aveiro (Portugal).

In each seep and micro-habitat, three replicates' cores were collected for the infaunal analyses. The overlying water of each liner was removed and filtered over a sieve of 32 µm before slicing. For one of the selected replicate cores where environmental characterization of the sediments was conducted, the pore-water was sampled prior to core slicing (for details see chapter 7.1.2). After the pore-water extraction was completed, each liner was sliced into 5 sediment depth layers (0-1cm, 1-2cm, 2-3cm, 3-4cm, 4-5cm) and fixed in a formaldehyde (4%)/seawater solution for morphological analyses. For the cores where the environmental parameters were also investigated, 1⁄4 of each sediment slice was kept in -20ºC (e.g, pore-water, sediment geochemistry and grain size analyses). Additionally, at each superstation cores were sub-sampled and sediments were preserved in 96% Ethanol solution or life-guard for future molecular studies. All samples collected for infauna diversity studies (including foraminifera and metazoan meiofauna) are listed in table below:

Sample list for micropaleontology and meiofauna diversity:

SS	Location	Sample code	Micro-habitat
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-01_1	Reference
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-02_2	Reference
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-02_3	Reference
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-04_1	Reduced sediments and tubeworms
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-04_2	Reduced sediments and tubeworms
KH03	Vestnesa seep NW	CAGE22-2-KH-03-MC-04_3	Reduced sediments and tubeworms
KH03	Vestnesa seep NW	CAGE22-2-KH-03-PusC-01	Tubeworm patch
KH03	Vestnesa seep NW	CAGE22-2-KH-03-BlaC-01	Tubeworm patch
KH03	Vestnesa seep NW	CAGE22-2-KH-03-PusC-02	Bacterial mat
KH03	Vestnesa seep NW	CAGE22-2-KH-03-PusC-06	inside pit
KH03	Vestnesa seep NW	CAGE22-2-KH-03-BlaC-02	Half in dense gastropods patch/Half Bacterial mat
KH03	Vestnesa seep NW	CAGE22-2-KH-03-BlaC-03	Bacterial mat
KH03	Vestnesa seep NW	CAGE22-1-03-PusC-07	Reduced sediments (reference within seep area)
KH03	Vestnesa seep NW	CAGE22-1-03-PusC-09	Reduced sediments (reference within seep area)
KH03	Vestnesa seep NW	CAGE22-1-03-PusC-10	Bacterial mat (intense bubbling)
KH04	Svyatogor ridge	CAGE22-2-KH-04-MC-01_3	Reference
KH04	Svyatogor ridge	CAGE22-2-KH-04-MC-01_4	Reference
KH04	Svyatogor ridge	CAGE22-2-KH-04-MC-01_5	Reference
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-01	Bacterial mat
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-02	Bacterial mat
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-05	Bacterial mat
KH04	Svyatogor ridge	CAGE22-2-KH-04-BlaC-01	Bacterial mat
KH04	Svyatogor ridge	CAGE22-2-KH-04-BlaC-02	Bacterial mat
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-06	Tubeworm patch
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-07	Tubeworm patch

KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-08	Reduced sediments (reference within seep area)
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-09	Reduced sediments (reference within seep area)
KH04	Svyatogor ridge	CAGE22-2-KH-04-PusC-10	Reduced sediments (reference within seep area)
KH04	Svyatogor ridge	CAGE22-2-KH-04-BlaC-03	Tubeworm patch
KH04	Svyatogor ridge	CAGE22-2-KH-04-BlaC-04	Transition between tubeworms and bakground
KH05	Prins Karl Forland Oil Seep	CAGE22-2-KH-05-PusC-01	Bacterial mat with oil
KH05	Prins Karl Forland Oil Seep	CAGE22-2-KH-05-PusC-02	Bacterial mat with oil
KH05	Prins Karl Forland Oil Seep	CAGE22-2-KH-05-PusC-03	Bacterial mat with oil
KH05	Prins Karl Forland Oil Seep	CAGE22-2-KH-05-BlaC-01	Bacterial mat with oil
KH05	Prins Karl Forland Oil Seep	CAGE22-2-KH-05-BlaC-02	Bacterial mat with oil
KH05	Prins Karl Forland Oil Seep	CAGE22-2-KH-05-PusC-06	Bacterial mat with oil

7.2.3 eDNA for benthic monitoring (0-2 cm depth only)

The protocol for sampling sediment eDNA for benthic monitoring according to ID-Gene ecodiagnostics, Campus Biotech, 15, av de Sécheron, 1202 Geneva, Switzerland was used to determine the biodiversity of foraminifera. Sediment was sampled using a sterilized spoon kept in a sterilized plastic bag, fixed with Life Guard TM (QIAGEN, ref. 12868-1000) solution for preserving eDNA, and stored at 5°C.

7.2.4 Macrofauna

The aim of macrofauna sampling was to get good coverage of the biodiversity of the various microhabitats of each seep site. To achieve this, macrofauna was extracted from samples collected with the ROV operated Push cores (Ø 8 cm), Blade cores (32*25*10 cm), Suction sampler and Scoop. In addition, some larger animals were collected using the ROV arm, and placed in the Bio-box of the ROV, where the samples are protected on the way up through the water column. At each cold seep site, we targeted areas with bacterial mats, tubeworm fields and rocky substrates to represent the different microhabitats. Reference samples from inactive sedimented areas were collected with the Multicorer.

All samples for macrofauna were carefully sieved through two stacked sieves with 2 mm and 1 mm mesh size. Most of the material was fixed on 96% ethanol, but some target taxa were sorted out using a Leica stereomicroscope, and frozen at -80 degrees for genomic studies. Some were also fixed on Glutaraldehyde for microscopy studies (SEM/TEM, FISH). In addition, specimens of all the common taxa at each site were frozen at -80 degrees for foodweb analyses using stable isotopes. Reference samples of sediments from the same stations were also collected and frozen. Foodweb analyses will be performed in collaboration between the University of Aveiro, Portugal, and the University of Bergen, Norway.

Figure 12. An example of subsampling for macrofauna. by Ciara Willis.

7.3 ROV photomosaics

A total of 17 ROV Dives were carried out using the ROV ÆGIR6000, among which 3 Dives (DIVE03, 08 and 13 – Table" Cruise log") were dedicated to collecting video footage at SS3, along parallel transects spaced from 1.8 to 2 m from each other. Dive 03 and Dive 08 acquired videos at a constant speed (0.1kn) and distance from the seafloor (2.4m) using a downward looking camera. Dive 13 surveyed two additional areas at SS3 using a forward-looking camera (45° oriented), also following parallel transects at a constant speed (0.1kn) and distance from the seafloor (2m). All videos from Dive03, 08 and 13 will be used to implement photomosaic reconstruction of the seafloor in key areas of SS3, applying photogrammetric techniques (i.e. Structure from Motion - SfM) on frames extracted from the videos. The accurate ROV positioning (from a USBL system), the depth measurements obtained from the ROV-based multibeam surveys (Dive03 and 08) and the information resulting from the use of the two ROV laser points will be fundamental to scaling and positioning the photomosaics in the associated geographical context. The high-resolution orthomosaics will allow us to reconstruct representative seafloor features of the sampled areas at SS3 and figure out the spatial pattern characterizing the observed distribution of bacterial mats and detected macrofauna (i.e. tubeworms).

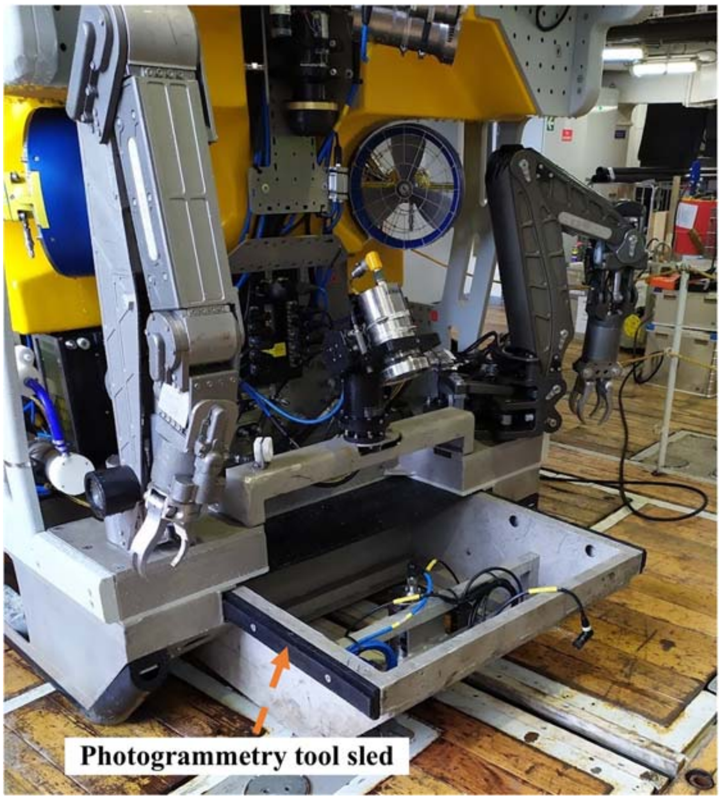

Figure 13. Aegir6000 photogrammetry setting

Using photogrammetry underwater is still in an exploratory phase, and relatively few SfM surveys have been carried out in the deep-sea due to the difficulty of acquiring controlled images at depth with appropriate illumination. High performed work-class ROVs , such as the AEGIR6000 ROV, however, can collect suitable images and data. A methodological protocol was therefore designed on board, focusing on defining (1) camera position and orientation, (2) intensity and coverage of lighting on the footage, (3) survey speed and altitude, and (4) appropriate overlap between adjacent lines, in accordance to the complexity and morphological attributes of the topography of the surveyed seabed.

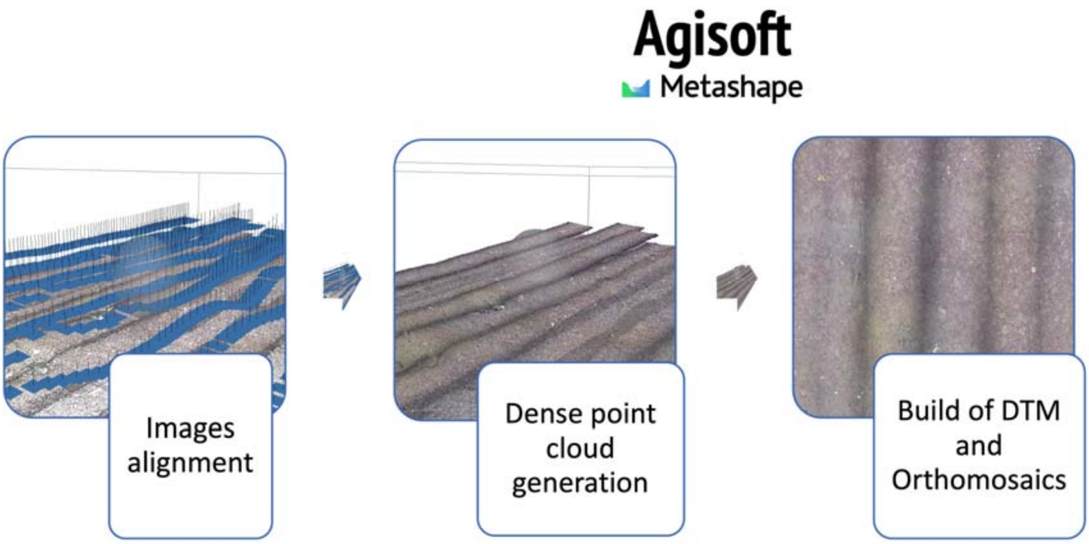

Figure 14. Structure from Motions (SfMs) processing workflow

7.3.1 SEAFLOOR MAPPING AND PHOTOMOSAICKING for Vestnesa Ridge (SS3)

ROV-based multibeam micro-bathymetry was collected during DIVE03 and DIVE08 (Figure below). The targeted pockmark was initially surveyed during DIVE03, where flares were detected during the preliminary ship-based multibeam survey. Two sub-parallel ROV multibeam lines, 70m spaced and oriented along the central axis of the pockmark, from NE to SW, were acquired at 30 m of altitude covering a total area of 0.04 km^2. During DIVE08, the ROV-based multibeam survey was planned to cover the entire remaining part of the identified pockmark, following 4 additional 500m long and 60m spaced multibeam lines, still oriented from NE to SW, and one line, 450 m long, oriented from NW to SE. The multibeam data were pre-processed on board, obtaining a DTM surface at 0.25x0.25m (grid cell size) of resolution.

At SS3, DIVE03 and Dive08 were also focused on collecting video footage using a downward looking camera in order to photomosaicing two sampled areas. Dive03 collected videos following 10 60m long parallel lines at a constant speed (0.1kn) and distance from the seafloor (2.4m). The surveyed lines are 1.8m spaced from each other and oriented from SE to NW, to cover an area characterized by the presence of large patches of bacterial mats and tubeworms, spanning approximately 1200 m2. During DIVE08, video footage was acquired along 7 parallel transects, approximately 60 meters long, applying the same configuration as DIVE03 (i.e. transects spaced 1.8 m apart followed at 0.1 kn with 2.4 m ROV altitude), to cover an area of approximately 800 m2, extended across the main pit sampled during the expedition at SS3, where seeping gas and gas hydrate were clearly visible.

Dive 13 collected footage using a forward looking camera (45° oriented) to survey at constant speed (0.1kn) and distance from the seafloor (2m), two other small “pits”, characterized by patches of bacterial mats and tubeworms: one located to the north of the pockmark and one towards the southernmost edge. To the north the survey was carried out following three 40 m long parallel transects covering a total of 240m^2, while to the south a larger area of approximately 800 m^2 was surveyed following 7 60 m long parallel lines.

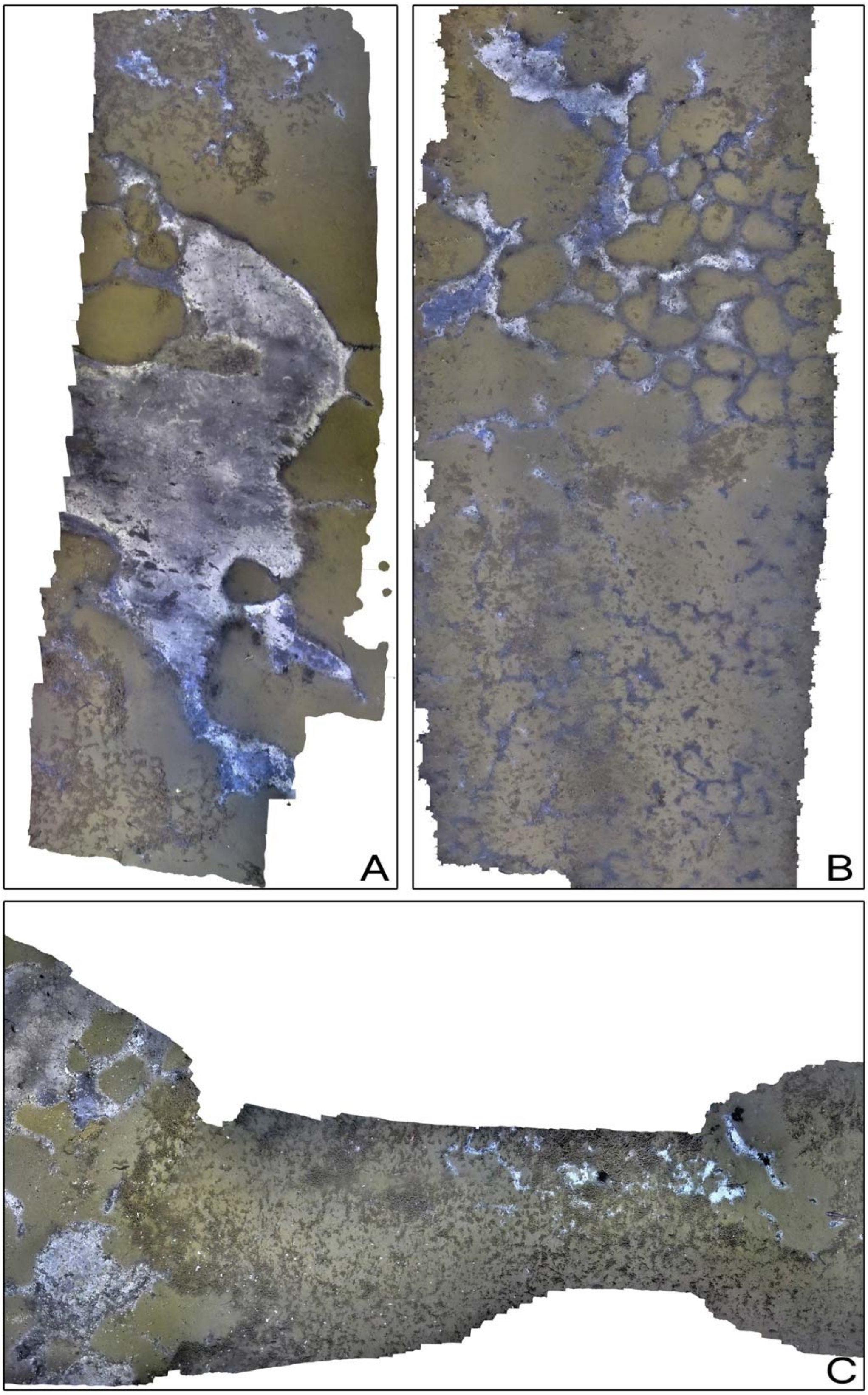

Figure 15. Examples of some small photomosaics produced on board to evaluate the performance and quality of video footages captured during Dive 3. A: large bacterial mat located in SS3 and extensively sampled during dive05 and dive06. B: Small photomosaic represe.

7.4 Work on sea ice

The ice coring device consists in a threaded plastic barrel, 1 m in length and with an inner diameter of 14 cm (Figure 16). The drill bit consists in two blades that grind into the ice, and the core is retained in the barrel by two spring devices that act as core catchers. The corer is powered by a hand drill and can be equipped with extension rods to reach up to 4 m depth.
Ice cores were placed into plastic bags and transported to a -20 °C cold room where they were prepared for further analyses. The ice cores were described in the -20 °C cold room and photographs were taken. Then we sliced the cores at 3 and 6 cm intervals to make them ready for spectrographic and compositional analyses. These slices were placed into plastic bags and stored under vacuum.

Figure 16. Sea ice work. The team is collecting ice cores.

Samples taken during Ice work:

Superstation	Local Station	Type*	Sample ID	Description
CAGE22-2-KH-02	115	IC	#1.0	Water sample from drill hole #1
CAGE22-2-KH-02	115	IC	#1	Core 1 – 1.33 m long
CAGE22-2-KH-02	115	IC	#2	Core 2 – 1.28 m long
CAGE22-2-KH-02	115	IC	#3	Core 3 – 1.30 m long
CAGE22-2-KH-02	115	IC	#4.0	Water sample from drill hole #4
CAGE22-2-KH-02	115	IC	#4	Core 4 – 1.16 m long

*IC = Ice; GC = Gravity corer;

8. Maps of the study sites samples

8.1. SS1 (Flare site, W.Prins Karls Forland) and SS2 (ice station) map

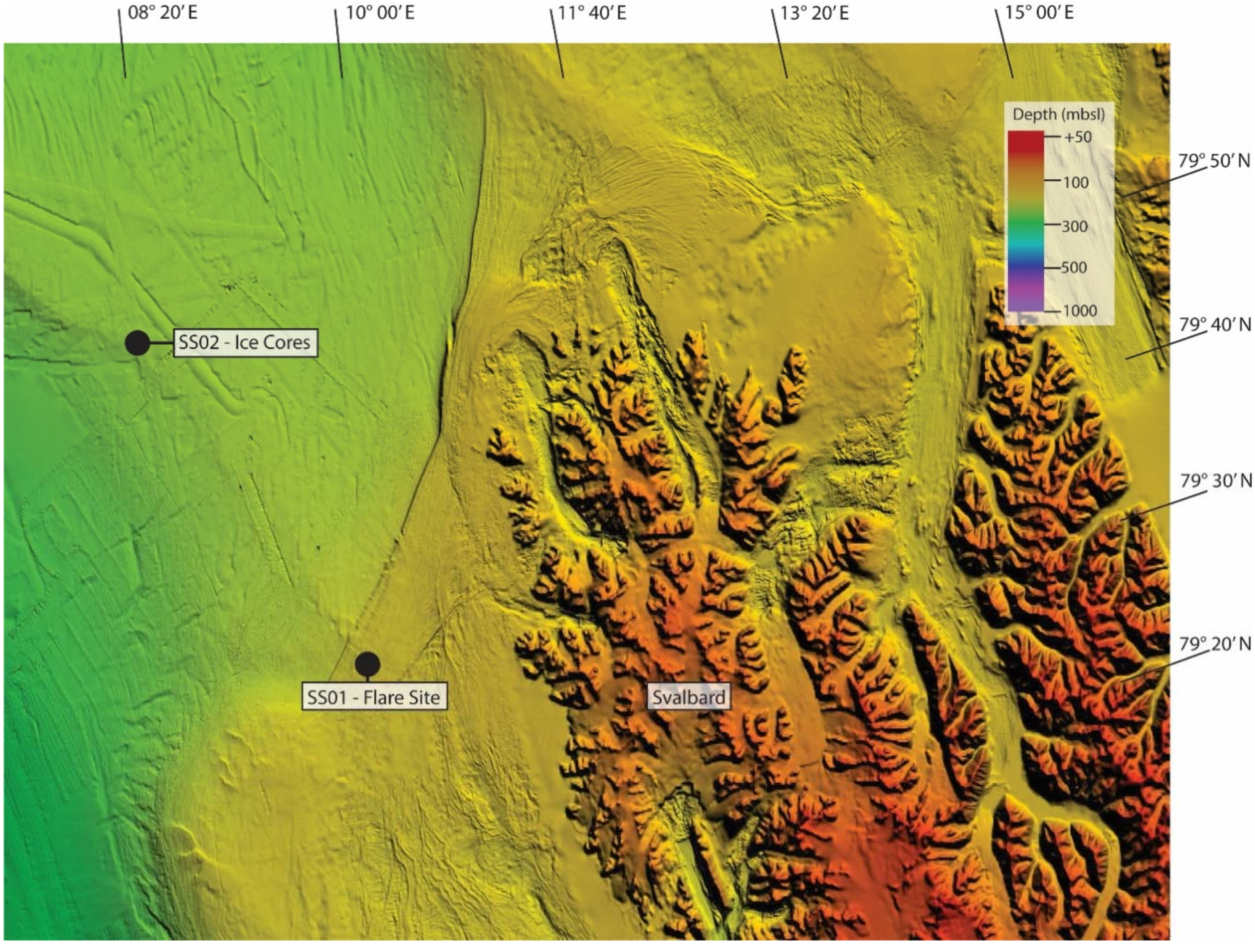

Figure 17. Map showing the Ice station (SS2) sampled during the cruise.

8.2 SS3 (Vestnesa Ridge) map and samples

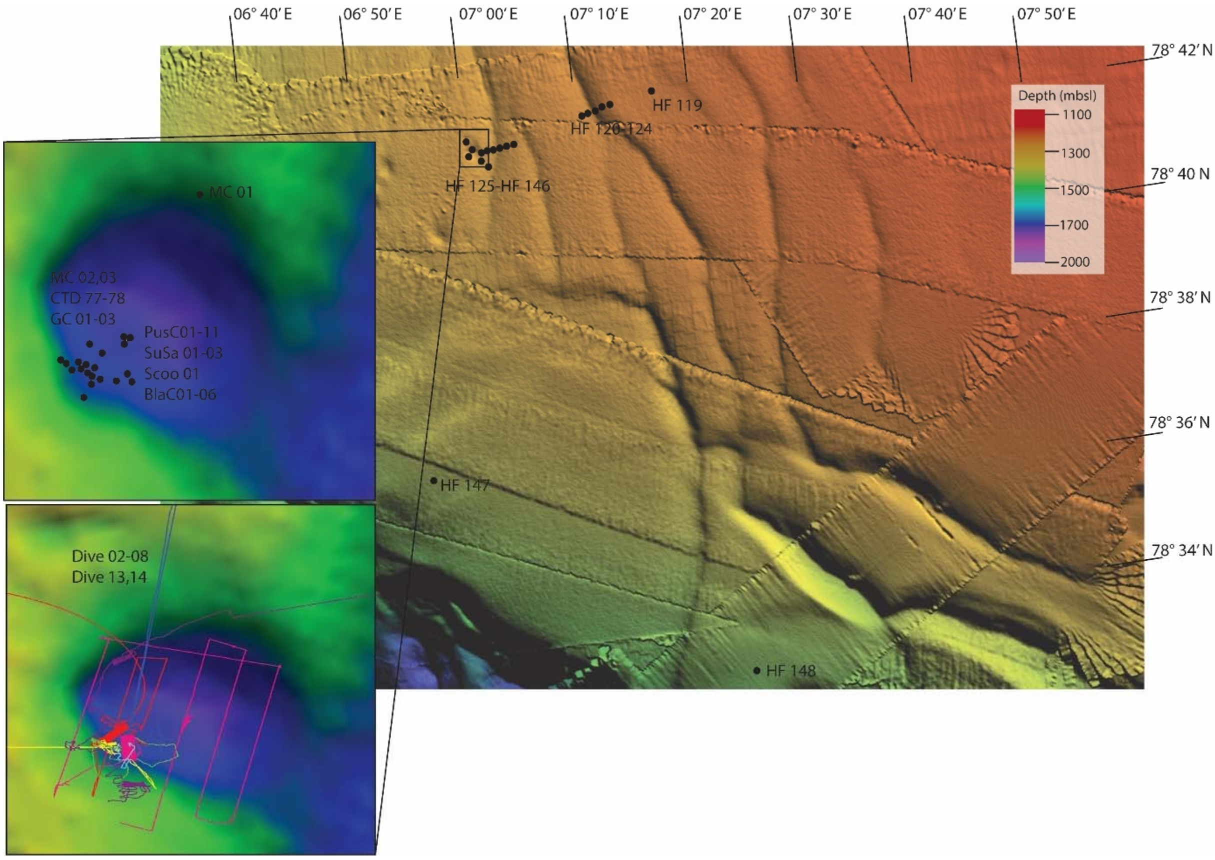

Figure. 18. Map showing multibeam survey, Dive tracks, sampling sites and area of photomosaic at the pockmark southeast of Vestnesa Ridge, western Svalbard continental slope.

8.3 SS4 (Svyatogor Ridge) map and samples

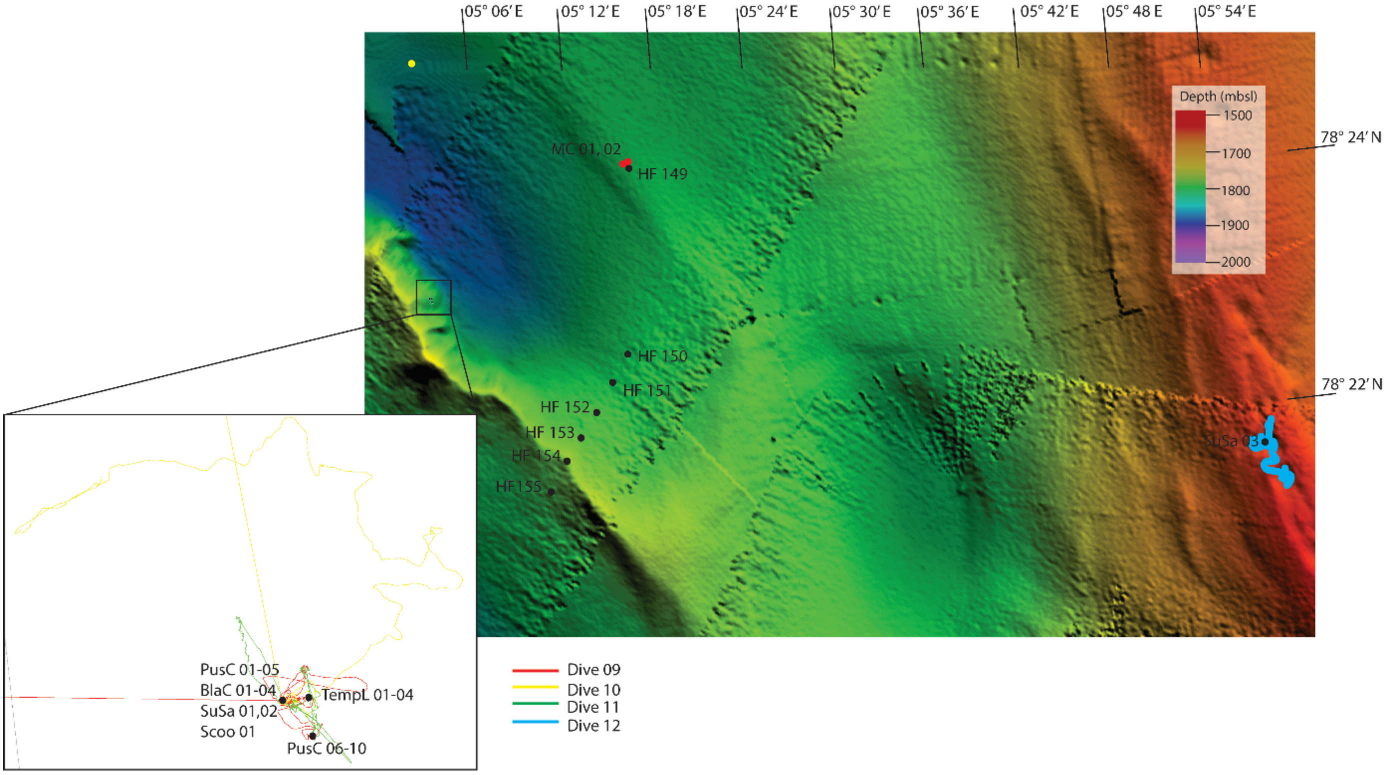

Figure 19. Heat Flow stations, ROV tracks and samples from Svyatogor Ridge

8.4 SS5 (Prins Karls Forland) map and samples

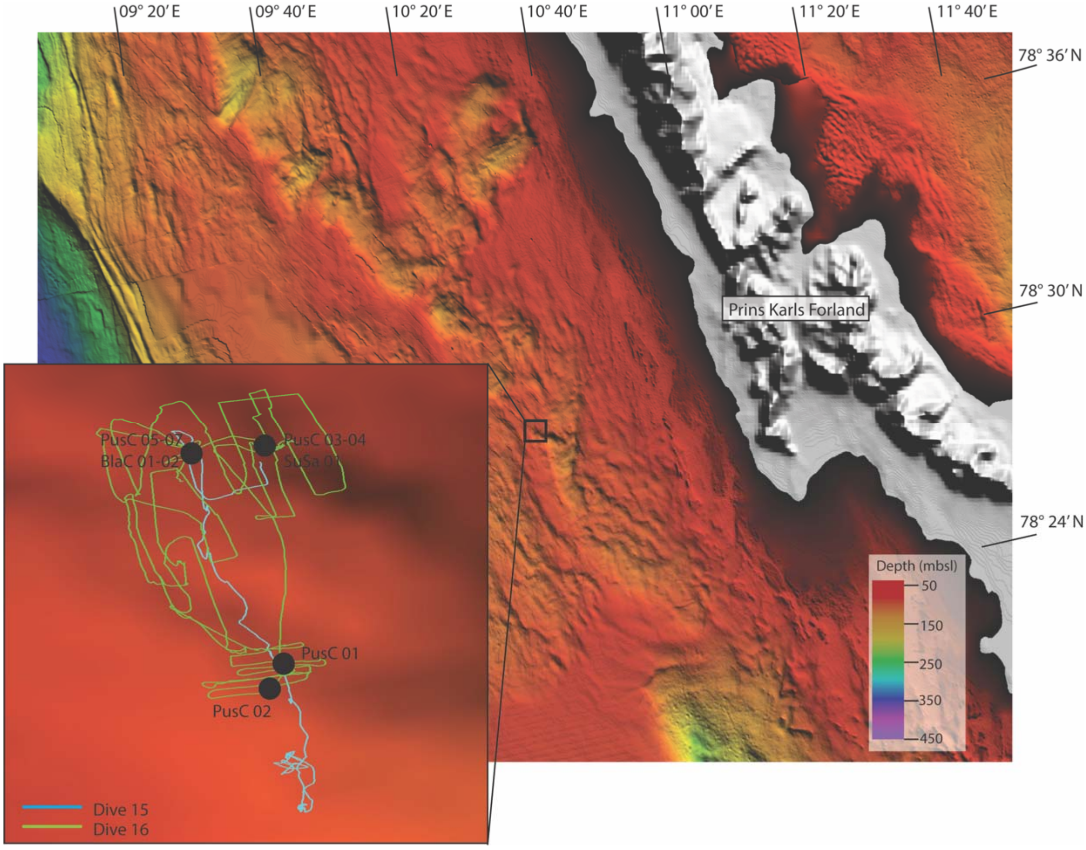

Figure 20. Map showing the ROV tracks and sampling sites, western Svalbard continental slope.

9. OceanSenses expedition narrative

Thursday 12th May DAY2

We began with a brief introduction about OceanSenses and the aims for the cruise. Todd and Willis joined the Sight team. All the teams had productive days with lots of brainstorming and discussions with the scientists. All teams made progress towards narrowing down ideas to further develop during the days on board. For example, Team Smell played around with ideas of developing a game around the smells we can experience on/near/under the sea floor. They also had an idea about getting school children to make and capture hydrogen sulphide. Once they have smelt this (maybe a few weeks later), then the teacher can teach about deep-sea environments where different animals and plankton live. These animals are dependent on the hydrogen sulphide, even though it smells so bad for us. Smells help us recall memories and experiences. Maybe this smell can help the student recall the story of the animals so dependent on this hydrogen sulphide.

Friday 13th May DAY3

We had an inspiring workshop with Zimmermann during which we sculpted foraminifera from modelling clay. We were inspired by pictures of forams on the screen and then made a modelling base from tin foil and continued to build the characters from clay. Zimmermann guided us through the process. As we worked, Pawlowski told stories about how the different forams behave, where they live, and shared information about their physiology. This clearly demonstrated the potential for dialogue when we gather around artistic processes using our hands. The characters we produced (all from non-experts!) would be perfect to make short time-lapse movies with. One related idea that emerged is to create a learning material that guides a teacher through a similar process. The process then rounds off with the students making short time lapse films telling a story based on the characteristics of the foraminifera the students have just heard about.

Team Taste made good progress today with a lengthy brainstorming session and further development of ideas for their scientist-teacher pairing film. They are finalizing the lesson plan and will continue to write the script. They will concentrate their idea on methane and gas hydrates. Their lesson plan will implement as a method called “jigsaw puzzle” to help the students learn about the distribution of methane using a world map, including information about smell/taste. During the lesson, groups of students gather information for part of the map for a time. Then, an “expert” from each group goes to a different group, and so on. In this way, the groups “collect” information about the whole map. Where they see a certain number of characteristics, then they can say that that area may show methane seepage. When all the information comes together then each group should be able to compile a complete map.

Saturday 14th May DAY4

Last night was full of action due to the sea ice, and the ice cores that were taken. Therefore, we did not start the working day until just after lunch. It was important to give everyone on board to witness this work and to have the chance to walk on the sea ice.

Mohadier and several of the scientists had a fruitful Zoom seminar with 20+ people from Iran. Thereafter we continued our OceanSenses work with an open discussion on progress in the different groups. All the groups have started developing fantastic ideas along the lines of the senses they are working on. Some of the groups are finding it challenging to focus on one sense alone, and we discussed different ways of tackling this. Team Sound has a variety of activities under development from storytelling and sound recordings to ultra-sonic sounds to songs. Team Smell is working on a larger idea about developing a board game. They are also working on a more targeted activity around the smell of organic decomposition and stories about animals on the sea bed and how they depend on hydrogen sulfide to survive. They also work on an extended activity grounded in the modelling workshop we had yesterday. Team Taste has continued to develop 4 videos that will form the basis of their teacher-scientist pairing scheme. Team Sight is looking into larger ideas about developing a "layered" map that can show different types of objects/animals/information in different colour "combinations". Willis explained a classroom activity where children are in a dark classroom wearing blue filtered goggles and try to find red fish that are difficult to see in the low light. The pupils need to communicate via hand signals like a scuba diver. Finally, Team Touch is developing a variety of teaching tools grounded in overarching themes like ocean floor location, composition, landscape, processes, temperature and so on. At present they have 15 activities with across these themes.

The group agreed that we develop low-tech, and low-cost teaching tools whilst on board to ensure the highest degree of accessibility. We can also use these thought processes to develop larger ideas that we can further develop, in particular in future funding proposals.

Sunday 15th May DAY5

As part of the morning seminar series, Stiller-Reeve spoke about the importance of planning one's writing and how one can do this. This was an important topic to introduce early since the OceanSense teams will be writing a considerable amount during the expedition. Thereafter we continued to work on our teamwork. For example, Team Smell had an extended meeting with both Ramalho and Eilertsen where we discussed the food web from the hydrogen sulfide to the bacteria to the nematodes and further to the worm forests and potentially larger predators. We are using this story in teaching materials that will start with the pupils capturing the smell of decomposing material. The smell (hydrogen sulfide "light") will be the foundation for the story afterwards. The teaching materials we develop will contain lists of materials needed, information about the nematodes and worms and also a powerpoint of photos that th teacher can use in class.

Later in the evening Team Smell joined Eilertsen and Ramalho in the lab when the samples were brought up on the ROV. We worked with Mari and Sofia fro several hours on the samples they had collected.

Many of the OceanSenses group are interacting and working a lot with the scientists in the labs. Several were up late again during the night. The teachers are getting superb, hands-on insight into ocean research (both the highs and lows) so they can talk in more detail and with more passion with their classes when they return home.

Monday 16th May DAY6

Today we began with a seminar and long discussion about Mohadier's work with ParsQuake, where she (and colleagues) have developed teaching materials for schools in Central and South Asia. The teaching tools help teachers and pupils understand the reasons for earthquakes and mitigation techniques to decrease risks if and when an earthquake happens. The presentation and video were followed up with a lengthy discussion about what the work achieved and the overlaps with other people's world- and academic-views.

Cusset then had an hour-long ZOOM session with a primary school in France. The children were enthralled to see different aspects of life and science on board. Otherwise, all the Sense Teams continued to work on their projects.

Later in the evening, we spent time making videos for the 17th May. We had a video of all of us and the crew waving flags on the heli-deck. We had a video of the ROV waiving a flag at 1400m. NRK had already told us they were interested in the videos, so we transferred them to NRK late in the evening.

Tuesday 17th May DAY7

17th May onboard was a wonderful experience. NRK decided to show some of our videos on the national program for the 17th of May, which was great to see.

Workwise, the day was also wonderful. In particular, Team Sound made some wonderful progress analysing recordings, composing songs and developing teaching materials. Holm and Losleben had a productive workshop with the Banjo. They were making musical sounds that represent many of the sounds we have heard on board and below the sea. The idea is to challenge school children to listen to the AKMA sounds and then make their own musical (or otherwise) sounds that sound similar. The school children can listen to Losleben and Holm sounds afterwards and compare how different or similar they are to their representations. Stiller-Reeve and Holm also worked on the song Holm has composed that communicates some basic, but important ideas about foraminifera.


Figure 21. Holm working on his song on the observation deck.

Team Smell continued to work on their 3 main projects. In particular, Rosnes and Zimmermann spent considerable time discussing different Foraminifera before Rosnes went to the lab and talked to Pawlowksi about many aspects of the life and history of these organisms.

In the evening, Mohadier and Aune told us about the teacher-pairing scheme that their project is contributing to. We also all spent time in the different labs helping to sort animals in the microscopes, slicing sediments and, of course labelling. The great collaboration across all the disciplines on board continues!

Wednesday 18th May DAY8

Rosnes started the day with a seminar on some of the techniques he uses in the classroom to awaken the curiosity of the students. He told us how he poses "simple" questions which do not necessarily have simple answers. He told us how these questions can spark the curiosity of his students and that sometimes they can research these challenges all day and come up with an answer. They become young researchers without even realizing it.

Then Holm and Stiller-Reeve held a music workshop on the observation deck where we all contributed to the lyrics of the song that Holm has been writing in collaboration with Jane and Losleben and Clerici. The song was awesome, and we all had a nice time singing it. It was important to experience the song before giving feedback. We sat in the observation deck and worked in pairs or threes to give feedback. An interesting discussion developed about the deeper meaning of some of the words that were used, which really illustrated the multidisciplinary background to everyone on board.

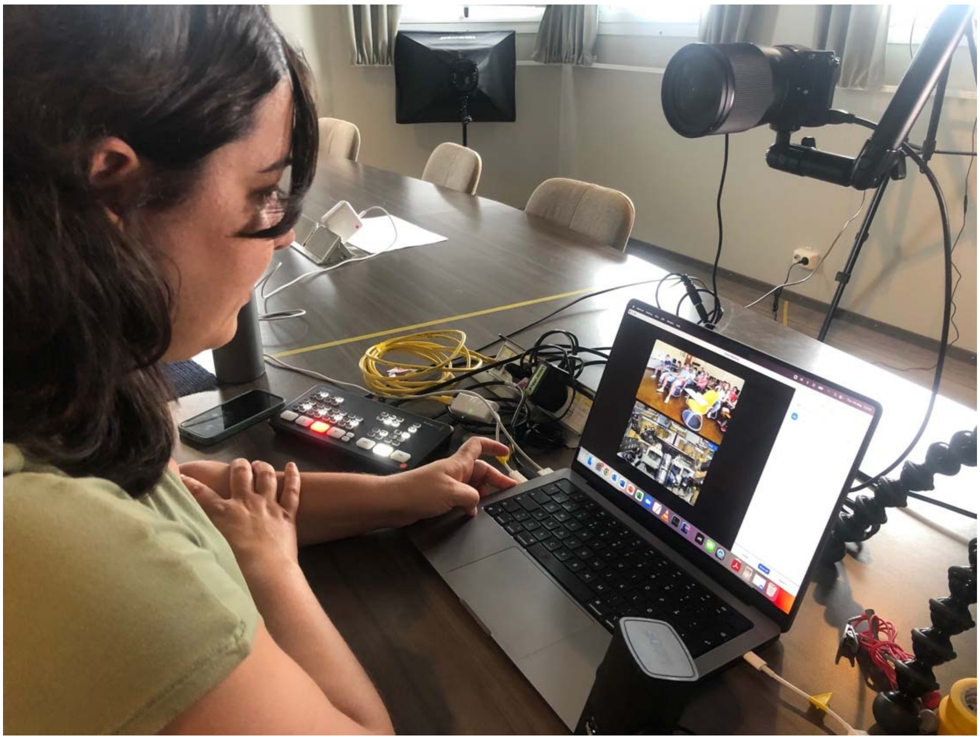

Figure 22. Sofia Ramalho presenting the cruise and her work onboard within a POLARoid project to a school in Portugal.

In the early afternoon we had a progress meeting with the core OceanSenses group. All the teams had made great progress, but several team members asked to get more direction on how to structure the teaching materials. Stiller-Reeve would develop a template to share as a benchmark for presenting the different ideas. Several of the project scientists turned up and another interesting discussion resulted about what the OceanSenses project is trying to do. There was a misunderstanding that the project is just targeting science lessons and science teachers. Stiller-Reeve tried to explain that the project brings different subject fields together to make teaching activities that could be used in natural science, social science, and arts lessons, depending on how the teacher wants to adapt it. After that the OceanSenses teams continued to work on the teaching materials, songs, and games.

Thursday 19th May DAY9

Stiller-Reeve began the day with a seminar on how to use the active voice in writing. This led to a lengthy discussion about writing and communication. Rosnes had a very successful zoom link-up with his school. The pupils were obviously very enthusiastic and asked questions, and they were excited to see the different videos of the sea and the ROV. Later, Panieri and Poto linked up with Olena Peftieva, professor in linguistics and students from Mariupol University to discuss the expedition and possible collaborations. Sofia linked up with her old school in Portugal (Figure 2). The kids were super excited and, after warming up a little, started asking lots of questions. Sofia found this very meaningful since it was her old school. This is something we have started putting focus on in OceanSenses. These interactions with one's own community have a really meaningful impact on all involved. It is especially important for the children who can see that pupils from their community can have such varied and exciting jobs. Finally, Mohadier and Ramalho linked up with another Portuguese school. Here also, the pupils were very enthusiastic and asked lots of questions. The ROV was not down at this point, so they showed videos from previous dives.

Otherwise, OceanSense worked continued. Stiller-Reeve discussed many things with Sofia about the “characters” in the teaching materials about smells. He continued to work with Jane on the graphical profile for the final versions of the teaching materials that will be tested by the teachers.

Mohadier, Aune and Panieri had a wonderful afternoon of filming for the teaching-pairing OceanSenses project. Oddone was instrumental in the filming and everything was completed on time. All that needs to be done now is the editing.

In the evening Maric held a seminar on his perspectives on how planetary health and the environmental humanities related to the work that is being done on board and what this background adds to the work and conversations of OceanSenses. He created a wonderfully complex thought map on the whiteboard to talk through all the ways that his various interests interact with important themes related to AKMA and OceanSenses.

In the evening and late into the night, several of the OceanSenses team worked in the labs again (Figure 3). Stiller-Reeve and Losleben helped Eilertsen and Ramalho with sorting and labelling before new samples come in tomorrow.

Figure 23. Losleben (and Stiller-Reeve) sorting macrofauna from samples taken with ROV Ægir in the lab with Eilertsen and Ramalho.

Friday 20th May DAY10

This day was slightly less productive due to the higher seas that we experienced after lunch and into the night. We continued with OceanSenses projects as much as possible. Stiller-Reeve completed a graphical template and example of what the teaching materials could look like. The goal was to give everyone a clear benchmark for how we will develop the project once we return to the mainland. The document gave a clear idea about the different sections that we will split the teaching materials into. Rosnes gave instrumental feedback to developing this template before Stiller-Reeve distributed it to the others.

In the evening Franchi gave an insightful presentation about how he and his colleagues use analogues on Earth in order to understand how environments may be in inaccessible locations, like on Mars or Saturn's moons. Afterwards, Poddevin gave us all some useful tips about how to make sketch notes when listening to a presentation or lecture, or when one is brainstorming ideas.

After the evening seminar the seas were too high to get much work done, and most people relaxed and tried to avoid sea-sickness.

Saturday 21st May Day 11

Victor started the day with an extremely enthusiastic Zoom meeting with his biology class in France. He was joined by Dessandier and Kalenitchenko. The atmosphere was lively as they flipped between French and English.

Many people writing blog posts that have earlier been held up due to issues with covid onboard. Stiller-Reeve and Mohadier completed their blog post about the integration of the paired-teaching scheme and the OceanSenses project.

Losleben and Clerici recorded the narrative of their project. Willis did a great job as the voice for the narration. All the other groups continued working on finalizing their projects as much as possible before the final presentation tomorrow. Also in Team Sound, Holm did a great job getting more input for his song lyrics. He was deep in discussion with a few different people from different disciplines.

Sunday 22nd May Day 12

We began our final full day onboard with an inspirational workshop led by Poto. She told us about the process she had been through with her indigenous network and illustrated storytelling when developing stories about knowledge. She split us into two working groups, and we had to develop something (our creativity was meant to decide) about the question "where can we find and treasure knowledge in order to be humble?". One group discussed different forms of knowledge and then landed on one of Mohadier's stories from her school days to illustrate how knowledge should not be communicated. The other group hid the contents of a touch book around the auditorium. The others had to find all the pieces of "knowledge" that were hidden. We were asked to consider how it felt finding the "knowledge" and whether we wanted to share it or not. Searching and finding knowledge were fun, but sharing knowledge came with its challenges and it was enriching to reflect on this.
In the evening Franchi gave a presentation on planetary sciences during the Piccolo Festival della Divulgazione organized by the Municipality of San Giorgi di Piano (Italy).

The OceanSenses Round-up meeting was a great success. All the groups have developed wonderful teaching materials. There are games about smell, teacher-pairing schemes, light activities, and soundscapes. There are songs and stories and videos and photos. Everyone presented their work with passion, which really shows how well we have all worked together. One of the highlights was Holm song which we all sang together, and we will sing again in the evening at the final scientific meeting. All-in-all we estimate that 15-20 teaching materials will arise from OceanSenses, which will be available via the AKMA website sometime this autumn. During the autumn, several of the team will also test out these materials in classrooms in Norway, France and hopefully beyond.
We rounded off the expedition with some really nice presentations from both Pawlowski and Cusset, and a very loud sing-a-long of the Foraminifera Folk song.

10.Activities performed within OceanSenses

ZOOM MEETINGS/OUTREACH

Date	Time	Name	Audience
12th May	1600-1700	Margherita Poto, Giuliana Panieri, Jane ZImmermann	Valentina Russo Mucho Amor: Illustrator, Italy
13th May	1400-1600	Katrin Losleben	Arctic Auditories, NFR prohect
13th May	2000-2100	Giuliana Panieri	Talk on Arctic Marine Mammals by dr. Marienne Blanchet, NPI and UiT
14th May	1130-1230	Solmaz Mohadjer, Stefan Buenz, Claudio Argentino	PhD/postdoc researchers from the Institute for Advanced Studies in Basic Science, Zanjan, Iran
15th May	1300-1400	G.Panieri, S.Ramalpho, K.Waghorn, D.Kalenitchenko	Giordano Bruno school, Italy
16th May	1000-1100	Fanny Cusset	Discussions with French students (8-9 years old) to discuss the life onboard, the research expedition and answer their questions, France
16th May	1540-1640	Sofia Ramalho	High-school students in 10ºA, Escola Sacadura Cabral de Celorico da Beira, Portugal
17th May	1900-1930	Filip Maric	Webinar for CoPEH-Canada Community of Practice in Ecosystem Approaches to Health 2022 Graduate level field course and webinar series https://copeh-canada.org/en/news-archive.html
18th May	0900-1000	Filip Maric	PART 1: Presentations and discussion sessions for the EPT Agenda 2023 (https://eptagenda2023.com/), a large international project aiming at the integration of environmental and sustainability science into healthcare education around the world
18th May	1500-1600	Filip Maric	PART 2: Presentations and discussion sessions for the EPT Agenda 2023 (https://eptagenda2023.com/), a large international project aiming at the integration of environmental and sustainability science into healthcare education around the world
19th May	0830-1000	Erling Rosnes	Danielsen Middle School, Valestrand, Norway
19th May	1000-1100	Giuliana Panieri, Margherita Poto	Professor Olena Peftieva from Mariupol University, Ukraine; exploring connections between SDGs 14 and 16

19th May	1230-1330	Sofia Ramalho	High-school students in 10º and 11º, Escola Básica e Secundária de Mora, Portugal
19th May	1430-1600	Solmaz Mohadier	Hélder Pereira, Escola Secundaria de Loule, Algarve, Portugal (26 students - 11th grade)
20th May	1000-1100	Solmaz Mohadier	Comms and Media undergraduate students from U of Central Asia, Naryn, Kyrgyzstan
20th May	1530-1630	Giuliana Panieri, Margherita Poto	Gloria Gordini: Scuola Media Statale G. Simoni, Medicina (BO), Italy
21st May	0900-1000	Victor Poddevin,P.A. Dessandier,D. Kalenitchenko	Lycée Sacré Coeur de Tourcoing, class du 2, 1, Terminale, France
22nd May	2100-2200	Fulvio Franchi	Festival Della Divulgazione, San Giorgio Di Piano, Italy
23rd May	0830-1000	Mathew Stiller-Reeve	General Assembly of European Geoscience Union. Session "Science and Society: Science Communication Practice, Research, and Reflection". Talk on AKMA Polaroid project

EVENING SEMINARS

Date	Name	Title
12th May	Alessandra Savini	How to produce photomosaics of the marine seafloor
14th May	Katrin Losleben	Sound, power and knowledge
	Andre Jensen	Natural hydrocarbon seepage
15th May	Vibeke Os	Iceland, farming, horses and nature
17th May	Solmaz Mohadier	Teaching pairing scheme
18th May	Monica Clerici	Exciting sustainability projects with VR
19th May	Filip Maric	How planetary health and the environmental humanities can enrich ocean science
20th May	Fulvio Franchi	Analogues of extreme environments on Earthfor planetary exploration: from Botswana to Mars and return
	Victor Poddevin	Sketching your notes
21st May	Claudio Argentino	Carbonate Tales
	Mari Eilertsen	Hydrothermal vents of AMOR
22nd May	Fanny Cusset	Seabirds as bioindicators of current and past mercury contamination: a global approach
	Rafael Moncelon	Biochemistry in temperate freshwater drained marshes
	Jan Pawlowski	Foraminifera from AKMA cruise and further afield.

MORNING SEMINARS

Date	Name	Title
13th May	Jane Zimmermann	Sculpting foraminifera
14th May	Mathew Stiller-Reeve	The power of planning your writing
16th May	Solmaz Mohadier	Parsquake: From advancements in Earth Science to practical geohazard awareness
18th May	Erling Rosnes	Inspiring young researchers with intriguing questions
	Villads Holm	The AKMA song workshop
20th May	Mathew Stiller-Reeve	What is the active voice?
22nd May	Margherita Poto	Co-creating stories

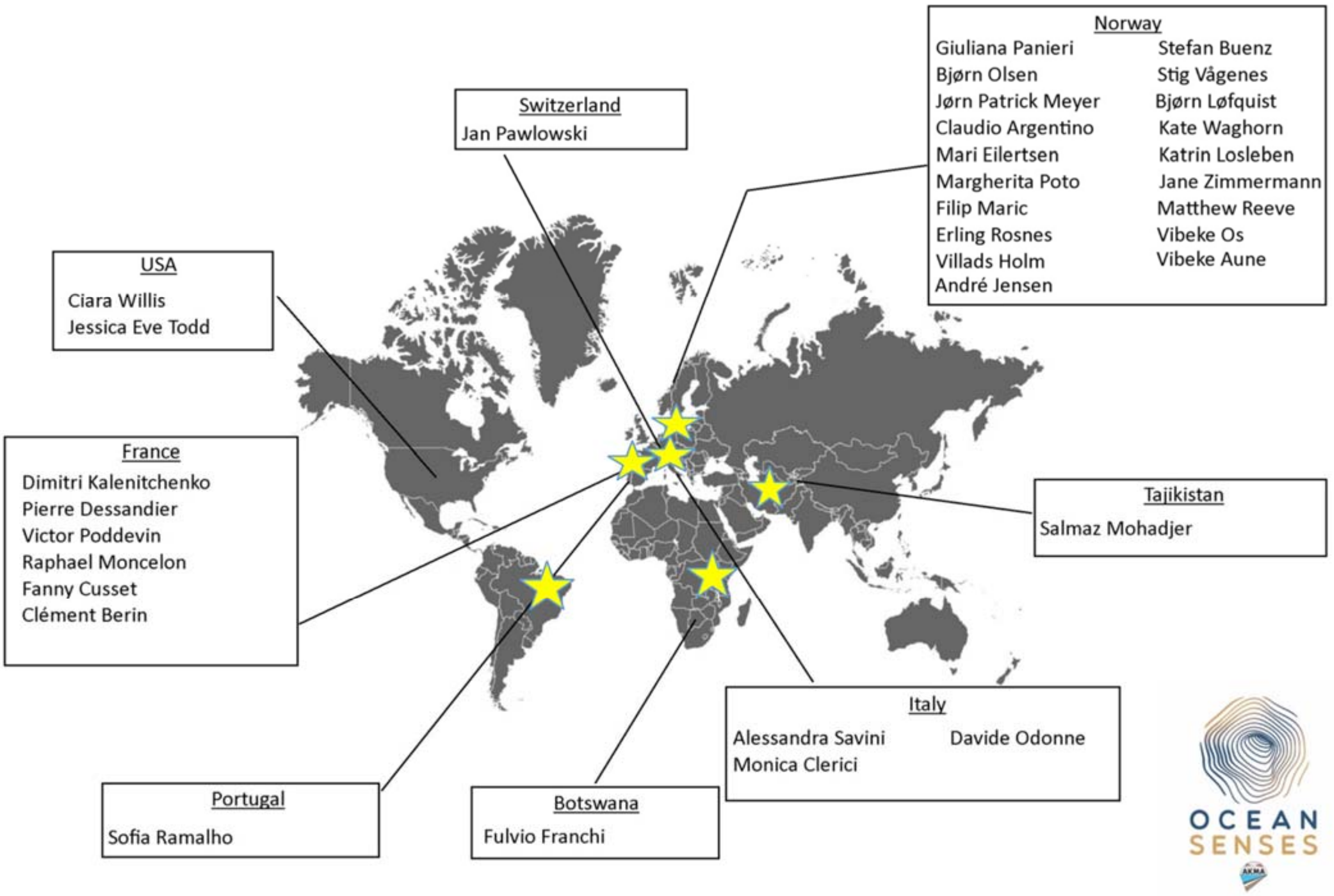

Figure 24. World map showing the list of the participants based on the countries where they work (not nationalities) and the countries reached during the AKMA expedition (zoom calls).

11. Data management

All the data collected during this expedition are deposited in the CAGE database at UiT and, work in progress, will be deposited at the UiT Dataverse.

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Appendix

Location	Station Id	Date	Time (UTC)	Lat. [N] Long. [E]	Bottles fired [#]	Water Depth [m]	Notes
Southern Yermak	CAGE22-2-KH-01-CTD-113	13.05	09:15	79°29.251' 08°51.244'		152	
Southern Yermak	CAGE22-2-KH-01-CTD-114	13.05	10:18	79°29.251' 08°51.244'		152	
Southern Yermak	CAGE22-2-KH-01-Dive-01	13.05	15:00	79°33.554' 09°35.289'		130	
Ice	CAGE22-2-KH-02-IC-01	13.05	23:38	79°56.929' 08°11.045'		500	
Ice	CAGE22-2-KH-02-IC-04	14.05	01:27	79°56.929' 08°11.045'		500	
Vestnesa	CAGE22-2-KH-03-MC-01	14.05	12:11	78°43.316' 07°01.932'		1380	2 tubes
Ice	CAGE22-2-KH-02-IC-02	14.05	12:15	79°56.929' 08°11.045'		500	
Vestnesa	CAGE22-2-KH-03-CTD-76	14.05	13:25	78°43.316' 07°01.931'		1380	failed
Vestnesa	CAGE22-2-KH-03-Dive-02	14.05	14:48	78°42.059' 07°00.892'		1394	
Vestnesa	CAGE22-2-KH-03-MC-02	14.05	17:33	78°43.358' 07°00.557'		1396	4 tubes
Vestnesa	CAGE22-2-KH-03-MC-03	14.05	19:01	78°43.359' 07°01.556'		1396	5 tubes
Vestnesa	CAGE22-2-KH-03-GC-01	14.05	20:41	78°42.061' 07°00.826'		1249	sampled gas hydrates at bottom (Fulvio, Claudio)
Vestnesa	CAGE22-2-KH-03-GC-02	14.05	22:20	78°42.061' 07°00.825'		1249	station is not in ship's log
Vestnesa	CAGE22-2-KH-03-HF-119	15.05	00:05	78°42.762' 07°16.902'		1250	HF1-1
Ice	CAGE22-2-KH-02-IC-03	14.05	01:05	79°56.929' 08°11.045'		500	
Vestnesa	CAGE22-2-KH-03-HF-120	15.05	02:00	78°42.621' 07°13.064'		1274	HF2-1
Vestnesa	CAGE22-2-KH-03-HF-121	15.05	03:05	78°42.586' 07°12.351'		1290	HF2-2
Vestnesa	CAGE22-2-KH-03-Dive-03	15.05	06:33	78°42.059' 07°12.351'			ROV Dive - multibeam and mosaiking
Vestnesa	CAGE22-2-KH-03-CTD-77	15.05	12:20	78°42.085' 07°00.855'		1392	sampled water 10 m above seafloor
Vestnesa	CAGE22-2-KH-03-Dive-04	15.05	15:02	78°42.086' 07°00.852'		1391	
Vestnesa	CAGE22-2-KH-03-MC-04	15.05	17:40	78°42.216' 07°01.499'		1388	3 tubes. # 1 ox profile, pore water samples, gas samples #2 fauna #3 fauna, eDNA
Vestnesa	CAGE22-2-KH-03-GC-03	15.05	20:21	78°42.051' 07°00.886'		1392	2 sections; contains gas hydrates; sampled pw
Vestnesa	CAGE22-2-KH-03-HF-124	15.05	23:30	78°42.520' 07°11.091'		1327	HF3-2 (planned pos., get exact pos from USBL)
Vestnesa	CAGE22-2-KH-03-HF-125	16.05	01:04	78°42.491' 07°10.529'		1326	HF3-3 (planned pos., get exact pos from USBL)
Vestnesa	CAGE22-2-KH-03-HF-126	16.05	02:36	78°42.184' 07°04.253'		1377	HF4-1 (planned pos., get exact pos from USBL)

Vestnesa	CAGE22-2-KH-03-HF-127	16.05	03:12	78°42.173' 07°03.678'		1391	HF4-2 (planned pos., get exact pos from USBL)
Vestnesa	CAGE22-2-KH-03-Dive-05	16.05	08:26	78°42.057' 07°00.855'		1390	
Vestnesa	CAGE22-2-KH-03-TemL-01	16.05	09:04	78°42.064' 07°00.786'		1390	LOT (temp probe) deployment
Vestnesa	CAGE22-2-KH-03-PusC-01	16.05	09:15	78°42.064' 07°00.789'		1390	ROV Push Core - valve corer
Vestnesa	CAGE22-2-KH-03-TemL-02	16.05	09:31	78°42.064' 07°00.815'		1390	HIT (temp probe) deployment
Vestnesa	CAGE22-2-KH-03-SuSa-01	16.05	09:44	78°42.065' 07°00.798'		1390	
Vestnesa	CAGE22-2-KH-03-Scoo-01	16.05	10:10	78°42.068' 07°00.793'		1390	
Vestnesa	CAGE22-2-KH-03-BlaC-01	16.05	10:33	78°42.066' 07°00.755'		1390	
Vestnesa	CAGE22-2-KH-03-Dive-06	16.05	12:29	78°42.057' 07°00.853'		1390	
Vestnesa	CAGE22-2-KH-03-Dive-06	16.05	12:29	78°42.057' 07°00.853'		1390	
Vestnesa	CAGE22-2-KH-03-BlaC-02	16.05	12:34	78°42.074' 07°00.702'		1390	ROV Blade Core - half gastropods half mat (4K recording)
Vestnesa	CAGE22-2-KH-03-HF-128	16.05	18:16	78°42.149' 07°02.472'		1398	HF5-1 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-129	16.05	18:59	78°42.138' 07°01.935'		1396	HF5-2 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-130	16.05	19:36	78°42.129' 00°71.490'		1402	HF5-3 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-131	16.05	20:02	78°42.124' 07°01.258'		1405	HF5-4 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-132	16.05	20:25	78°42.121' 07°01.090'		1400	HF5-5 probe malfunctionend
Vestnesa	CAGE22-2-KH-03-HF-133	16.05	21:09	78°42.118' 00°70.963'		1398	HF5-6 probe malfunctionend
Vestnesa	CAGE22-2-KH-03-HF-134	16.05	21:35	78°42.111' 07°00.590'		1388	HF5-7 probe malfunctionend
Vestnesa	CAGE22-2-KH-03-HF-135	16.05	22:03	78°42.102' 07°00.183'		1386	HF5-8 probe malfunctionend
Vestnesa	CAGE22-2-KH-03-HF-136	16.05	23:16	78°42.321' 07°00.128'		1386	HF6-1 23:49 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-137	17.05	00:40	78°42.213' 07°00.556'		1387	HF6-2 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-138	17.05	01:28	78°42.069' 07°01.124'		1398	HF6-3 01:45 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-139	17.05	02:28	78°42.024' 07°01.302'		1397	HF6-4 02:36 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-140	17.05	03:18	78°41.929' 07°01.676'		1397	HF6-5 03:15 check USBL for nav
Vestnesa	CAGE22-2-KH-03-HF-141	17.05	04:22	78°42.102' 00°70.183'		1386	HF7-1 check USBL for nav
Vestnesa	CAGE22-2-KH-03-Dive-07	17.05	11:46	78°42.061' 07°00.834'		1393	
Vestnesa	CAGE22-2-KH-03-PusC-07	17.05	12:57	78°42.048' 07°00.968'		1398	ROV Push Core - reference (within seep area)

Vestnesa	CAGE22-2-KH-03-PusC-08	17.05	13:09	78°42.047' 07°01.040'		1400	ROV Push Core - reference (within seep area); liner label"5"
Vestnesa	CAGE22-2-KH-03-PusC-09	17.05	13:14	78°42.052' 07°01.033'		1402	ROV Push Core - reference (within seep area)
Vestnesa	CAGE22-2-KH-03-BlaC-04	17.05	13:29	78°42.084' 07°01.036'		1406	ROV Blade Core - tubeworm habitat
Vestnesa	CAGE22-2-KH-03-SuSa-02	17.05	13:33	78°42.084' 07°01.039'		1406	suction tubeworms; 2 chambers
Vestnesa	CAGE22-2-KH-03-PusC-10	17.05	13:44	78°42.085' 07°01.037'		1411	ROV Push Core - microbial mats; bubbles while sampling; close to 2 previous samplings;liner label"2"
Vestnesa	CAGE22-2-KH-03-PusC-11	17.05	13:48	78°42.085' 07°01.037'		1406	ROV Push Core - microbial mats (twin of Pusc10); while sampling sediment cloud so maybe not perfect sed interface; underwater tornado
Vestnesa	CAGE22-2-KH-03-SuSa-03	17.05	14:07	78°42.086' 07°01.045'		1406	suction shrimp
Vestnesa	CAGE22-2-KH-03-BlaC-05	17.05	14:26	78°42.087' 07°01.034'		1407	ROV Blade Core - empty
Vestnesa	CAGE22-2-KH-03-CarC-02	17.05	14:28	78°42.087' 07°01.034'		1407	
Vestnesa	CAGE22-2-KH-03-CarC-03	17.05	14:33	78°42.087' 07°01.034'		1407	ROV Carbonate Crust Collection - covered by bacteria, siboglinids attached to carbonates
Vestnesa	CAGE22-2-KH-03-Biol-01	17.05	14:45	78°42.087' 07°01.034'		1406	ROV Biology - anemone+gastropod
Vestnesa	CAGE22-2-KH-03-Biol-02	17.05	14:50	78°42.087' 07°01.034'		1406	ROV Biology - starfish
Vestnesa	CAGE22-2-KH-03-TemL-01	17.05	15:02	78°42.037' 07°00.794'		1397	LOT (temp probe) recovery
Vestnesa	CAGE22-2-KH-03-TemL-02	17.05	15:12	78°42.065' 07°00.817'		1398	HIT (temp probe) recovery
Vestnesa	CAGE22-2-KH-03-GasS-01	17.05	16:27	78°42.054' 07°00.870'			ROV Gas Sampling - bubble catcher recovery
Vestnesa	CAGE22-2-KH-03-CTD-78	17.05	19:12	78°42.064' 07°00.862'			
Vestnesa	CAGE22-2-KH-03-HF-142	18.05	05:49	78°42.110' 07°00.590'		1398	HF8-1, repeat of HF5-7 (probe failed)
Vestnesa	CAGE22-2-KH-03-HF-143	18.05	06:52	78°42.118' 07°00.962'		1399	HF8-2, repeat of HF5-6 (probe failed)
Vestnesa	CAGE22-2-KH-03-Dive-08	18.05	08:30	78°42.118' 07°00.974'			ROV Dive - multibeam and mosaiking
Vestnesa	CAGE22-2-KH-03-BlaC-06	18.05	15:11	78°42.076' 07°00.903'		1397	ROV Blade Core - tubeworms (A) transition to background (B)
Vestnesa	CAGE22-2-KH-03-HF-144	18.05	16:15	78°42.111' 07°00.936'		1398	HF9-1 (30 min) (check USBL for accurate nav)
Vestnesa	CAGE22-2-KH-03-HF-145	18.05	17:37	78°42.027' 07°01.062'		1394	HF9-2 (10 min) (check USBL for accurate nav)
Vestnesa	CAGE22-2-KH-03-HF-147	18.05	20:01	78°36.900' 06°53.887'		1707	HF10 (10 min) northern flank of MTF
Vestnesa	CAGE22-2-KH-03-HF-148	18.05	22:35	78°33.157' 07°19.696'		1825	HF11 (10 min) northern flank of MTF
Svyatogor	CAGE22-2-KH-04-MC-01	19.05	02:50	78°24.503' 05°14.374'		1958	5 cores
Svyatogor	CAGE22-2-KH-04-Dive-09	19.05	06:42	78°23.555' 05°04.939'		1933	
Svyatogor	CAGE22-2-KH-04-MC-02	19.05	07:18	78°24.511' 50°14.257'			

Svyatogor	CAGE22-2-KH-04-PusC-01	19.05	09:09	78°23.553' 05°04.964'		1933	ROV Push Core - liner label "2"
Svyatogor	CAGE22-2-KH-04-PusC-02	19.05	09:12	78°23.553' 05°04.964'		1933	ROV Push Core - same mat
Svyatogor	CAGE22-2-KH-04-PusC-03	19.05	09:14	78°23.553' 05°04.964'		1933	ROV Push Core - same mat
Svyatogor	CAGE22-2-KH-04-PusC-04	19.05	09:16	78°23.553' 05°04.964'		1933	ROV Push Core - same mat; liner label "1"
Svyatogor	CAGE22-2-KH-04-PusC-05	19.05	09:26	78°23.553' 05°04.964'		1933	ROV Push Core - same mat;
Svyatogor	CAGE22-2-KH-04-BlaC-01	19.05	09:46	78°23.553' 05°04.964'		1933	ROV Blade Core - mat next to the pusch mat
Svyatogor	CAGE22-2-KH-04-BlaC-02	19.05	09:50	78°23.553' 05°04.961'		1933	
Svyatogor	CAGE22-2-KH-04-Dive-10	19.05	11:29	78°23.555' 05°04.939'		1933	
Svyatogor	CAGE22-2-KH-04-SuSa-01	19.05	12:50	78°25.553' 05°05.012'		1933	
Svyatogor	CAGE22-2-KH-04-Scoo-01	19.05	13:04	78°25.553' 05°05.050'		1933	
Svyatogor	CAGE22-2-KH-04-TemL-01	19.05	13:11	78°23.552' 05°05.058'		1933	HIT (temp probe) deployment
Svyatogor	CAGE22-2-KH-04-TemL-02	19.05	13:13	78°23.551' 05°05.020'		1933	LOT (temp probe) deployment
Svyatogor	CAGE22-2-KH-04-RocC-01	19.05	13:35	78°23.556' 05°04.992'		1933	ROV Rock Collection - non-carbonate rocks at seafloor
Svyatogor	CAGE22-2-KH-04-HF-149	19.05	19:30	78°24.512' 05°14.252'		1958	HF12 , probe at 1900 m for 10 min prior to penetration taking measurements for calibration
Svyatogor	CAGE22-2-KH-04-HF-150	19.05	21:41	78°22.922' 05°13.597'		1946	HF13-1 (30 min)
Svyatogor	CAGE22-2-KH-04-HF-151	19.05	23:01	78°22.692' 05°12.780'		1943	HF13-2 (10 min)
Svyatogor	CAGE22-2-KH-04-HF-152	19.05	23:58	78°22.461' 05°11.977'		1926	HF13-3 (10 min)
Svyatogor	CAGE22-2-KH-04-HF-153	20.05	00:56	78°22.260' 05°11.198'		1892	HF13-4 (30 min deployment failed, heat pulse before penetration)
Svyatogor	CAGE22-2-KH-04-HF-154	20.05	02:10	78°22.064' 05°10.492'		1852	HF13-5 (10 min)
Svyatogor	CAGE22-2-KH-04-HF-155	20.05	03:11	78°21.829' 05°09.677'		1878	HF13-6 (10 min)
Svyatogor	CAGE22-2-KH-04-Dive-11	20.05	07:20	78°23.550' 05°05.011'			
Svyatogor	CAGE22-2-KH-04-PusC-06	20.05	09:01	78°23.519' 05°05.058'		1944	ROV Push Core - tubeworms
Svyatogor	CAGE22-2-KH-04-PusC-07	20.05	09:03	78°23.519' 05°05.059'		1944	ROV Push Core - tubeworms
Svyatogor	CAGE22-2-KH-04-PusC-08	20.05	09:07	78°23.517' 05°05.059'		1944	ROV Push Core - reference in seep area (between mats and tubeworms)
Svyatogor	CAGE22-2-KH-04-PusC-09	20.05	09:08	78°23.518' 05°05.058'		1944	ROV Push Core - reference in seep area (between mats and tubeworms)
Svyatogor	CAGE22-2-KH-04-PusC-10	20.05	09:12	78°23.518' 05°05.058'		1944	ROV Push Core - reference in seep area (between mats and tubeworms)
Svyatogor	CAGE22-2-KH-04-BlaC-03	20.05	09:38	78°23.519' 05°05.061'		1943	ROV Blade Core - tubeworms

Svyatogor	CAGE22-2-KH-04-BlaC-04	20.05	09:42	78°23.518' 05°05.058'		1941	ROV Blade Core - transition between tubeworms and bakground
Svyatogor	CAGE22-2-KH-04-SuSa-02	20.05	09:54	78°23.518' 05°05.058'		1941	tubeworms
Svyatogor	CAGE22-2-KH-04-TemL-03	20.05	10:05	78°23.550' 05°04.998'		1941	HIT (temp probe) recovery
Svyatogor	CAGE22-2-KH-04-TemL-04	20.05	10:06	78°23.550' 05°04.998'		1941	LOT (temp probe) recovery
Svyatogor	CAGE22-2-KH-04-Dive-12	20.05	10:53	78°21.325' 05°42.230'		1691	
Svyatogor	CAGE22-2-KH-04-SuSa-03	20.05	14:17	78°23.217' 05°42.399'		1619	foraminifera
Vestnesa	CAGE22-2-KH-03-Dive-13	21.05	07:28	78°42.216' 07°01.511'		1390	ROV Dive - mosaiking (front-looking camera)
Vestnesa	CAGE22-2-KH-03-PusC-12	21.05	11:26	78°42.008' 07°00.906'		1391	ROV Push Core - liner label "3"; gastropods eating mat; hardground at ~30 cm; macrofauna
Vestnesa	CAGE22-2-KH-03-PusC-13	21.05	11:30	78°42.008' 07°00.906'		1391	ROV Push Core - liner label "1"; no mat sediment; eDNA; pore water; sliced
Vestnesa	CAGE22-2-KH-03-PusC-14	21.05	11:34	78°42.008' 07°00.990'		1391	ROV Push Core - liner label "4"; mat; sliced
Vestnesa	CAGE22-2-KH-03-SuSa-04	21.05	11:37	78°42.008' 07°00.890'		1391	
Vestnesa	CAGE22-2-KH-03-PusC-15	21.05	12:06	78°42.010' 07°00.910'		1391	ROV Push Core - liner label "2"; gastropods eating mat; eDNA; sliced
Vestnesa	CAGE22-2-KH-03-PusC-16	21.05	12:41	78°42.009' 07°00.827'		1391	ROV Push Core - liner label "5"; no mat sediment; lost material during ROV ascent
Vestnesa	CAGE22-2-KH-03-Dive-14	21.05	14:16	78°42.041' 06°53.656'		115	
Vestnesa	CAGE22-2-KH-03-BlaC-07	21.05	14:30	78°42.041' 06°53.656'		115	
Vestnesa	CAGE22-2-KH-03-BlaC-08	21.05	15:00	78°42.041' 06°53.656'		115	
Oil Seep	CAGE22-2-KH-05-Dive-15	22.05	06:21	78°29.563' 10°31.387'		115	
Oil Seep	CAGE22-2-KH-05-SuSa-01	22.05	09:32	78°29.466' 10°31.422'		115	
Oil Seep	CAGE22-2-KH-05-PusC-01	22.05	09:46	78°29.460' 10°31.428'		115	
Oil Seep	CAGE22-2-KH-05-PusC-02	22.05	10:00	78°29.454' 10°31.392'		115	
Oil Seep	CAGE22-2-KH-05-PusC-03	22.05	10:13	78°29.466' 10°31.422'		115	
Oil Seep	CAGE22-2-KH-05-PusC-04	22.05	10:20	78°29.466' 10°31.422'		115	
Oil Seep	CAGE22-2-KH-05-PusC-05	22.05	10:46	78°29.580' 10°31.392'		115	
Oil Seep	CAGE22-2-KH-05-BlaC-01	22.05	10:59	78°29.580' 10°31.392'		115	
Oil Seep	CAGE22-2-KH-05-BlaC-02	22.05	11:05	78°29.580' 10°31.392'		115	
Oil Seep	CAGE22-2-KH-05-Dive-16	22.05	12:00	78°29.580' 10°31.392'		115	
Oil Seep	CAGE22-2-KH-05-PusC-06	22.05	12:20	78°29.580' 10°31.500'		115	

Oil Seep	CAGE22-2-KH-05-PusC-07	22.05	12:24	78°29.580' 10°31.500'		115	
Oil Seep	CAGE22-2-KH-05-Dive-17	22.05	12:44	78°29.578' 10°31.386'		115	
Oil Seep	CAGE22-2-KH-05-Dive-18	22.05	14:10	78°29.417' 10°31.386'		115	

Location	Line ID	Date	Time (UTC) START	Lat. [N] Long. [E] START	Time (UTC) STOP	Lat. [N] Long. [E] STOP	Pulse mode	Shot Rate (HZ)	Ship Speed (kn)	Comments
Oil Seep	CAGE22-2-KH-001-CHIRP	13.05	17:12	79°43.968' 09°09.357'	21:27	79°55.936' 08°32.186'				
Oil Seep	CAGE22-2-KH-002-CHIRP	14.05	02:23	79°56.983' 08°04.675'	11:21	78°43.339' 07°02.048'				
Vestnesa	CAGE22-2-KH-003-CHIRP	14.05	20:26	78°43.250' 07°01.600'	20:29	78°42.085' 07°00.997'				
Vestnesa	CAGE22-2-KH-004-CHIRP	15.05	00:30	78°42.115' 07°02.338'	01:04	78°42.793' 07°16.755'				
Vestnesa	CAGE22-2-KH-005-CHIRP	15.05	21:31	78°42.040' 07°01.225'	21:54	78°42.538' 07°11.714'				
Vestnesa	CAGE22-2-KH-006-CHIRP	16.05	00:34	78°42.531' 07°10.443'	00:58	78°42.160' 07°04.365'				
Vestnesa	CAGE22-2-KH-007-CHIRP	16.05	04:07	78°42.278' 07°09.269'	07:14	78°42.719' 07°02.380'				