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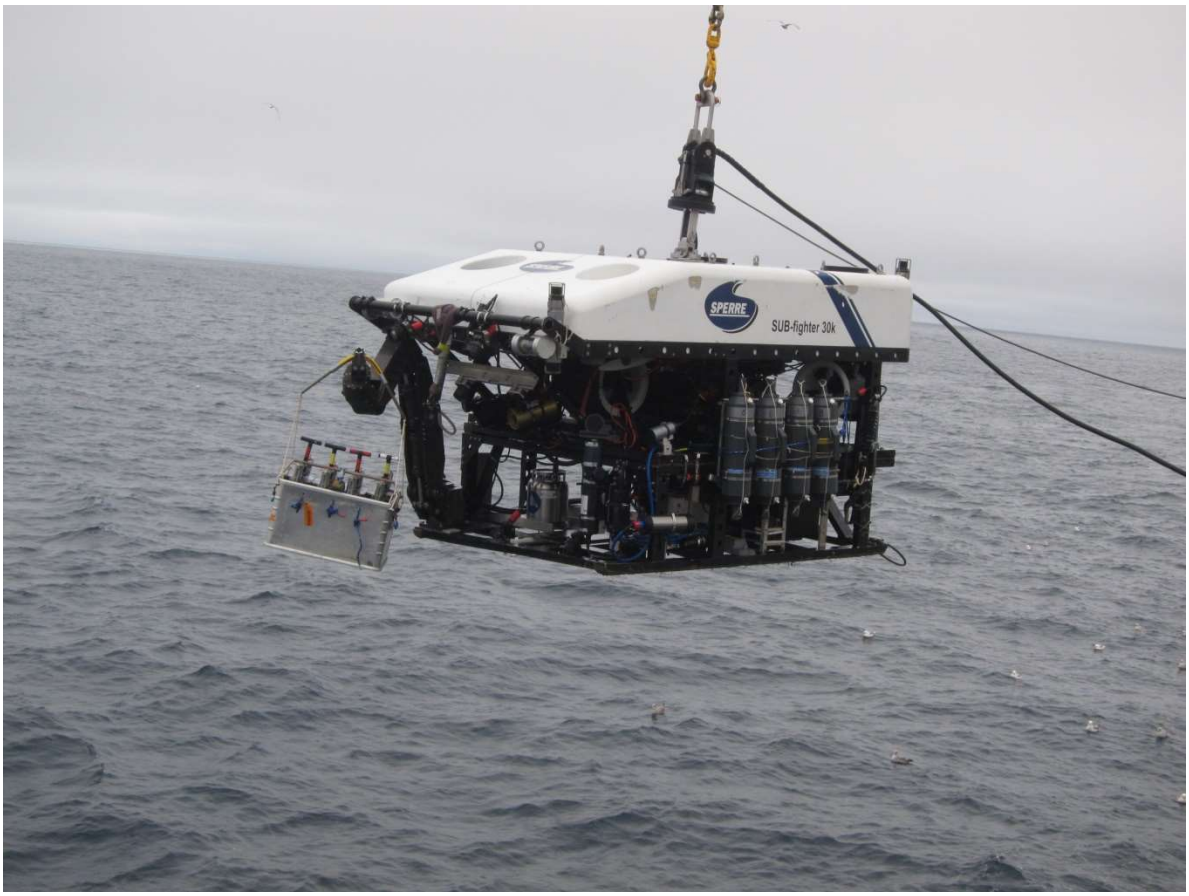
CRUISE REPORT

ROV-based Geological and Biological Investigations of Methane Seeps at Prins Karls Forland, Storfjordrenna Pingos and Bjørnøyrenna Craters

R/V Helmer Hanssen 16th June – 4th July, 2016



Sperre 30k ROV being deployed at the Bjørnøyrenna crater area with benthic sampling gear

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1 Introduction and scientific objectives

The cruise was an activity in of the Centre of Excellence for Gas Hydrate, Environment and Climate (CAGE) at UiT - The Arctic University of Norway.

The overall aim of the cruise was to utilize the NTNU/AMOS SK30k ROV for seafloor mapping and targeted sample collection at selected CAGE sites, focusing on methane seepage areas west and south of Svalbard.

More specific objectives of the cruise were to:

- Use an ROV-mounted multibeam system to acquire very high resolution (10cm) seabed bathymetry in areas of methane seeps
- Conduct detailed visual seabed surveys for habitat mapping and photomosaicking at specific seep features
- Collect seabed samples of authigenic carbontate crusts, sediments, microbes, foraminifera and macro organisms associated with methane seeps from the ROV, and complimented with more traditional sampling methods
- Continue time series investigations of water column measurements of methane concentrations, and of methane oxidizing microbes in the seawater
- Net sampling for planktic forams at seeps

Sampling activities were designed with a multi-disciplinary approach, with research groups from all CAGE work packages working together in the same locations to develop a holistic understanding of the geological, oceanographic and biological components at key methane seep sites. This cruise prioritized the acquisition of information for mapping seabed features and habitat characterizations (e.g. photomosaicking, visual information) combined with in-situ site sampling using ROV technologies, and complimented by our 'traditional' technologies (e.g. CTD, net, and coring devices).
With these objectives in mind, the strategy for each of the selected locations is to first carry out visual survey work to acquire framework measurements and data to be of use for all groups within CAGE, followed by a consolidated sampling plan to satisfy the needs of individual researchers for sample material.

2 Cruise participants

Table 1: Cruise participants

Name	Institution	Shift	Cabin
Michael Carroll	CAGE WP3/APN	open	505
Bjørn Runar Olsen	UiT engineer	day	411
Roy Robertson	UiT engineer	night	404
Henry Patton	CAGE WP2	day	213
Alexey Portnov	CAGE WP1	day	214
Pär Jansson	CAGE WP4	night	215
Pavel Serov	CAGE WP3	night	214
Arunima Sen	CAGE WP3	day	211
Wei-Li Hong	CAGE WP3	night	322
Scott Klasek	Oregon State Univ	night	213
Friederike Gründger	CAGE WP3	day	212
Sophie George	CAGE WP3	day	216
Emmelie Åström	CAGE WP3	day	211
Helge Niemann	CAGE WP3	day	323
Johan Faust	NGU/CAGE WP5	day	215
Katarzyna Melaniuk	CAGE WP5	day	216
Haoyi Yao	CAGE WP5	night	322
Siri Ofstad	CAGE WP6	night	216
Julie Meilland	CAGE WP6	night	212
Frode Volden	AMOS/NTNU	day	318
Stein Nornes	AMOS/NTNU	day	210
Pedro de la Torre	AMOS/NTNU	day	210
Bo Krogh	Bo Krogh ApS	day	209

Day shift: 08:00-20:00

Night shift: 20:00-08:00

Breakfast: 07:30-08:30. Lunch: 13:30-14:30. Dinner: 19:30-20:30

Shifts started: June17th, 8pm; **Stopped:** July 4th, 8am; **Total time**: 13 days

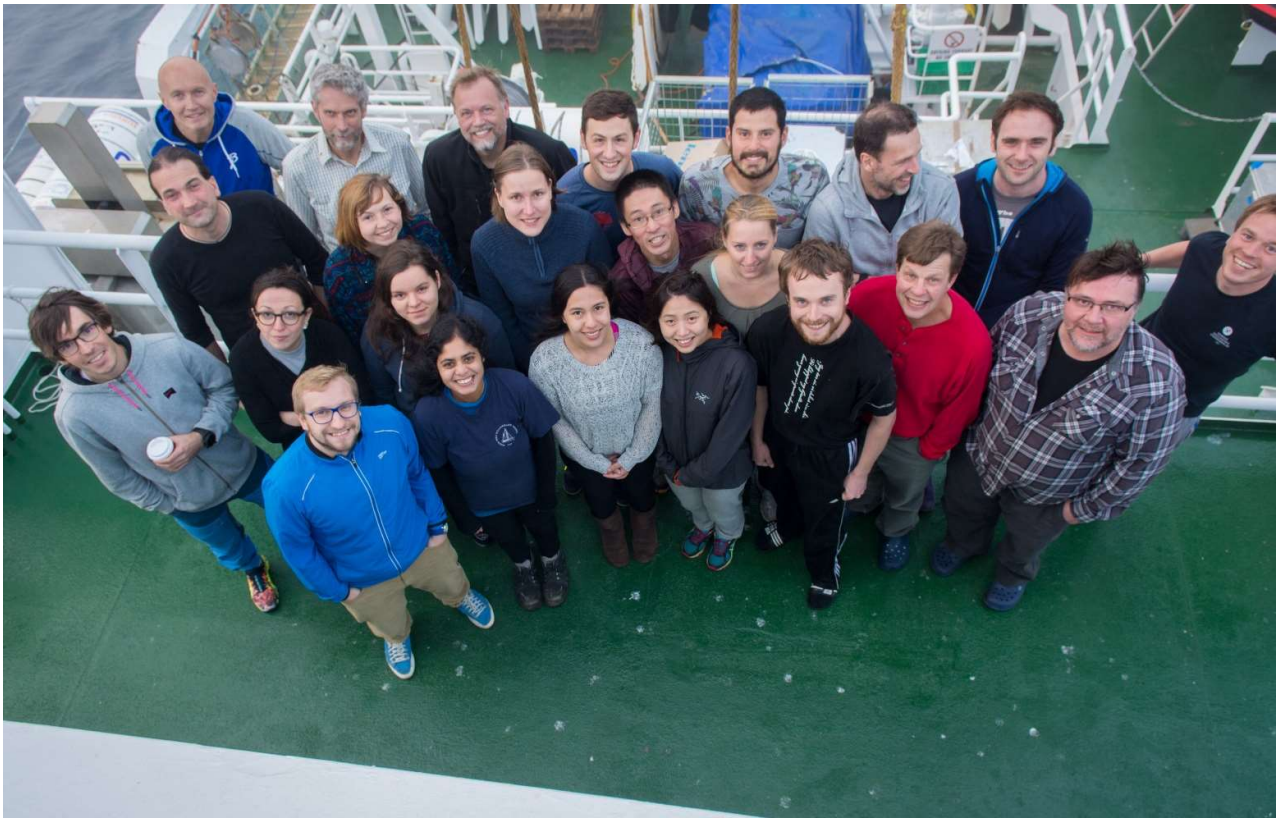


Figure 1: All participants of CAGE 16-5, with the NTNU-AMOS ROV. (Photo: J. Faust)

3 Areas of Investigation

We worked in 3 areas of intense methane seepage from the seafloor that are of key foci for CAGE:

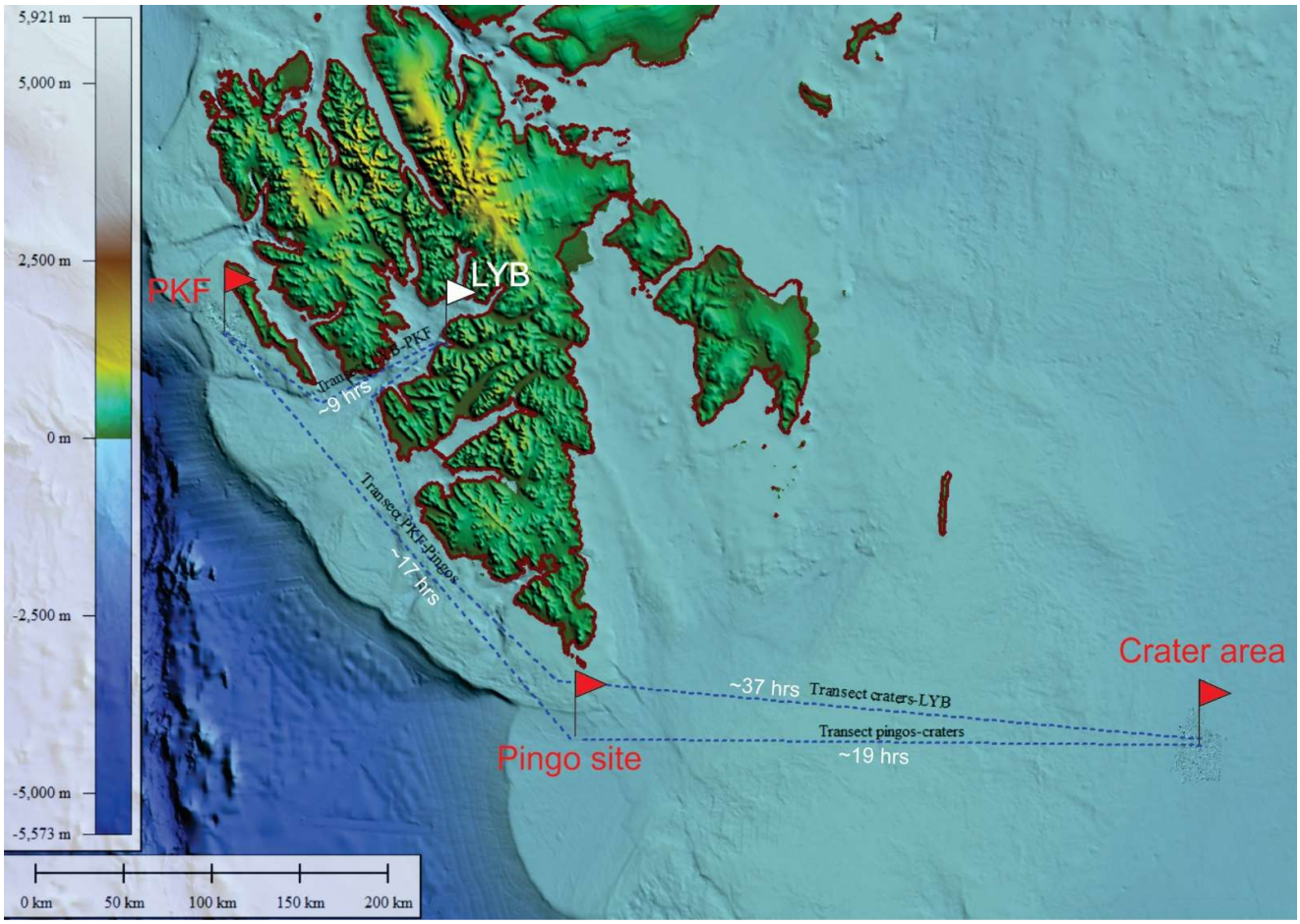


Figure 2: Map of the three main study areas and reference site for cruise CAGE 16-5: Prins Karls Forland, the gas hydrate pingo-like features at Storfjordrenna and the CraterArea in Bjørnøyrenna.

3.1 Prins Karls Forland

The Prins Karls Forland study area is located west of Svalbard on the continental shelf (water depths 50-200 m) and the shelf break (water depth 350-400 m), between the troughs of Kongsfjorden and Isfjorden. The Svalbard continental margin was formed by rifting processes and is reshaped by the advance-retreat of ice sheets. Ice streams eroded troughs across the shelf seaward of Kongsfjorden and Isfjorden. The continental shelf was flooded as the ice sheet retreated after the last glaciation.

West Spitsbergen current (WSC) carries relatively warm, saline Atlantic Water to the area. The WSC tends to meander on- and offshore. During offshore periods, the shelf and shelf break is influenced by fresher, colder water from the extension of the East Spitsbergen Current. Ice formation and melting as well as seasonal surface heating and cooling affects the hydrography, changing the stratification, especially on the shelf.

Acoustic flares, indicating free gas emissions from the seafloor has been documented since 2009 on the outer shelf (~240m bsl) and the upper slope (~400 m bsl) and more flares were found at the Forland shelf in 2011 (Westbook 2009, Wright 2012).
As seepage on the shelf occurs in shallow water depth, methane can potentially be transported towards the surface mixed layer and subsequently equilibrate with the atmosphere. The shelf break seepage location is located at the hydrate phase boundary and is therefore speculated to be associated with seasonal buildup and dissociation of hydrates.

3.2 Storfjordrenna

The study area is located at the outer part of Storfjordrenna Trough 50 km to the South from the southern tip of Svalbard Archipelago. Outer sector of Storfjordrenna Trough comprises numerous cross-shelf oriented depressions (channels) erased by Last Glacial Maximum (LGM) ice streams. Several generations of grounding zone wedges and ploughmarks are imposed upon them, indicating standstill and, otherwise, more active episodes of ice-sheet dynamics.

The northernmost cross-shelf channel hosts 7 distinct Gas Hydrate Pingos (GHPs), 5 of which emit large quantities of free gas to the water column. The GHPs contain abundant gas hydrates, methane-derived authigenic carbonates and sediments highly saturated with hydrocarbon gas. GHPs occur in water depth of 390-360 m within gas hydrate stability zone close to its shallow termination. Subcircular GHP 1 and GHP 2 have similar height and size: they rise 8-10 m above the adjacent seafloor, and at their bases have diameters of 280 to 400 m. GHP 2, as distinct from the others, comprises two individual summits separated with a saddle. GHP 3, GHP 4, GHP 5 and GHP 6 are aligned in northeastern direction, and show remarkably similar shape and orientation (Figure 14). They have eastward-elongated contours with short and long axis lengths varying from 150 to 250 m and 350 to 450 m, respectively. The GHP 7 is significantly smaller (~150m in diameter and 3 m high) and locates 3 km Northwest from the main cluster at 360m water depth. Oceanographic settings of Storfjordrenna, e.g. bottom water temperature – an important parameter for hydrate stability, are highly variable throughout a year. Here, eastward-deviating brunch of warm West-Spitsbergen current interacts with cold Arctic water masses of East-Spitsbergen current and brines outflowing from Storfjord. This results in pronounced variation of bottom water temperatures – from 0.5 to 2.5 C (see CAGE 15-2 and CAGE 15-5 cruise reports for CTD data).

The GHPs were discovered and studied during CAGE 15-2 cruise. The westernmost structure (GHP 7) was mapped in CAGE 16-5 cruise for the first time. However, water column hydroacoustic anomalies, “gas flares”, above it were observed already during CAGE 15-2. CAGE 16-5 cruise was aimed to visually study

the seafloor and benthic communities of GHPs and collect video-guided site-specific samples for multidisciplinary geobiogechemical studies.

3.3 Bjørnøyrenna craters

Study area "Craters" of CAGE16-5 cruise is located on the northern flank of Bear Trough at 74°54.947' N and 27°46.049'E. The area is a part of a large group of craters and pingo like features, counting ~100 big (~500-1000 m in diameter) and small (50-100 m) features in total. Craters are irregularly spaced within the area of ~480 km^2 in water depths of 310-360 m and are 5 to 30 meters deep. Bear Trough formed as a result of multiple episodes of enhanced subglacial ice stream activity, which started ~2.5 Ma and reactivated during each subsequent glaciation stage latest of which happened during the Late Weichselian (~20 ka). Subglacial ice streams determine extremely high erosion rates in the inner shelf areas, transporting large amounts of the eroded material towards the trough mouth fans on the shelf break. Our study area is located ~370 km eastward from the shelf break in the inner trough, where several hundred meter-thick sedimentary sequence has been scraped out during the stadials, exposing underlying Triassic bedrocks (mainly shale and sandstone). Hard bedrocks constitute the seafloor in the study area, making it a difficult target for geological sampling (gravity coring and box coring) and seismic acquisition. Moreover, during the CAGE towed camera survey in 2015 abundant of rectangular-shaped blocks were found at the seafloor. These blocks were up to several meter high, wide and long and were scattered all over the area. Presumably, these blocks are pieces of ancient bedrock, exposing on the surface, or an alien space station, however their irregular distribution across the area is somewhat unclear.

Our study area covers a ~1000 m long and ~500 m wide crater-pingo system, which had been discovered during the previous CAGE cruises and later chosen for detailed multibeam mapping and multidisciplinary sampling activities. Maximum water depth difference within the study area is between the apex of a pingo and the deepest part of the crater (325 and 354 m deep respectively). One of the hypothesis explaining crater formation is explosive release of gas from dissociating gas hydrates, triggered by the retreating ice sheet and changing pressure/temperature conditions. Nowadays CAGE 16-5 study area is located just outside the methane hydrate stability zone limit, which appears some 7-10 km southward beyond the ~350 m isobath. During the previous CAGE cruises hundreds of active gas flares (indication of gas bubble streams raising from the seafloor to the water column) were detected on the EK60 split-beam echosounder records. Numerous gas flares were previously also documented above the targeted crater-pingo system, pointing on active processes of gas release, which defined the study area as particularly attractive for detailed research.

4 Deviations from Intended Cruise Schedule

Due to a critical failure of the ship-mounted USBL system we were unable to conduct ROV operations at Prins Karls Forland, and had to return to port in Longyearbyen on 19 June to pick up a replacement USBL system shipped from the supplier (Applied Underwater Acoustics) in the UK.

Equipment and Instrumentation

4.1 Remotely Operated Vehicle (ROV)

NTNU provided a Sperre Subfighter 30K remotely operated vehicle for the cruise. The payload of the ROV depended on the type of activity to be done in each dive. The following list indicates some of the instruments used to deliver scientific data to the research team.

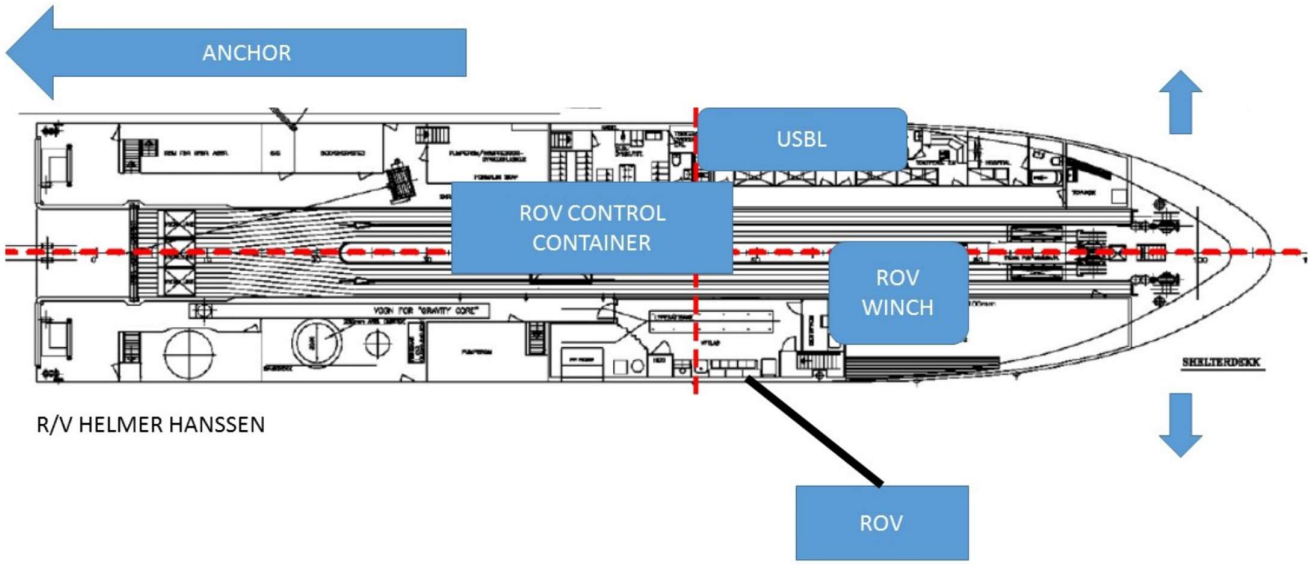


Figure 3: Installation diagram for the 30k ROV on RV Helmer Hansen. The ship anchored from the aft. The USBL was installed with a pole on the port side for every dive. The winch at the center let cable out to the ROV on the starboard side while the control room was located one deck under it.

- A gas sampler: a metallic funnel that when placed over gas areas concentrates the gas into a plastic bottle which then is transferred to a pressurized metallic sampling bottle activated remotely by the ROV operator.
- The Bear Claw: a longitudinal actuator opens and closes a three finger claw capable of grabbing a carbonate crust or a slab and bring it to the surface.
- Niskin bottles: a frame with 4 niskin bottles collected water at specific sites selected by visual reconnaissance of the area. The mechanism consisted in triggering the four bottles at the same time with an actuator and a string to each bottle.
- HD camera. The high definition camera provided quality video useful to identify the water column and seafloor features of the research sites.
- Norbit Multibeam. The ROV-based multibeam provided high resolution acoustic imaging of the area. In combination with the software hypack, the surveyor is capable to geolocate the data gathered and identify prominent features from it.

- Phins intertial navigation system. This high precision INS provided feedback on motion to the multibeam to create high quality acoustic data.
- Valport pressure sensor. The main measurement of depth on the ROV.
- Workhorse doppler velocity log. The DVL measures the altitude at which the ROV swims and the speed at which it moves. In combination with NTNUs AUR lab control system software, it enables the ROV to hold position, maintain a constant altitude of follow a preprogramed pattern,
- Raptor Arm. On the ROV, this 7 degrees of motion actuator enables the ROV team to take or bring objects to or from the bottom or use instruments to collect samples.
- Applied Acoustic Systems Easy Track ultra short base line (USBL) positioning system. the USBL system was used to reveal the position of the ROV with respect to the vessel during a dive.

4.1.1 Multibeam

To perform accurate surveys with a Multibeam Echosounder on an ROV requires a chain of instruments on both the ship and the ROV to be interfaced to a navigation and positioning software, where data from all these instruments are collected and processed.

For this cruise, on the ship, we interfaced to the GPS Compass and the USBL (Ultra Short Base Line, the underwater positioning instrument). The ships MRU (Motion Reference Unit) was already interfaced to the USBL, so the signal received from there was corrected for the movements of the ship.

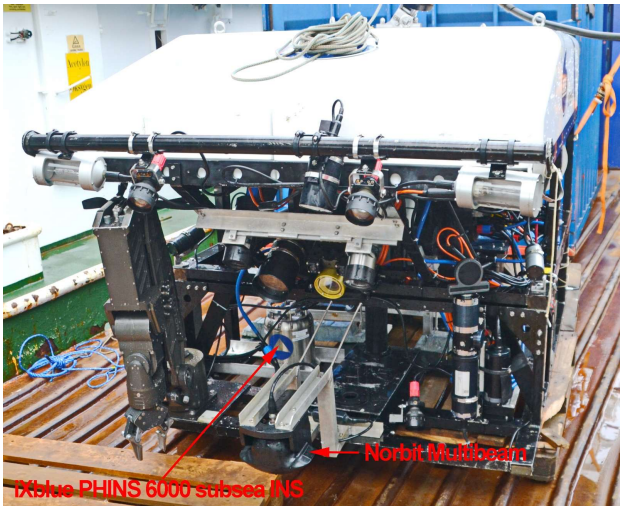


Figure 4: Picture of the forward section of the ROV with the Norbit WBMS and other instrumentation mounted. (Photo: Bo Krogh)

The Norbit WBMS is a quite new Multibeam sonar on the market. New to the industry is the cylindrical array wideband system using frequency modulated transmission signals and built-in sound speed probe. On the ROV the following instruments were interfaced (see Figure 4): The Mulibeam Echosounder itself, a

Norbit WBMS (Wide Beam Multibeam Sonar) with built-in Velocity of Sound sensor and an iXBlue PHINS 6000 Subsea Inertial Navigation System, which provides heading, depth, velocity and attitude of the ROV. Interfaced into the PHINS 6000 were also a Valeport miniIPS (mini Intelligent Pressure Sensor which measures the depth of the ROV below the sea surface) and an RD Instruments 1200 kHz Workhorse Navigator Doppler Velocity Log (which measures the ROVs speed over the ground). All these instruments were interfaced into the Hypack Software for Hydrographic Data Collection and Processing.

4.1.2 Arm claw

At a meeting held in Trondheim in March 2016 regarding the sampling and instrumentation necessary for the ROV cruise in June/July, 2016, it was decided that it would be of great interest to sample large pieces of carbonate crusts from the seafloor. The arm of the ROV to be utilized for this work did not have the sufficient opening to grab anything of the desired size.

After a discussion, it was decided to try to design and manufacture a large claw shaped tool to be attached to the ROV. After drawing a few sketches in 2D then in 3D we ended up with something resembling a large sugar cube picker or children's arcade game.

The original design was made by Bjørn Runar Olsen, Engineer with the Institute of Geology at the University of Tromsø, Norway, final 3D design and manufacturing was done by Pål Vevang, Engineer at the Physics department at the University of Tromsø, Norway.

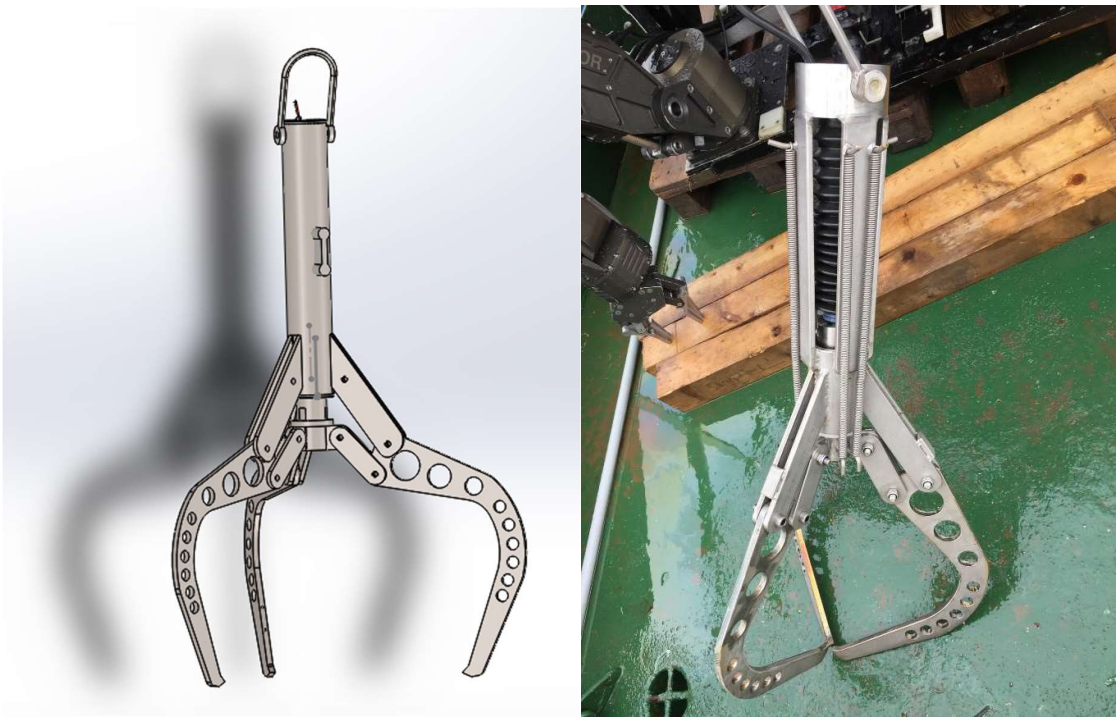


Figure 5: The initial design of the Bear Claw (left) and the actual device on deck of the Helmer Hanssen (right).

At sea the Bear Claw functioned exactly as intended and allowed the ROV to collect larger carbonate crusts of 50x50 cm, with weight of approx. 30kg, and also a piece of crater stone of 30x30cm and 20kg in weight.

Figure 6: The Bear Claw collecting a carbonate crust at the Storfjordrenna pingos (left) and a crater blowout slab from Bjørnøyrenna (right).

4.1.3 Gas sampler

The gas sampler consists of a funnel which is hold above the gas seepage. The free gas trapped by the funnel is lead into a transparent measuring pipe which allows to observe the gas flow and amount of gas collected during sampling. After sufficient amount of gas (>1/2l) is collected in the transparent cylinder a valve is opened by the ROV which lead the gas flow into a stainless steel cylinder. The sample filling relies simply on pressure differential between the isolated sea level pressure inside the steel cylinder and the surrounding ambient sea water pressure. After the retrieval of the gas sample on board the cylinder is stored until the gas analysis onshore.

Figure 7: Gas sampler (Photo: Bo Krogh)

4.1.4 Water sampler

Four standard 5L Niskin bottles were mounted on a metal rack, which was secured to the port side of the ROV. There was an actuator system and tether to the tension wires of the bottles, so that when the actuator was activated by the ROV controller, the tension wires were released and the bottles closed immediately. This allowed very precise spatial (both horizontal and vertical) targeting of water sampling.

4.1.5 Camera systems

The ROV for this cruise was equipped with two, overlapping stereo cameras, separated by about 40 cm in liner distance from each other, set at a 35 degree vertical tilt. Photo resolutions are 1360 x 1024 pixels. Stereo cameras cannot be deployed on the ROV at the same time as the multibeam systems.

4.2 Sub-bottom Profiler (Chirp)

A X-STAR Full Spectrum Sonar is a versatile wideband FM sub-bottom profiler that generates cross-sectional images of the seabed and collects digital normal incidence reflection data over many frequency ranges. X-STAR transmits an FM pulse that is linearly swept over a full spectrum frequency range (also called “chirp pulse”).
The chirp system comprises of a hull-mounted 4 x 4 transducer array operated at an energy level of 4 kW and at a shot rate of 1 s. The signal lasts 40 ms, starts at 1.5 kHz and end at 9 kHz. The system can operate in up to 8000 m of water. The penetration depth depends on the sediment type/thickness, it can be up to 80 m in soft clay.

4.3 Multibeam Echosounder

In the hull of R/V Helmer Hansen a Kongsberg Simrad EM 302 multi-beam echo sounder has been installed capable of transmitting 432 beams within a 120° swath. The multi-beam system measures the two-way travel time that a sound wave initiated by a transmitter needs to reach the sea floor and come back. These waves have a frequency of 30 kHz, which is too high to penetrate the seafloor sediments, but gives a high resolution for a bathymetric map. Once data have been acquired, programs such as, Neptune, SIS, and Fledermaus were used to visualize, clean, filter and process them.

4.4 Single Beam Echosounder

R/V Helmer Hanssen has a keel-mounted Simrad EK 60 single beam echo sounder with transducers at three different frequencies, 18 KHz, 38 KHz and 120 KHz. The 18 KHz transducer can be used for depths up to 10 km whereas 38 KHz and 120 KHz can only be used for depths up to 2 km and 500m respectively.
The single beam echo sounder can also be used for detecting gas leakages from the seafloor using 18KHz and 38KHz transducers. We continuously recorded single beam data during the entire cruise and we identified "flares" with QPS Midwater and subsequently plotted in Fledermaus (QPS software).

4.5 CTD

CTD (Conductivity, Temperature, Depth) sensors measure the physical properties of seawater. In addition to measuring the conductivity, temperature and pressure (from which depth is calculated), the CTD sensors measure or calculate salinity of seawater, density, sound velocity, turbidity, fluorescence/chlorophyll, and oxygen content. Furthermore, the CTD deck unit can trigger closing of an array of 12 5L Niskin bottles at discrete depths. Water samples may be taken from the Niskin bottles for further analysis.
R/V Helmer Hanssen uses SBE 911plus CTD for producing vertical profiles of seawater properties. A winch is used to lower the CTD system into the water. The SBE 911plus CTD can measure physical properties of the seawater from up to eight auxiliary sensors, in marine or fresh-water environments at depths up to 6000 meters. However, the winch wire length limits CTD measurements to approximately 3200 meters. The CTD sensors record data at a rate of 24 samples per second. The 911plus system uses the modular SBE 3plus temperature sensor, SBE 4C conductivity sensor, SBE 5T submersible pump, and TC duct. The submersible pump pumps water along the sensor to measure the conductivity. The TC duct makes sure that temperature and conductivity are measured on the same parcel of water. If required, 12 water bottles can be attached to the CTD instrument set up to collect the water samples from any depth. A single conductor cable supplies the power to the system and transmits data from and to the CTD system real time. During our cruise, we used the sound velocity profiles from different CTD stations to calibrate depth calculations in the swath bathymetry data.

4.6 Sediment sampling

4.6.1 Gravity coring

The gravity corer on-board the Helmer Hanssen consists of a 6 m long iron barrel with lead weights attached to its top. The whole apparatus weighs approximately 2 tons. The inner diameter of the gravity corer is 11 cm. A plastic liner (outer diameter 11 cm, inner diameter 10 cm) is inserted into the barrel before deployment. A core catcher and core cutter are attached to the bottom of the coring device. The core catcher keeps sediments from falling out of the core, while the core cutter aids penetration of the corer into the

sediment. The gravity corer lies on a rail, which during operation lifts the core to a vertical position. A winch then lowers the corer down to 20 m above the seabed. Once above the target location, the corer is dropped. The winch has a wire length of 2900 meters. When the corer is lifted from the seabed and brought on deck, the core cutter and core catcher are sampled first, if any sediments are present on them. The plastic liner is then removed, cleaned, cut into 1 m sections, and labelled. Cores sections are split in half with a table saw to obtain working and archive halves. Porewater was sampled nondestructively on the archive half using rhizones. Specimens for micropaleontology and microbiology were sampled from the working half using sterile spatulas. 5 ml cut-off syringes were used to sample sediments into glass vials capped with rubber stoppers for methane measurements. After sampling, core halves were stored in a cold room.

4.6.2 Van Veen Grab sampling

For quantitative benthic sampling, grab sampling is a common method. We used a van Veen grab (0.1 m^2) to sample benthic soft bottom fauna accordingly ISO 16665:2014 fieldwork protocols for quantitative and qualitative samples. Prior to processing a grab sample, each grab was visually inspected from the inspection port to ensure sample integrity, (i.e. closed jaws, filled and undisturbed surface layer). Quantitative samples were sieved on board with a mesh size of 500 µm. Material retained on the sieve was fixed in formaldehyde (4 %), mixed with rose bengal for staining living tissues, and the solution was buffered with borax (sodium tetra-borate decahydrate). Samples will further on be sorted, identified and weighed in the biological laboratory of Akvaplan-niva (Tromsø, Norway), and stored in 80% ethanol. Organisms are separated into main phyletic groups and identified to the lowest possible taxonomic level.

This sampling technique gives a representative view of the bottom macrofaunal community, and provides data for statistical analysis for taxa, diversity, species richness and biomass.

Figure 8: Van Veen grab in open mode from RV Helmer Hanssen (Photo E. Åström).

4.6.3 Push cores

We used the push cores from Akvaplan-niva and NGU. Each of the push core consist of a rubber top and a transparent liner 8 cm in (inside) diameter and about 50cm long. The rubber top and liner were connected with a metal ring with five screws. Push cores were fitted into PVC sleeves which were secured either outside of the metal cage brought down by the ROV or the push core frame from Akvaplan-niva. The bottom of the push cores were secured by rubber stoppers that fit the inner dimension of the push core liners. Four to six push cores were transported to seafloor during each ROV dive.

After retrieving the push cores on-board, metal rings and the rubber tops were removed from the liners. Cores were transferred to extruders that has been fabricated to fit the size. Once the cores were secured, both the bottom rubber stoppers and the PVC sleeves can be removed. Sediments then can be extruded and sampled.

Figure 9: Push core sample take by ROV directly at a flare in the Storfjordrenna Pingos.

4.6.4 Box Core

A box core is a semi-quantitative benthic sampling method that can be used for harder soft bottom types as gravel and sand. The corer is let down to the seafloor and the chamber is pushed into the sediment, the slicer tilts and cuts out a block of surface sediment that is excavated together with the bottom water directly above the sediment surface. The box corer can recover the uppermost ca. 50 cm of sediment and preserves the stratigraphy during its way upwards through the water column.
The retained surface water of a box core can be used for sampling before removed with a hose followed by an inspection of the surface sediment, which allows characterizing of the surface. Bulk sediments from surface can be retrieved by scooping a tablespoon for surface sediment characteristics i.e. TOC, grainsize, chlorophyll, porosity and methane. Sub cores ø 10 cm can be used to sub-sample the box core quantitatively following the ISO 16665:2014 fieldwork protocols.

Figure 10: A box core in action from RV Helmer Hanssen, and subsampling of a box core sample (Photos: M. Carroll).

4.6.5 Blade cores (ROV)

Blade corers are rectangular (10x20cm sample area) coring devices attached to a T-handle to be grasped by an ROV arm. There are retractable plates, activated by turning the T-handle that slide closed once the corer is seated within the sediment, securing the sample within the catchment area. The samples can be used in their entirety for quantitative analyses, or subsampled with smaller core tubes for a variety of analyses.

Figure 11: A blade corer sampling at a bacterial mat at the Storfjordrenna pingo site.

4.7 Benthic Organism Scoop

A 40 cm diameter circular stainless steel ring with a net attached and a T-handle was used by the ROV for targeted sampling of individual infaunal and epifaunal organisms.

Figure 12: A benthic scoop collecting infaunal at the Storfjordrenna Pingos.

4.8 Net Sampling

Plankton net samples were collected using a Multinet (multi stratified plankton tow Hydrobios, type Midi) equipped with five 63um mesh size. One station was collected from the Reference Site in southern Bjørnøyrenna and we acquired eight stations in the Crater Area along a transect from east to west. Poor weather conditions in Maud Basin meant sample stations were not carried out. At each collected station five depth intervals had been sampled in one stroke, dividing the water column into the following depths intervals: 300-200m, 200-150m, 150-100m, 100-50m and 50-surface.
The contents of each cast were sieved on a 63 um sieves and placed in separate bottles, resulting in 45 bottles in total. Samples were preserved in 96% ethanol solution and buffered with Hexamethylenetetramine. Calcifying organisms including planktonic foraminifera, pteropods and bivalves will be studied from the collected samples. A particular interest will be given to their shell structure ($CaCO_3$) with regard to the ocean chemistry (DIC, CH_4 concentration, pH). The small mesh size and covering of the entire water column allows the analyses of other zooplankton groups (e.g. copepods, dinoflagellates, cladocerans), which provide additional information about water masses dynamic in the crater area.

5 Cruise Narrative

Thursday, 16 June:
Planned departure at 2000 delayed because pretesting of ROV revealed communication problem between controller and ROV itself. New instrument card ordered from Sperre for delivery the following day.

Friday, 17 June:

New part arrives, and further testing reveals that communication problem is solved. Departure from Longyearbyen at 1200 local time and heading to testing site just outside Adventfjorden in Isfjorden. Testing is conducted first with the plough anchor to see how it helps with stability and navigation of the ship for ROV operations (it does nicely). A CTD is taken with water.

The USBL system is tested and there are problems. Extensive troubleshooting reveals a severe problem with the hull mounted transceiver, while the remote transponders appear to be working properly. A new transceiver system is sent from England, and we head to Prins Karls Forland to begin conducting CTD surveys at the shallow location.

Saturday, 18 June:

Under ideal conditions of calm winds and overcast skies, we arrived Prins Karls Forland at 0035 and started shallow cross-shelf CTD transect of 6 stations at the 90m location. We moved west and started a cross-shelf CTD transect at 0526of 5 stations at the depths of 360-390m at the so-called "MASOX" site. 3 multinet samples were also taken here. Continuing in the same area, starting at 1330 we did 2 gravity cores and a box core at a strong flare location followed by 3 ship-mounted multibeam lines. We the proceeded back to the east to the 90m location to finish some key CTD stations.

Sunday, June 19:

Conducted CTDs at 6 stations along the shelf at the 90m location of Prins Karls Forland. We then departed the area and went south to the Isfjordrenna Trough Mouth Fan, and conducted some area exploration with the ship multibeam. Following this we departed the area at 0900 for Longyearbyen to pick up the new USBL transceiver. We arrived Longyearbyen at 1600 to collect the new USBL transponder. It was mounted on the hull and initial testing was positive and we had a first ROV wet test at 2200 local time. After that, the mounting system holding the USBL to the hull failed.

Monday, 20 June:

We sourced new pipe in Longyearbyen for mounting the new USBL on the hull and the day was spent working with designing and fabricating the system to keep the new USBL in the water and secure from damage.

Tuesday, 21 June:

Testing and calibration of USBL system at Isfjorden test site. ROV test dive to test navigation and retrieve USBL beacon on the bottom. Nav is improving, but still not optimal. We depart Isfjorden test site at 0900UTC with a course for the Storfjordrenna Pingo area. We stop en route for 3 CTDs.

Wednesday, 22 June:

We arrive Storfjordrenna Pingo area at 0600UTC and begin work there, starting with a ship multibeam survey over the whole region. We decide to focus sampling at Pingo3, in the southwest part of the area. Many fishing boats (both longliners and trawlers) are working in the area, but we are able to continue with our activities. ROV dive 1 starts at 1300UTC and is a visual reconnaissance survey to identify features and targets for sampling. ROV is on the bottom for about 90 minutes, and the dive is aborted due to strong currents at the bottom. ROV dive 2 at Pingo 3 is to conduct sampling activities. Sampling gear is lowered with a basket, and the ROV is used to take the gear to the sampling locations, and then return with the sample to the basket. It is a very complicated set of manoeuvres, but results in sediment push core, blade core, and carbonate crust samples. The basket wire reconnection at the end of the dive was tricky, but also successful. Late in the evening, a CTD transect of 9 stations is started over the working area.

Thursday, 23 June:

The CTD transect continues through the morning, along with a multinet and gravity core sample. At 1100 we begin a ship multibeam survey of the northern part of the area. During this survey, a new pingo is observed 3-4 km west of the main pingo area. It is leaking lots of gas. We conduct another calibration of the USBL transponder system. A triangle calibration test with a beacon on the sea bottom. We then conduct an ROV dive (D3) with the gas sampler attached to collect gas from a flare at Pingo 3. Despite continued issues with the navigation, we successfully locate again the flare at Pingo 3 where seabed samples were taken the previous day and collected gas rising from the sea bottom. But one of the connectors of the funnel system was leaking on the way to the surface and there was no sample in the bottle once the ROV was recovered on deck.

Friday, 24 June:

Overnight we conduct 3 CTD and multinet samples at Pingos 2,3, and 5. In addition we also collected gravity cores at Pingo 3 and 5. Recovery was variable at Pingo 3, ranging from 30 cm to 345cm. Following that, we did multinet and a grab station of 7 replicate samples at the top of Pingo 3. We conducted another test of the USBL system, this time in a figure 8 configuration.We then used the ROV (Dive 4) to collect gas again at the flare sampled the previous evening, with a better result, and a good gas sample. We also took water sample directly at the flare with 4 Niskin bottles mounted on the ROV and triggered at the same time as the gas sample. The ROV was returned to the ship and then re-rigged for a multibeam survey at Pingo 3.

Saturday, 25 June:

The ROV dived during the night for a high-precision multibeam survey. Completed about 100 m of survey, about half a planned 200m line and finished the dive about 0200UTC. We then ran 2 ADCP lines. Then we did a CTD for bottom water collection at the Pingo 3 top; using the altimeter on the CTD we collected water <1 m above the bottom. Throughout the day, we conducted a transect of 5 multicorer samples from the top of the pingo, them moving off the pingo toward the south, with 6 replicate core samples at each station, divided among the sediment geochemistry, microbiology, methane concentration, biomarker and foraminifera projects. This was followed by another CTD with bottom water (<1m over bottom) at the5th (control) multicorer station. At 1830UTC, ROV dive 6 was launched for photomosiacs at Pingo 3.

Sunday, 26 June:

We conducted 3 gravity cores during the night at pingo 5, with recoveries from 227-326 cm, followed by a ROV dive (7) for photomosaics at Pingo 5. Did photo capture at 3 different areas on the pingo. We then conducted EK60 survey lines over Pingos 1, 3, and 5, followed by a narrow swath (60 degrees) for higher resolution over some key areas in the pingos. A control grab station was taken (6 samples) 3km to the south (upstream) of pingo 3. Then ROV dive (8) was conducted to retrieve a large carbonate crust sample using "The Claw". This was followed immediately by another ROV dive (9) equipped with a scoop for scooping seabed animals. We finished the day with a triangle scrape over Pingo 3.

Monday, 27 June:

We completed a ROV dive (10) with a precision multibeam survey over Pingo 3, with 5 lines at 50m spacing. We then proceeded on a transit to the crater region.

Tuesday, 28 June:

We arrived in the crater region at 0700UTC, took a CTD for water property calibration of the multibeam, then conducted 2 ship multibeam lines. We then conducted ROV dive (12) consisting of 5 NorBit multibeam lines over the crater-pingo complex, named Yin-Yang. In the evening, we started a CTD transect (described below).

Wednesday, 29 June:

During the night and early morning, we conducted a CTD transect of 10 stations running from Northe to south over the Yin Yang pingo crater set and followed that with two multinet/CTD samples. Late in the morning, we conducted ROV dive (12), to rerun one of the Norbit multibeam surveys from the previous day, when there was a data acquisition problem during part of the survey. In the afternoon, we did ROV dive (13) for photomosaics and video reconnaissance at the location right at the confluence of the pingo and crater, what we call the ridgetop feature. In the evening, we began the multinet transect.

Thursday, 30 June:

During the night and early morning, we completed the multinet transect survey, and followed with a grab station (6 samples) at the Bjørnøya flare field, first visited in 2014. We then conducted a series of 3 ROV dives (14, 15, and 16) at the Yin Yang pingo crater black bacterial mat with blade and push cores. In the evening, we started ship multibeam surveys and continued through the night.

Friday, 1 July:

We continued ship narrow swath mutibeam lines until the middle of the morning, then did ROV dive (17), for gas sampling at identified flare locations at Yin-Yang. The next ROV dive (18) was also for gas sampling at a different flare, and ROV dive (19) using the Bear Claw to collect a slab stone from the blowout section. ROV dive (20) was the multibeam patch test to calibrate the Norbit multibeam. During the evening, we conducted 2 box cores at the crater, and then commenced a single beam echosounder survey (see below).

Saturday, 2 July:

Overnight, we ran a series of 10 single beam (EK60) lines north-south over Yin and Yang. During the day we conducted ROV dive (21) for bubble quantification, ROV dive (22) for a video reconnaissance survey, mostly of the deepest part of the crater, and ROV dive (23) for 2 additional NorBit multibeam lines for full coverage of all parts of Yin Yang. Finally, we filled in some additional ship multibeam of new areas in the northwest of the crater area. At 1800 UTC, scientific activities on board were completed and we set sail with a course to Longyearbyen.

Sunday, 3 July:

On transit to Longyearbyen. Report writing, gear packing and storage, laboratory cleaning.

Monday, 4 July:

We arrive Longyearbyen, kulkaia at 0600UTC.

6 Ship tracks and study areas

6.1 Prins Karls Forland

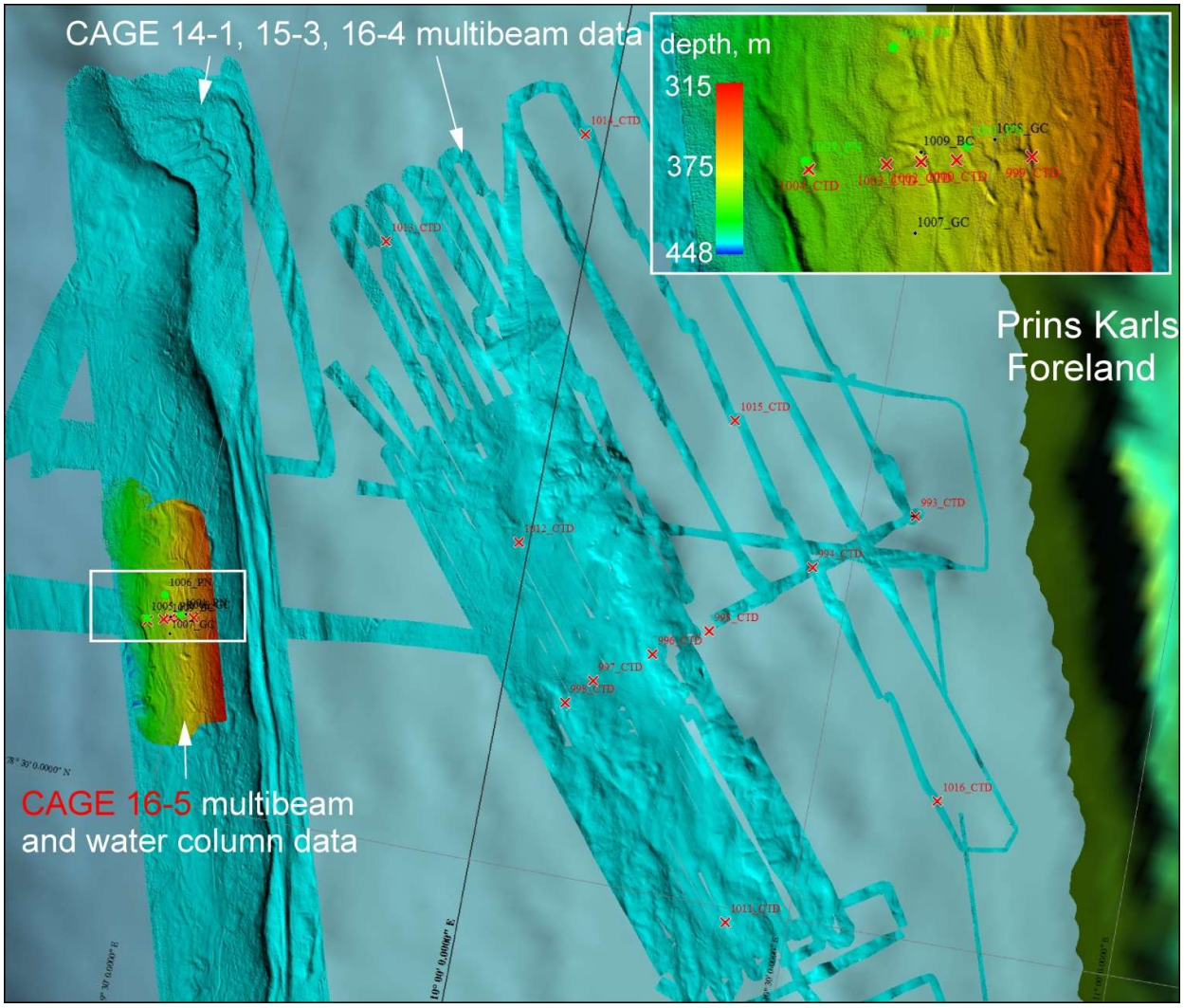


Figure 13: The Prins Karls Forland (& MASOX) study site

6.2 Storfjordrenna Pingos

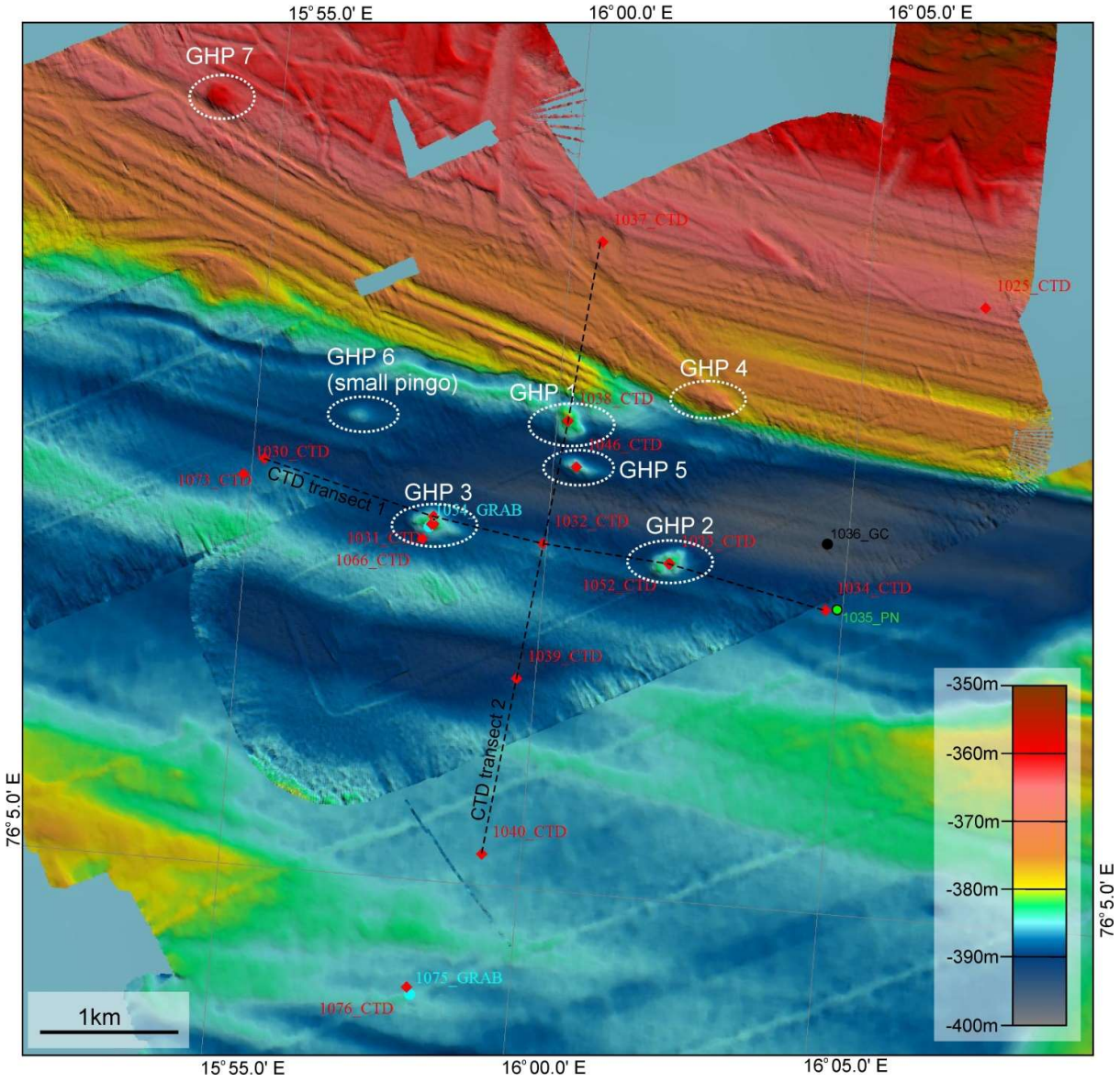
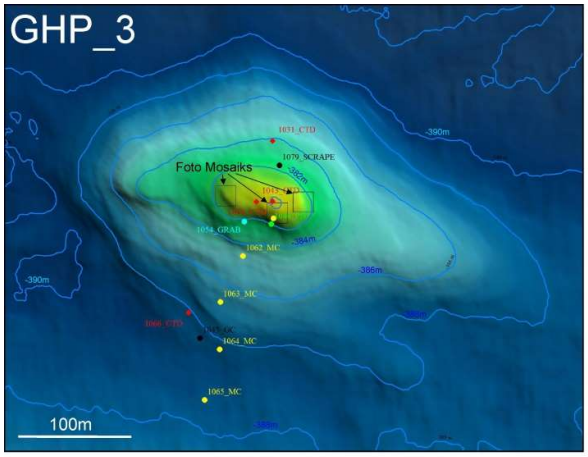
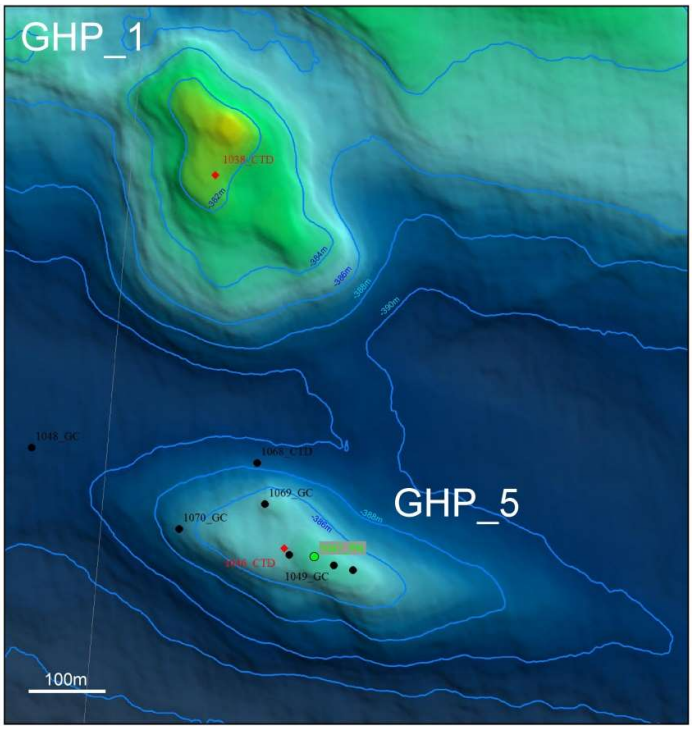
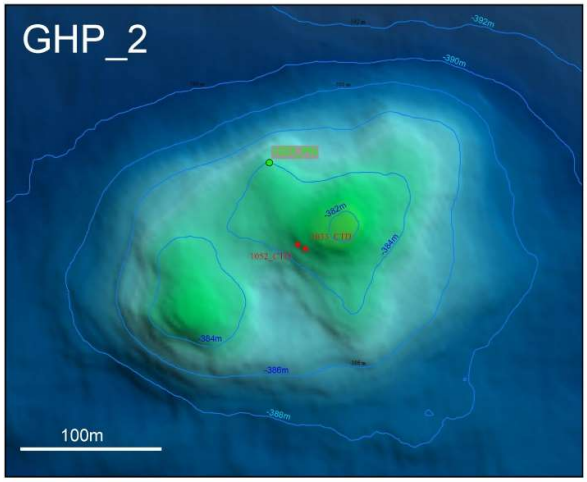
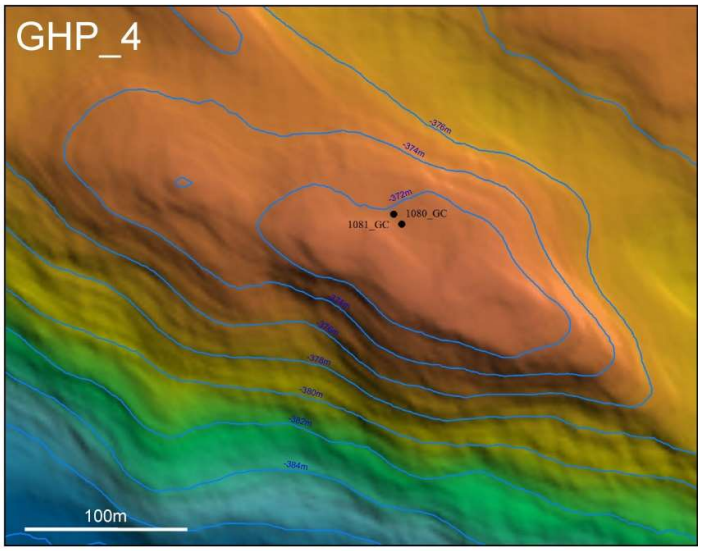


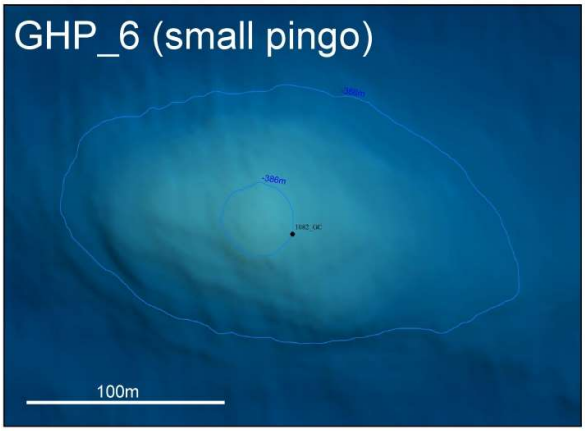
Figure 14: The Storfjordrenna study site, overview of the entire area.











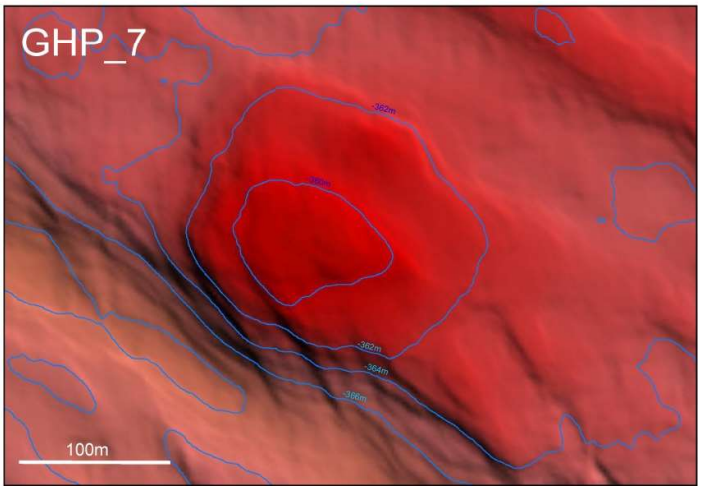


Figure 15: Individual pingos and sample stations in Stofjordrenna

6.3 Bjørnøyrenna Craters

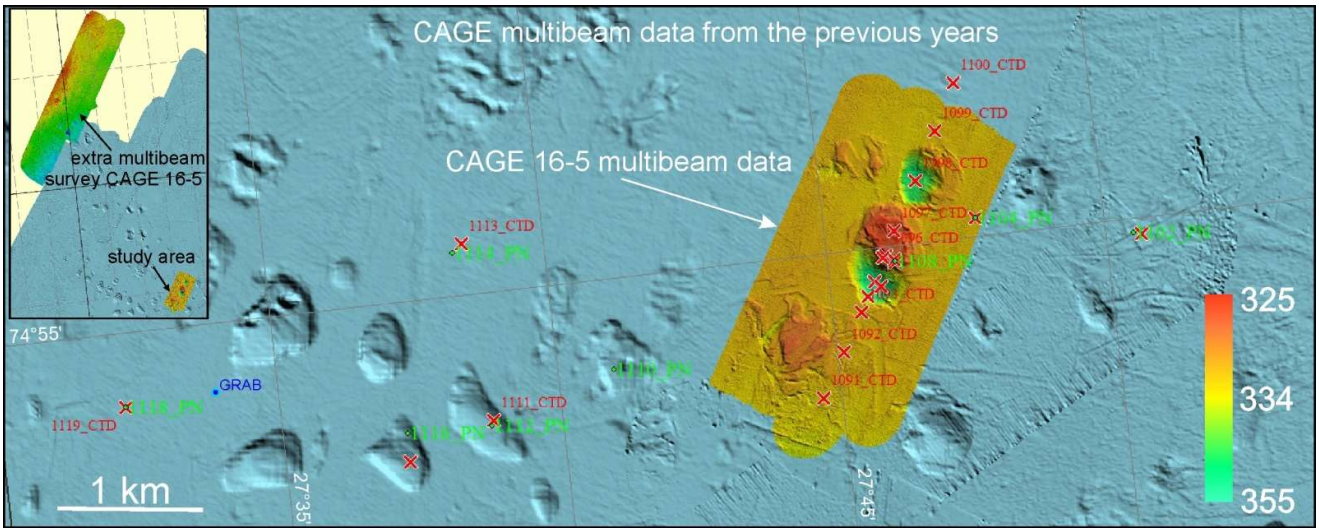


Figure 16: The Bjørnøyrenna Crater area.

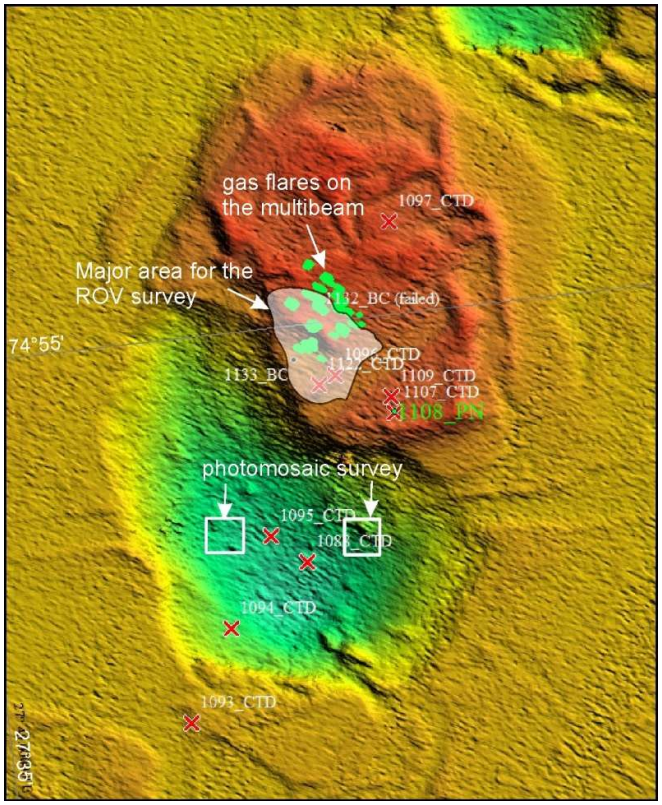


Figure 17: "Yin Yang" crater-pingo system, the focus of our sampling at this study area.

7 Samples and Analyses

7.1 Summary of samples taken

Following table is a summary of the activities, including ship stations, ROV dives, lines run, surveys areas acquired, and samples taken.

Table 2: Station acquisitions summary

Sample/Survey	Number Acquired (stations/lines)
Ship Stations	150
ROV dives	23 (+2 tests)
CTD	65
Multinet	16
Multicorer	7
Box core	4
Gravity core	14
Grab	3/18
Triangle scrape	1
Ship Multibeam (stations/lines)	12/37
ROV Multibeam (stations/lines)	4/14
ROV Photomosaic areas	9
ROV Crust/stone collections	3
ROV Gas samples	3
ROV bubble quantification	3
ROV Push/Blade cores	18
ROV Scoop samples	2
Ship Ek60 (stations/lines)	2/16

7.2 Coordinates for all seabed samples taken from the ROV.

The following is a summary of all the samples collected via the ROV, including the specific location and time for the specific samples.

Table 3: Summary information for all samples taken with the ROV.

Area	Location	Date	Ship station	Sampling Device	Sample/action	Water depth	Geographic		UTM 34		UTC	Notes
							Lat	Long	x	y		
Storfjordrenna Pingo	GHP 3; tube worm tufts	6/22/2016	1029	Timelapse camera	camera dropped	376.05	76.10701	15.96685	365250.729	8452875.007	18:06.26	
Storfjordrenna Pingo	GHP 3; 30 cm from bubble stream	6/22/2016	1029	push core	blue core	377.02	76.10697	15.96725	365261.060	8452870.051	18:19:18	
Storfjordrenna Pingo	GHP 3; 30 cm from bubble stream	6/22/2016	1029	push core	red core	376.88	76.10697	15.96726	365261.457	8452870.008	18:38:54	the core was dropped on the seafloor
Storfjordrenna Pingo	GHP 3; 30 cm from bubble stream	6/22/2016	1029	push core	green core (pore water)	377.04	76.10695	15.96717	365258.983	8452868.198	19:02:33	
Storfjordrenna Pingo	GHP 3; 30 cm from bubble stream	6/22/2016	1029	blade core	blade core 3 (yellow/black handle)	376.99	76.10717	15.96668	365247.886	8452893.837	19:20:27	
Storfjordrenna Pingo	GHP 3; tube worm tufts	6/22/2016	1029	blade core	blade core 2 (red/black handle)	377.49	76.10711	15.96695	365254.595	8452886.236	19:39:37	
Storfjordrenna Pingo	GHP 3; bacterial mat, tube worms	6/22/2016	1029	blade core	blade core 4 (red/blue handle)	376.9	76.10686	15.96743	365264.976	8452857.095	20:04.27	
Storfjordrenna Pingo	GHP 3; carbonate crust field	6/22/2016	1029	scoop net	carbonate crust	377.95	76.10689	15.96798	365279.797	8452859.022	20:51:08	
Storfjordrenna Pingo	GHP 3; bubble stream	6/24/2016	1055	gas funnel	free gas	377.17	76.10663	15.96758	365266.755	8452831.276	19:21:33	
Storfjordrenna Pingo	GHP 3; bubble stream	6/24/2016	1055	niskin bottles	water samples	377.27	76.10678	15.96823	365285.657	8452847.031	19:21:43	
Storfjordrenna Pingo	GHP 3; bubble stream	6/24/2016	1056	bubble quantification pannel	bubble survey	377.17	76.10663	15.96758	365266.755	8452831.276	23:33:20 - 23:41:05	
Storfjordrenna Pingo	GHP 5; normal seafloor with outcropping carbonates	6/26/2016	1071	Timelapse camera	camera dropped	385.69	76.11137	16.00741	366375.336	8453268.440	04:29.02	
Storfjordrenna Pingo	GHP 3; carbonate crust field	6/26/2016	1077	carbonate grab (claw)	carbonate crust	378.46	76.10700	15.96941	365319.087	8452868.049	19:00:55	
Storfjordrenna Pingo	GHP 3; normal seafloor	6/26/2016	1078	scoop net	bulk sediments, benthic fauna	379.23	76.10713	15.96681	365250.963	8452889.044	20:10:30	the seafloor was scraped 6 times with the same scoop; massive free gas release from the sample when ROV was floating up
	GHP 3; bacterial mat; tube worm tufts					379.1	76.10706	15.96686	365251.540	8452881.209	20:13:21	
							76.10706	15.96686	365251.540	8452881.209		
	GHP 3; bacterial mat; tube worm field					377.85	76.10709	15.96710	365258.353	8452884.290	20:18:05	
	GHP 3; bacterial mat; tube worm tufts					378.1	76.10652	15.96699	365249.974	8452821.198	20:20:53	
	GHP 3; 50 cm from bubble stream					377.5	76.10722	15.96778	365277.837	8452897.210	20:27:51	
Bjørnoyrenna Craters	Yin Yang crater; black sediments	6/30/2016	1123	blade core	blade core with red handle	329.64	74.91619	27.76664	696162.493	8325455.066	8:13:02	
Bjørnoyrenna Craters	Yin Yang crater; black sediments	6/30/2016	1123	blade core	blade core with yellow/black handle	330.19	74.91620	27.76664	696162.572	8325455.529	8:20:45	
Bjørnoyrenna Craters	Yin Yang crater; black sediments	6/30/2016	1123	blade core	blade core with red/blue handle	329.65	74.91619	27.76662	696162.045	8325454.419	8:30:26	
Bjørnoyrenna Craters	Yin Yang crater; white fluffy bacterial communities on the	6/30/2016	1123	blade core	blade core with yellow/silver handle	330.22	74.91620	27.76670	696164.159	8325455.740	8:38:46	

	side of black patch											
Bjørnoyrenna Craters	Yin Yang crater; white fluffy bacterial communities on the side of black patch	6/30/2016	1123	ROV manipulator	starfish	329.4	74.91613	27.76659	696162.002	8325447.672	8:43:24	
Bjørnoyrenna Craters	Yin Yang crater; normal seafloor close to black sediment patch	6/30/2016	1124	push core	push core 1	330.53	74.91620	27.76659	696160.960	8325455.855	10:17:02	
Bjørnoyrenna Craters	Yin Yang crater; white fluffy bacterial communities	6/30/2016	1124	push core	push core with yellow/silver handle	329.64	74.91616	27.76660	696161.704	8325451.531	10:26:43	
Bjørnoyrenna Craters	Yin Yang crater; white fluffy bacterial communities	6/30/2016	1124	push core	push core 15 (pore water)	330.41	74.91620	27.76672	696164.701	8325456.721	10:53:40	
Bjørnoyrenna Craters	Yin Yang crater; 30 cm from white fluffy bacterial communities	6/30/2016	1124	push core	push core 9 (pore water)	329.18	74.91617	27.76675	696166.017	8325453.612	11:09:44	
Bjørnoyrenna Craters	Yin Yang crater; 50 cm from small black patch	6/30/2016	1124	push core	push core 11	330.01	74.91610	27.76629	696153.720	8325443.730	11:24:42	
Bjørnoyrenna Craters	Yin Yang crater; black patch, bacterial mat	6/30/2016	1125	blade core	blade core 2	330.13	74.91616	27.76659	696161.667	8325451.308	14:41:23	
Bjørnoyrenna Craters	Yin Yang crater; black patch, bacterial mat	6/30/2016	1125	blade core	blade core 3	330.18	74.91615	27.76652	696159.716	8325450.276	14:48:40	blade core was dropped on the seafloor
Bjørnoyrenna Craters	Yin Yang crater; white fluffy bacterial communities	6/30/2016	1125	blade core	blade core 1	330.43	74.91617	27.76641	696156.296	8325452.037	15:19:10	
Bjørnoyrenna Craters	Yin Yang crater; white fluffy bacterial communities	6/30/2016	1125	blade core	blade core 4	330.34	74.91616	27.76635	696154.625	8325450.226	15.23:50	
Bjørnoyrenna Craters	Yin Yang crater; twin flares	7/1/2016	1128	gas funnel	free gas	326.9	74.91663	27.76830	696204.937	8325509.071	08:13:25 (start of sampling)	
Bjørnoyrenna Craters	Yin Yang crater; twin flares	7/1/2016	1128	niskin bottles	water sample	326.9	74.91663	27.76830	696204.937	8325509.071	8:13:25	
Bjørnoyrenna Craters	Yin Yang crater; small bubble stream	7/1/2016	1129	gas funnel	free gas	325.77	74.91677	27.76723	696172.319	8325521.425	11:18:13 (middle of sampling)	
Bjørnoyrenna Craters	Yin Yang crater; small bubble stream	7/1/2016	1129	niskin bottles	water sample	325.32	74.91677	27.76726	696173.105	8325520.943	11:40:55	
Bjørnoyrenna Craters	Yin Yang crater	7/1/2016	1130	carbonate grab (claw)	shale slab	341.52	74.91561	27.76190	696033.186	8325374.490	13:56:20	
Bjørnoyrenna Craters	Yin Yang crater	7/2/2016	1137	bubble quantification pannel	bubble survey	327.46	74.91665	27.76842	696208.242	8325512.055	07:30:50 - 07:40:53	
						326.83	74.91687	27.76753	696179.681	8325533.851	07:43:45 - 07:51:20	

7.3 Multibeam

7.3.1 Ship mounted (A. Portnov)

Ship-mounted multibeam echosounder data has been acquired at each study area prior to other survey and sampling activities. Major advantages of the newly installed EM302 multibeam system are: larger number of beams per one ping, resulting in better resolution and ability to record the water column data in 3D space. This makes EM 302 a perfect tool for reconnaissance and choosing the targets for sampling based on the detailed geomorphology and precise locations of gas flares in the water column. At each site a separate CTD station was planned to measure the hydrographic parameters of the water column and adjust the sound velocity profile for EM 302. Multibeam data recording required max 4-knots vessel speed with disabled EK60 split-beam echosounder and ADCP system to avoid any interference.

At PKF study area we have acquired three 7-km long lines, covering the area around "MASOX" site with the 2-m grid bathymetry and run testing of the water column data acquisition and processing. Similar bathymetric survey was held at the Isfjorden trough mouth fan (two 5.2 km-long lines) for exploration purposes. At Storfjodrenna pingo study area we have tried different configurations of multibeam survey with various beam angles. Narrow (30-60°) beam angle allowed for better resolution of the bathymetric data (~0.5-1 m) and higher quality of the water column data. Narrow-beam multibeam survey is time consuming due to a smaller footprint, however it helps to precisely indicate the locations of gas release spots at the sea bottom, helping to significantly save time during the ROV operations. Additionally to three 5 km-long lines with the wide angle beam configuration and two lines with narrow angle beam configuration (for water column survey), we have acquired three 7 km-long exploration lines NW from the study area. These extra lines revealed one more pingo structure leaking gas, similar to those, explored during the previous years. At the crater area after the additional multibeam calibration we have covered the study area with a 1 m grid bathymetry data and 3D water column data. It allowed to precisely allocate the most promising area for the ROV dives. Additionally, three 7 km-long exploration lines were acquired with 120° beam angle configuration in the NW part of the crater area. The location of the lines were chosen based on the hypothesis that craters are aligned along the geological fault structure, stretching under the study area in SE-NW direction. Several smaller crater and pingo structures were found, and more of them are likely to exist further NW.

7.3.2 ROV mounted (B. Krogh)

When operated at working altitude of approximately 20m over the seabed, the sonar delivered a swath of at least 150m. Two areas were surveyed with the Norbit ROV Multibeam, the GHP-3 site at Storfjordrenna where 2 surveys were carried our covering an area of approximately 275m x 270m, and the “Yin Yang” crater-pingo system in Bjørnøyrenna Crater Area, where 3 surveys were carried out including a so-called

Patch-Test, which is used for calibration of the multibeam, covering a total area of approximately. 750m x 790m.

For the survey of these two areas the Norbit Multibeam collected a point cloud of approximately 20 points per square meter. Such a point density is adequate to reveal seabed features of interest. This was the case for the deepest part of the crater area of the Yin-Yang, which was subsequently investigated by a video reconnaissance survey.

Although the result from the multibeam surveys were immediately acted upon during the cruise, the final results were not so good. This was due to a Windows10 timing error, where the timing accuracy drifted several seconds during the actual survey. In order to georeference a dataset like this, the different instruments must timetag each measurement with the precision of a microsecond, and the timetag is then used to combine all the instruments described above, so that, for example, he correct roll-angle of the ROV from the PHINS Subsea INS is combined with the correct swath of depth measurements from the Norbit Multibeam. If it only had been a constant time error, then it could easily have been corrected for during the post processing, but it was variable over the data acquisition period, resulting in a far more difficult task of post-processing the data.

7.4 CTD (P. Jansson)

CTD casts were performed at the three main survey areas, Prins Karls Forland, Storfjordrenna Pingos and Crater Areas. In addition, we performed casts along the transit from Prins Karls Forland to Storfjordrenna Pingos. Table 4 shows the positions of all casts.

The objective of CTD casts is to add general background information about the water properties. For example, the bottom water temperature can, in some locations be important for the gas hydrate stability. It is generally possible to determine the origin of the water masses by looking at the temperature and salinity. Other useful information such as fluorescence, oxygen concentration and turbidity is also contained in the CTD data files. These files are also necessary for the calculation of methane concentrations after the mole fraction has been determined by Gas Chromatography (See Methane Concentration section).

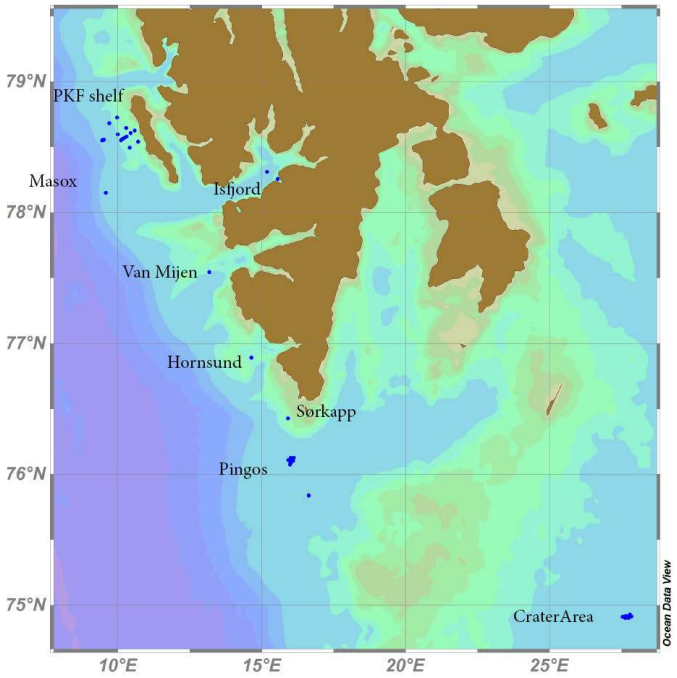


Figure 18: CTD locations (blue)

Table 4: List of CTD stations and area description

Station	Area	# Depths	yyyy-mm-ddThh:mm:ss.sss	Longitude [degrees_east]	Latitude [degrees_north]
CAGE_16-5_HH_991_CTD	Isfjorden	-	2016-06-17T11:59:50.000	15.17950	78.31100
CAGE_16-5_HH_992_CTD	Isfjorden	8	2016-06-17T12:40:22.000	15.17950	78.31100
CAGE_16-5_HH_993_CTD	PKF-shelf	8	2016-06-18T00:28:00.000	10.57967	78.62783
CAGE_16-5_HH_994_CTD	PKF-shelf	8	2016-06-18T01:16:47.000	10.44233	78.60750
CAGE_16-5_HH_995_CTD	PKF-shelf	8	2016-06-18T02:13:31.000	10.29850	78.58234
CAGE_16-5_HH_996_CTD	PKF-shelf	8	2016-06-18T03:00:09.000	10.21850	78.57200
CAGE_16-5_HH_997_CTD	PKF-shelf	8	2016-06-18T03:44:02.000	10.14200	78.56084
CAGE_16-5_HH_998_CTD	PKF-shelf	8	2016-06-18T04:28:30.000	10.10017	78.55283
CAGE_16-5_HH_999_CTD	Masox	8	2016-06-18T05:25:00.000	9.50900	78.55717
CAGE_16-5_HH_1000_CTD	Masox	8	2016-06-18T06:34:55.000	9.49033	78.55583
CAGE_16-5_HH_1002_CTD	Masox	8	2016-06-18T08:29:27.000	9.47933	78.55550
CAGE_16-5_HH_1003_CTD	Masox	8	2016-06-18T09:37:23.000	9.46933	78.55450
CAGE_16-5_HH_1004_CTD	Masox	8	2016-06-18T10:38:17.000	9.44733	78.55300
CAGE_16-5_HH_1011_CTD	PKF-shelf	8	2016-06-18T20:57:55.000	10.40483	78.49533
CAGE_16-5_HH_1012_CTD	PKF-shelf	8	2016-06-18T22:02:33.000	9.98583	78.59783
CAGE_16-5_HH_1013_CTD	PKF-shelf	8	2016-06-18T22:54:11.000	9.69350	78.68217
CAGE_16-5_HH_1014_CTD	PKF-shelf	8	2016-06-18T23:37:27.000	9.96867	78.72583
CAGE_16-5_HH_1015_CTD	PKF-shelf	8	2016-06-19T00:39:21.000	10.28100	78.64750
CAGE_16-5_HH_1016_CTD	PKF-shelf	8	2016-06-19T01:48:00.000	10.69433	78.54350
CAGE_16-5_HH_1017_CTD	Isfjord TMF	-	2016-06-19T04:44:09.000	9.57567	78.15050
CAGE_16-5_HH_test_CTD	Isfjorden		2016-06-19T18:49:44.000	15.17783	78.31067
CAGE_16-5_HH_1020_CTD	Isfjorden	-	2016-06-21T08:10:58.000	15.17867	78.31067

CAGE_16-5_HH_1022_CTD	Van Mijen fjord	8	2016-06-21T17:03:43.000	13.17300	77.54716
CAGE_16-5_HH_1023_CTD	Hornsund fjord	8	2016-06-21T21:46:00.000	14.63300	76.89150
CAGE_16-5_HH_1024_CTD	South Cape	8	2016-06-22T01:23:03.000	15.90317	76.42767
CAGE_16-5_HH_1025_CTD	Storfjordrenna Pingos	-	2016-06-22T03:38:15.000	16.10400	76.12600
CAGE_16-5_HH_1027_CTD	Storfjordrenna Pingos	8	2016-06-22T09:50:37.000	15.97050	76.10683
CAGE_16-5_HH_1030_CTD	Storfjordrenna Pingos	8	2016-06-23T01:04:02.000	15.91633	76.10983
CAGE_16-5_HH_1031_CTD	Storfjordrenna Pingos	8	2016-06-23T01:47:36.000	15.96883	76.10783
CAGE_16-5_HH_1032_CTD	Storfjordrenna Pingos	8	2016-06-23T02:38:02.000	15.99933	76.10650
CAGE_16-5_HH_1033_CTD	Storfjordrenna Pingos	8	2016-06-23T03:25:16.000	16.03583	76.10600
CAGE_16-5_HH_1034_CTD	Storfjordrenna Pingos	8	2016-06-23T04:19:21.000	16.08067	76.10367
CAGE_16-5_HH_1037_CTD	Storfjordrenna Pingos	8	2016-06-23T07:38:30.000	16.01133	76.12666
CAGE_16-5_HH_1038_CTD	Storfjordrenna Pingos	8	2016-06-23T08:28:53.000	16.01000	76.11650
CAGE_16-5_HH_1039_CTD	Storfjordrenna Pingos	8	2016-06-23T09:34:29.000	15.99583	76.09783
CAGE_16-5_HH_1040_CTD	Storfjordrenna Pingos	8	2016-06-23T10:31:26.000	15.99617	76.08650
CAGE_16-5_HH_1043_CTD	Storfjordrenna Pingos	10	2016-06-24T02:28:51.000	15.96617	76.10700
CAGE_16-5_HH_1046_CTD	Storfjordrenna Pingos	8	2016-06-24T05:25:57.000	16.00717	76.11100
CAGE_16-5_HH_1052_CTD	Storfjordrenna Pingos	8	2016-06-24T09:41:14.000	16.03167	76.10567
CAGE_16-5_HH_1058_CTD	Storfjordrenna Pingos	2	2016-06-25T04:43:57.000	15.97317	76.10700
CAGE_16-5_HH_1067_CTD*	Storfjordrenna Pingos		2016-06-25T15:15:09.000	15.96550	76.10533
CAGE_16-5_HH_1073_CTD	Storfjordrenna Pingos	-	2016-06-26T10:41:02.000	15.92433	76.10950
CAGE_16-5_HH_1076_CTD	Storfjordrenna Pingos	1	2016-06-26T15:28:09.000	15.97450	76.07484
CAGE_16-5_HH_1085_CTD	Storfjordrenna GZW	8	2016-06-27T12:45:31.000	16.62800	75.84133
CAGE_16-5_HH_1086_CTD	Storfjordrenna GZW	8	2016-06-27T13:24:33.000	16.63100	75.83900
CAGE_16-5_HH_1088_CTD	Crater area	-	2016-06-28T07:37:54.000	27.76600	74.91350
CAGE_16-5_HH_1091_CTD	Crater area	8	2016-06-28T19:13:59.000	27.74167	74.90533
CAGE_16-5_HH_1092_CTD	Crater area	8	2016-06-28T20:02:10.000	27.75317	74.90833
CAGE_16-5_HH_1093_CTD	Crater area	8	2016-06-28T20:52:54.000	27.75900	74.91150
CAGE_16-5_HH_1094_CTD	Crater area	8	2016-06-28T21:35:48.000	27.76067	74.91250
CAGE_16-5_HH_1095_CTD	Crater area	8	2016-06-28T22:28:41.000	27.76250	74.91367
CAGE_16-5_HH_1096_CTD	Crater area	8	2016-06-28T23:15:37.000	27.76733	74.91617
CAGE_16-5_HH_1097_CTD	Crater area	8	2016-06-28T23:56:37.000	27.77083	74.91700
CAGE_16-5_HH_1098_CTD	Crater area	8	2016-06-29T00:35:02.000	27.77750	74.92083
CAGE_16-5_HH_1099_CTD	Crater area	8	2016-06-29T01:12:36.000	27.78533	74.92484
CAGE_16-5_HH_1100_CTD	Crater area	8	2016-06-29T01:50:13.000	27.79117	74.92867
CAGE_16-5_HH_1101_CTD	Crater area	8	2016-06-29T02:35:37.000	27.84400	74.91534
CAGE_16-5_HH_1103_CTD	Crater area	9	2016-06-29T03:57:38.000	27.79483	74.91800
CAGE_16-5_HH_1107_CTD	Crater area	9	2016-06-29T18:08:42.000	27.77000	74.91550
CAGE_16-5_HH_1109_CTD	Crater area	9	2016-06-29T19:38:56.000	27.68267	74.90950
CAGE_16-5_HH_1111_CTD	Crater area	9	2016-06-29T21:05:40.000	27.64633	74.90667
CAGE_16-5_HH_1113_CTD	Crater area	9	2016-06-29T22:32:28.000	27.64233	74.92067
CAGE_16-5_HH_1115_CTD	Crater area	9	2016-06-29T23:51:24.000	27.62083	74.90533
CAGE_16-5_HH_1117_CTD	Crater area	9	2016-06-30T01:15:48.000	27.54067	74.91250
CAGE_16-5_HH_1119_CTD	Crater area	1	2016-06-30T02:21:50.000	27.53783	74.91167
CAGE_16-5_HH_1122_CTD	Crater area	8	2016-06-30T05:38:24.000	27.76667	74.91583

* Station listed as 1066 in cruise spreadsheet

7.5 Methane Concentration (P. Serov)

The primary target of sediment headspace gas sampling is to estimate concentrations and molecular composition of hydrocarbon gas in various seabed environments. Headspace gas concentrations give an overall estimate of seepage activity. Methane concentrations are essential for geobiochemical and microbiological studies as well as for studies of seep-associated fauna. Collected samples can be used for analyses of carbon and hydrogen stable isotopes in methane to unravel the source of hydrocarbon gas. During the CAGE 16-5 cruise we collected ~150 headspace sediment gas samples from sediment cores, multicores, box cores, blade cores, push cores and grabs. Normally, we aimed to sample recovered sediment section in push cores and multicores with 2-10 cm spacing. The same sampling strategy was applied for the first meter of gravity cores. From subsequent sections of gravity cores the samples were taken every 25 cm. From grabs and box cores we took samples from the sediment surface only. The headspace gas sampling was accompanied with sampling for bulk sediment porosity in most of the stations. Samples of overlying bottom water in multicores, push cores, box cores and grabs were taken opportunistically.

7.5.1 Gas in bottom sediments

For compositional analyses of hydrocarbon gas (C_1-C_5) conventional headspace sampling preparation technique was applied. Bulk sediments (5ml) were subsamples with a 5 ml cut-off plastic syringe. The sediments were transferred into 20 ml headspace glass vials, containing 5 ml of 1-molar NaOH solution and 2 glass beads. The vials were immediately capped with rubber septa, sealed with aluminum crimp caps and shaken afterwards. All samples were stored in a fridge with a temperature of +2 C.

7.5.2 Gas in water

Water samples were analysed with a Gas Chromatograph equipped with a FID. The chromatograms allow for detection of hydrocarbon gases such as methane, ethane, ethylene and propane.
Headspace gas extraction method was applied for sample preparation for subsequent GC-FID gas analyses. Water samples from Niskin bottles were placed into 120ml glass vials, We added 1 ml of 1M NaOH solution for preservation. Bottles were sealed with rubber septa and crimped. Subsequently we added 5ml of instrument nitrogen gas into each of the bottles and shake them to equilibrate gas dissolved in a water sample and headspace gas. Samples were stored in the fridge (+2 C) and analysed within 0.5-2 hours after the sampling.

7.6 Echosounder & Gas Bubbles (P. Jansson)

Background

Quantifying bubble flux from the seafloor with remote sensing (split beam echosounder, EK60) requires knowledge about the size distribution of bubbles and rising speed. The backscatter intensity from bubbles can be used to calculate bubble flow rates, but different bubbles scatter sound differently, depending on physical properties, such as size, gas composition, depth, water density, surfactants etc. (Medwin & Clay, 1997). Knowing something about the typical bubbles in a survey area is therefore very helpful for the quantification of gas flow rates. Of special interest is, if there is a hydrate rim on the bubbles near the seafloor and/or higher in the water column.

Method

We performed bubble size measurements with a ROV based camera and a checkerboard type panel. The video will be post-processed to evaluate bubble sizes and rising velocities. The equipment was deployed at seep sites in the Pingo and Crater area.

<table>
<tr>
<td> 

View from high mounted camera.</td>
<td> 

Screenshot of recorded video at the Crater area.</td>
</tr>
<tr>
<td> 
Rope used to hold the panel while diving.</td>
<td> 
Weight to for negative buoyancy.</td>
</tr>
</table>

ROV manipulator arm

Figure 19: Equipment used is measuring gas bubble flow rate.

7.7 Gas composition (J. Faust)

The three gas samples collected during this cruise will be carried to the Geological Survey of Norway (NGU). To identify hydrocarbon sources (in-situ methanogenesis or secondary methanogenesis resulting from higher hydrocarbon degradation), potential migration pathways to the seafloor and potential differences between the Pingo and Crater area all gas samples will be analysed for their isotopic composition (δ13C, δD) on methane, ethane, propane and butane.

Table 5: Gas flare sample stations.

Station #	Location
1055	GHP3 (Storfjordrenna)
1128	Yin Yang (Bjørnøyrenna)
1129	Yin Yang (Bjørnøyrenna)

7.8 Carbonate Crusts (J. Faust)

Two carbonate crusts, collected from Storfjordrenna GHP-3 will be investigated for their mineralogical and petrographical structure at the Geological Survey of Norway. The aim is to better understand the origin and growth of the carbonate crusts and the environmental setting of carbonate precipitation at cold seepages. Stable carbon (δ13C) and oxygen (δ18O) isotopes on bulk and micro-drilled samples will be measured for constraining the carbon sources and assessing the possible influence of seawater, gas hydrate water and/or clay dehydration water in the carbonate precipitation environment. Additionally, U-Th geochronology will be used to constrain the age and times of carbonate precipitation and thus, by inference, the past seepage activity.

Table 6: Carbonate crust samples

Station #	Location
1029	GHP-3
1077	GHP-3

7.9 Geomicrobiology

7.9.1 Surveys of benthic and pelagic methanotrophic activities (F. Gründger, S. George, H. Niemann)

Our overall aims in CAGE 16-5 were to determine the activity of methanotrophic microbes and the composition of the microbial community in the water column and in sediments at different cold seep areas of the coast of Svalbard. An overview of the different sampling locations and sample types collected is shown in Table 7. Our biogeochemical and microbiological data will be complemented with geochemical analyses of pore water constituents, methane concentration and stable isotope composition. These are essential for the interpretation of biogeochemical reactions and community composition of microbes. Geochemistry samples were collected from the same sites and depths as our sample sets.

7.9.2 Water column sampling

Aerobic Methane oxidation rates

Aerobic methane oxidation (MOx) is final barrier for methane before its release to the atmosphere, where it acts as a potent greenhouse gas. MOx is mediated by bacteria and proceeds according to the following net reaction:

$CH_4 + 2\ O_2 \rightleftharpoons CO_2 + 2\ H_2O$

For analysis of MOx rates at discrete water depths, we sampled the water column with a 12 × 5-Liter CTD/Rosette sampler at 8 different water levels. Sub-samples were taken immediately upon recovery of the sampler. Additionally, we collected bottom water samples by using 4 x 5-L Niskin bottles attached to the ROV. MOx rates were determined by *ex situ* incubations with trace amounts of tritium labelled methane (C^3H_4), allowing to trace the label transfer by measuring the activity of substrate (C^3H_4) and product pools (^3H_2O) after incubation (Berndt et al., 2014; Niemann et al., 2015, Steinle et al., 2015). Briefly, for each sampling depth, six 20-ml crimp-top vials were filled and closed bubble-free with PTFE coated bromobutyl stoppers (Wheaton, USA). Subsequently, each sample was amended with 5 µl gaseous C^3H_4/N_2 mixture (~5 kBq, <50 pmol CH_4, American Radiolabeled Chemicals, USA) and incubated for 3 days at *in situ* T in the dark. The incubations were terminated by unsealing one triplicate and subsampling a 10-mL aliquot of the incubation medium. This was then amended with aqueous NaCl solution (1 mL, 20%, w/v) and purged

for 30 min with air to strip out the remaining methane. The activity of the produced ^3H_2O will be determined in our home laboratories by liquid scintillation counting. Similarly, the radioactivity of both, the remaining C^3H_4 and the produced ^3H_2O will be determined from the second triplicate (fixed with 0.5 mL $HgCl_2$ solution after incubation) by liquid scintillation counting in our home laboratories. MOx rates will be corrected for (most probably insubstantial) tracer turnover in killed controls (fixed with HgCl solution just after tracer amendments). MOx rates will be calculated from the fractional turnover of labelled CH_4 and water column CH_4 concentration assuming first order kinetics (Reeburgh, 2007):

rMOx = k×[CH4]

where k is the first-order rate constant (determined from the fractional turnover of labelled CH_4 per unit time and corrected for tracer turnover in killed controls) and [CH_4] is the concentration of CH_4 at the beginning of the incubation.

Microbial community composition and cultivation

1 L seawater aliquots from selected water levels were collected for microbial community analyses with DNA tools (next generation sequencing, Illumina). Seawater samples were filtered through polycarbonate filters (0.2 µm pore size, Millipore) and stored at -20°C until further analyses in our laboratories.

Additional samples were collected for determining the identity and abundance of key microbial communities through fluorescence *in situ* hybridisation with catalysed reporter deposition (CARD-FISH); Pernthaler and Pernthaler, 2007). For this purpose, 300 mL of aqueous sample were fixed with 15 mL formaldehyde solution (38%) for 4 h at 4°C in the dark. Subsequently, samples were filtered through polycarbonate filters (0.2 µm pore size, Millipore) rinsed with deionised water and stored at -20°C until further analyses in our home laboratories.

MOx rates will be determined from all collected samples. The resolution of microbial community analyses (FISH, DNA) will depend on the results of rate measurements.

For cultivation and isolation studies of methanotrophic bacteria, seawater from selected water depths (10-20 L) was filtered through sterile GF/F filters (Whatman). The filter was then transferred into 100-mL glass bottles filled with 50 mL sterile filtered seawater, sealed with rubber stoppers, and the headspace was mended with 10 mL CH_4. Incubation of enrichment cultures were started on board at 4°C in the dark.

7.9.3 Sediment sampling

Anaerobic methane oxidation and sulphate reduction rates

Most methane produced in ocean deep sediments is consumed anaerobically with sulphate as the terminal electron acceptor (anaerobic oxidation of methane – AOM; Knittel and Boetius, 2009):

$$CH_4 + SO_4^{2-} \rightleftharpoons HCO_3^- + HS^- + H_2O.$$

To study the magnitude of methane oxidation and sulphate reduction at the water-sediment interface and in anoxic sediment layers beneath, we used radioactive tracers (^{14}C-labeled methane and ^{35}S-labeled sulfate, respectively) for *ex situ* incubations on board.

Sediment samples were recovered from GHP-3 and the Bjørnøyrenna Crater area with a multicorer and/or the ROV Subfighter 30K (push and blade coring). Sediments were sub-sampled in triplicates with acrylic core liners for methane oxidation and sulfate reduction measurements (Treude et al., 2003). Radioactive tracers, $^{14}CH_4$ (dissolved in water, injection volume 25 µL, activity ~3 kBq) and $^{35}SO_4$ (in water, injection volume 25 µL, activity 115 kBq) were injected in 1 cm intervals through silicon sealed wholes into the sediment. Sediments were then incubated for 36 h day on board at in situ T in the dark. The subcores were then sectioned (the upper 5 cm into 1 cm intervals, the following sediment layers into 2 cm intervals). For fixation and to stop the microbial activity, sediment sections were mixed with 20 mL sodium hydroxide (2.5 % w/w) in 50-mL glass bottles sealed with rubber stoppers (AOM) or 20 mL zinc acetate (20 % w/w) in 50-mL Falcon tubes (SR). Fixed sediment samples were stored at 4°C (AOM) or -20°C (SR) until further processing in our home laboratories.

Microbial community composition and cultivation

For the characterization of the microbial community and their metatranscriptome, sediment samples were collected from multi- or push cores (sampled in 2-cm intervals). The 2-cm slices of sediment were transferred into sterile plastic bags and frozen immediately (-80°C). From these samples DNA and RNA will be extracted in our home laboratories and analyzed by high throughput sequencing.

For quantification of different microbial groups in sediment, 0.5 mL of sediment aliquots (taken from the same intervals as DNA/RNA samples) were fixed with formaldehyde solution (4 %). After 4 h fixation at 4°C in the dark, sediment samples were washed twice with PBS buffer (pH 7.2) and stored in PBS/ethanol (1:1) solution at -20°C. Hybridization and microscopy will be conducted in our home laboratories.

For cultivation and isolation studies of methanotrophic bacteria, sediment from the sediment-water interface (~5 ml) was transferred into 100-mL glass bottles filled with 50 mL sterile filtered seawater, sealed with rubber stoppers, and the headspace was amended with 10 mL CH_4. Incubations of enrichment cultures were started on board at 4°C in the dark.

In addition to our regular sampling (Table 7), we also subsampled a (presumably) thick biofilm from a fracture 3 m deep in GC1048 for identification of potential source organisms. We also collected small gastropods from ROV1123 for identifying and quantifying potential symbionts as well as for compound specific isotope analyses in order to unravel potential trophic links to methane dynamics.

Table 7: Overview of seawater and sediment samples collected during the cruise. Abbreviations: rMOx = aerobic methane oxidation rate, rAOM = anaerobic methane oxidation rate, SRR = sulphate reduction rate, FISH = fluorescence in situ hybridization, CDOM, coloured dissolved organic matter, Cult. = cultivation.

Area	Ship Station	Depth [m]	Lat N [°]	Long E [°]	Sampling device	rMOx	rAOM/ SRR	DNA/ RNA	FISH	CDOM	Cult.
Isfjorden	992	282	78 18.66	15 10.78	CTD	x		x	x	x	
Prins Karls Forland	993	75	78 37.72	10 35.04	CTD	x					
	994	118	78 36.45	10 26.43	CTD	x		x	x	x	
	995	126	78 34.95	10 18.00	CTD	x					
	996	150	78 34.26	10 13.20	CTD	x					
	997	92	78 33.68	10 08.54	CTD	x		x	x	x	
	998	110	78 33.18	10 06.06	CTD	x					
MASOX	1000	386	78 33.364	9 29.460	CTD	x					
	1002	389	78 33.320	9 28.590	CTD	x		x	x	x	
	1004	405	78 33.165	9 26.817	CTD						x
	1009	389	78 33.333	9 28.615	BC	x	x	x	x		
Prins Karls Forland	1011	109	78 29.729	10 24.38	CTD	x					
	1012	114	78 35.91	9 59.05	CTD	x					
	1013	127	78 40.89	9 41.51	CTD	x					
	1014	93	78 73.53	9 58.03	CTD	x		x	x	x	
	1015	90	78 38.85	10 16.83	CTD	x					
	1016	78	78 32.617	10 41.655	CTD	x					x
Outer Bellsund	1022	168	77 31.888	13 10.858	CTD	x		x	x	x	
Outer Hornsund	1023	121	76 53.481	14 37.929	CTD	x		x	x	x	
S-tipp Spitsbergen	1024	85	76 25.596	15 54.407	CTD	x		x	x	x	
Pingo area	1029	381	76 06.398	15 58.151	ROV		x	x	x		
	1030	389	76 06.563	15 54.830	CTD	x					
	1031	383	76 06.468	15 58.152	CTD	x		x	x	x	
	1032	387	76 06.393	15 59.909	CTD	x					
	1033	380	76 06.353	16 02.164	CTD	x		x	x	x	x
	1034	387	76 06.217	16 04.730	CTD	x		x	x	x	
	1037	368	76 07.563	16 00.586	CTD	x					
	1038	379	76 06.885	16 00.163	CTD	x		x	x	x	
	1039	388	76 05.860	15 59.692	CTD	x					
	1040	385	76 05.187	15 59.738	CTD	x					
	1055	378	76 06.395	15 58.081	ROV	x		x			x
	1058	380	76 06.422	15 58.091	CTD	x					x
	1061	377	76 06.413	15 58.097	MC	x	x	x	x		x
	1062	381	76 06.392	15 58.037	MC	x	x	x	x		x
	1063	384	76 06.367	15 57 997	MC	x	x	x	x		
	1064	386	76 06.342	15 58.004	MC	x	x	x	x		x
	1065	386	76 06.315	15 57.981	MC	x	x	x	x		x
	1066	386	76 06.360	15 57.929	CTD	x		x		x	
	1075	385	76 04.541	15 58.369	Grab		x				
Pingo reference	1086	349	75 50 344	16 37.931	CTD	x					
Crater area	1091	337	74 54.324	27 44.508	CTD	x				x	
	1092	336	74 54.506	27 45.206	CTD	x				x	
	1093	335	74 54.368	27 45.515	CTD	x				x	
	1094	337	74 54.745	27 45.633	CTD	x				x	
	1095	351	7454.82698	27 45.750	CTD	x				x	x
	1096	326	74 54.989	27 45.917	CTD	x				x	x
	1097	326	74 55.022	27 46.252	CTD	x				x	
	1098	347	74 55.259	27 46.662	CTD	x				x	x
	1099	336	74 55.495	27 47.119	CTD	x				x	
	1100	336	74 55.726	27 47.470	CTD	x					
	1122	325	74 54.954	27 46.001	CTD	x					
	1123	338	74 54.991	27 45.665	ROV	x	x	x	x		x
	1124	337	74 54.987	27 45.697	ROV	x					x
	1125	338	74 54.986	27 45.694	ROV		x	x	x		
	1128	325	74 55.039	27 45.921	ROV	x					x

7.9.4 High pressure incubations (S. Klasek):

The anaerobic oxidation of methane (AOM) is a globally significant, microbially-mediated process that removes 60-90% of methane from marine sediments before it can reach the water column. To investigate how microbial communities in marine sediments that anaerobically oxidize methane adapt temporally to increases in methane flux, sediments collected from gas seeps will be incubated at *in situ* temperatures and pressures in a timeseries under varying methane concentrations. AOM and sulphate reduction rates will be measured, and changes in microbial communities during incubation will be described. Sediment samples from sulphate-methane transition zones (SMTZs) of gravity and ROV-push cores were collected and preserved anoxically in sterile bags at 4C for incubations. Corresponding sediment samples were also frozen for DNA analysis of *in situ* microbial communities and fixed in 4% formalin for fluorescence in situ hybridization (FISH). To complement incubation-based studies, additional sediment samples were collected and frozen for DNA and RNA analysis of *in situ* microbial communities. All samples collected are listed in Table 8 below, which indicates which analyses each sample was preserved for.

Table 8: Sediment samples taken for high-pressure incubations and complimentary community analyses.

date	site	core	station number	recovery (cm)	depth sampled (cm)	anoxic fresh samples for incubations	FISH	DNA	RNA	notes
6/18/16	Prince Karls Foreland flare	GC	1008	116	105-115	x	x	x		Directly on top of a strong flare. Transi-tion from dark brown to dark gray at 100 cm. Est. SMTZ just below recovery.
6/22/16	Pingo 3 Flare	ROV Push Core	1029	50	10-20	x	x	x		ROV dive 1074. Push core #1 (blue). Very black, sulfidic sediment.
6/22/16	Pingo 3 Flare	ROV Push Core	1029	50	20-30	x	x	x		ROV dive 1074. Push core #1 (blue). Very black, sulfidic sediment.
6/22/16	Pingo 3 Flare	ROV Push Core	1029	50	30-40	x	x	x		ROV dive 1074. Push core #1 (blue). Very black, sulfidic sediment.
6/22/16	Pingo 3 Flare	ROV Push Core	1029	50	40-50	x	x	x		ROV dive 1074. Push core #1 (blue). Very black, sulfidic sediment. Small hydrate chunks (2 cm diameter, 1 cm thick) observed at 45-50 cm.
6/23/16	Pingo area reference	GC	1036		20-35	x	x	x		No sulfide smell, pockets of gas expansion,clams, worms, or anything to suggest methane migration
6/24/16	Pingo 3 South slope	GC	1045	130	3-5			x		Very black sediment.
6/24/16	Pingo 3 South slope	GC	1045	130	23-25			x		Very black sediment.
6/24/16	Pingo 3 South slope	GC	1045	130	43-45			x		Shells in core at 40-80 cm.
6/24/16	Pingo 3 South slope	GC	1045	130	65-67			x		
6/24/16	Pingo 3 South slope	GC	1045	130	75-77			x		Est. SMTZ at 80 cm.
6/24/16	Pingo 3 South slope	GC	1045	130	80-90	x	x	x		Est. SMTZ at 80 cm.
6/24/16	Pingo 3 South slope	GC	1045	130	85-87			x		Est. SMTZ at 80 cm.
6/24/16	Pingo 3 South slope	GC	1045	130	91-100	x	x	x		
6/24/16	Pingo 3 South slope	GC	1045	130	105-115	x		x		
6/24/16	Just west of Pingo 5	GC	1048	335	6-9			x		No sulfide smell. Likely a reference core, did not hit SMTZ.
6/24/16	Just west of Pingo 5	GC	1048	335	20-22			x		
6/24/16	Just west of Pingo 5	GC	1048	335	40-42			x		
6/24/16	Just west of Pingo 5	GC	1048	335	60-62			x		

6/24/16	Just west of Pingo 5	GC	1048	335	80-82			x		
6/24/16	Just west of Pingo 5	GC	1048	335	100-102			x		
6/24/16	Just west of Pingo 5	GC	1048	335	120-122			x		
6/24/16	Just west of Pingo 5	GC	1048	335	140-142			x		
6/24/16	Just west of Pingo 5	GC	1048	335	160-162			x		
6/24/16	Just west of Pingo 5	GC	1048	335	180-182			x		
6/24/16	Just west of Pingo 5	GC	1048	335	200-202			x		
6/24/16	Just west of Pingo 5	GC	1048	335	220-222			x		
6/24/16	Just west of Pingo 5	GC	1048	335	240-242			x		Sand-clay boundary.
6/24/16	Just west of Pingo 5	GC	1048	335	260-262			x		
6/24/16	Just west of Pingo 5	GC	1048	335	280-282			x		
6/24/16	Just west of Pingo 5	GC	1048	335	305			x	x	5 cm diagonal fracture in core containing a macroscopic yellowish biofilm with a snotlike texture. Biofilm separately sampled in 2x 2 ml eppendorf tubes.
6/25/16	Pingo 3 transect-center	MC	1060	35	5-7			x		
6/25/16	Pingo 3 transect-center	MC	1060	35	10-12			x		
6/25/16	Pingo 3 transect-center	MC	1060	35	15-17			x		
6/25/16	Pingo 3 transect-center	MC	1060	35	20-22			x		
6/25/16	Pingo 3 transect-center	MC	1060	35	25-27			x		
6/25/16	Pingo 3 transect-center	MC	1060	35	30-32			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	1-3			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	3-5			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	7-10			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	11-13			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	15-17			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	19-21			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	23-25			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	27-29			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	31-33			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	35-37			x		
6/25/16	Pingo 3 transect- near center	MC	1062	43	39-41			x		Carbonates below 41 cm at bottom of core.
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	2-3			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	5-7			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	9-11			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	13-15			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	17-19			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	21-23			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	25-27			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	29-31			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	33-35			x		
6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	37-39			x		

6/25/16	Pingo 3 transect- mid-slope	MC	1063	45	41-43			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	1-3			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	3-5			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	5-7			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	7-10			x		Reddish iron deposits.
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	10-11			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	13-15			x		Reddish iron deposits.
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	17-19			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	21-23			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	25-27			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	29-31			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	33-35			x		
6/25/16	Pingo 3 transect- outer slope	MC	1064	41	37-39			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	1-3			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	5-7			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	9-11			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	13-15			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	17-19			x		Reddish iron deposits and black coal-like deposits that might be sulfides (?)
6/25/16	Pingo 3 transect- reference	MC	1065	37	21-23			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	25-27			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	29-31			x		
6/25/16	Pingo 3 transect- reference	MC	1065	37	33-35			x		
6/26/16	Pingo 5 North flank	GC	1068	295	20-22			x		Dark gray clayey sediment. Strong sulfidic smell in first 2 m.
6/26/16	Pingo 5 North flank	GC	1068	295	40-42			x		
6/26/16	Pingo 5 North flank	GC	1068	295	60-62			x		Est. SMTZ at 70 cm.
6/26/16	Pingo 5 North flank	GC	1068	295	65-67			x		Est. SMTZ at 70 cm.
6/26/16	Pingo 5 North flank	GC	1068	295	70-72			x		Est. SMTZ at 70 cm. Interesting 5 cm-long sticklike carbonate oriented vertically from 70-75 cm.
6/26/16	Pingo 5 North flank	GC	1068	295	75-77			x		Est. SMTZ at 70 cm. Interesting 5 cm-long sticklike carbonate oriented vertically from 70-75 cm.
6/26/16	Pingo 5 North flank	GC	1068	295	80-82			x		Est. SMTZ at 70 cm.
6/26/16	Pingo 5 North flank	GC	1068	295	103-105			x		
6/26/16	Pingo 5 North flank	GC	1068	295	150-152			x		
6/26/16	Pingo 5 North flank	GC	1068	295	200-202			x		Possible gas pocket at 190 cm.
6/26/16	Pingo 5 North flank	GC	1068	295	226-228			x		Above interface.
6/26/16	Pingo 5 North flank	GC	1068	295	231-233			x		Interface from dark (almost black) breccia with possible small gas bubbles/pockets to smooth gray mud at 232 cm. Smooth, gray mud. Sulfidic when sampled.
6/26/16	Pingo 5 North flank	GC	1068	295	235-237			x		Below interface.
6/26/16	Pingo 5 North flank	GC	1068	295	255-257			x		

6/26/16	Pingo 5 North flank	GC	1068	295	282-284			x		Very sandy, cakey sediment.
6/26/16	Pingo 5 Center pimple	GC	1069	227	20-22			x		Reddish iron deposits at top of core.
6/26/16	Pingo 5 Center pimple	GC	1069	227	40-42			x		
6/26/16	Pingo 5 Center pimple	GC	1069	227	60-62			x		
6/26/16	Pingo 5 Center pimple	GC	1069	227	80-82			x		
6/26/16	Pingo 5 Center pimple	GC	1069	227	90-93			x		Strangely-shaped, 8 cm long black carbonate recovered from 90-95 cm depth. Has little protrusions with holes coming out of them that broke off easily when handled. Est. SMTZ at 100 cm.
6/26/16	Pingo 5 Center pimple	GC	1069	227	91-108	x	x	x		FISH sample taken from 99 cm depth. Est. SMTZ at 100 cm. The sample for incubation does not contain much of 102-104 depths because I had sampled it already
6/26/16	Pingo 5 Center pimple	GC	1069	227	102-104			x		Very black and sulfidic. Est. SMTZ at 100 cm.
6/26/16	Pingo 5 Center pimple	GC	1069	227	108-110			x		Very black and sulfidic.
6/26/16	Pingo 5 Center pimple	GC	1069	227	114-116			x		Very black and sulfidic.
6/26/16	Pingo 5 Center pimple	GC	1069	227	130-132			x		Almost black, breccia-like sediment.
6/26/16	Pingo 5 Center pimple	GC	1069	227	150-152			x		Almost black, breccia-like sediment.
6/26/16	Pingo 5 Center pimple	GC	1069	227	175-177			x		Almost black, breccia-like sediment.
6/26/16	Pingo 5 Center pimple	GC	1069	227	200-202			x		Almost black, breccia-like sediment.
6/26/16	Pingo 5 SW ridge	GC	1070	326	11-13			x		Surface sediments are sandy and black.
6/26/16	Pingo 5 SW ridge	GC	1070	326	21-23			x		
6/26/16	Pingo 5 SW ridge	GC	1070	326	31-33			x		
6/26/16	Pingo 5 SW ridge	GC	1070	326	41-43			x		Sulfide smell begins below 40 cm.
6/26/16	Pingo 5 SW ridge	GC	1070	326	51-53			x		
6/26/16	Pingo 5 SW ridge	GC	1070	326	55-57			x	x	
6/26/16	Pingo 5 SW ridge	GC	1070	326	61-62			x	x	Yellowish snotlike biofilm embedded in sediment at 60 cm. No fracture or other feature present. Est. SMTZ <70 cm.
6/26/16	Pingo 5 SW ridge	GC	1070	326	62-64			x	x	Yellowish snotlike biofilm embedded in sediment at 63 cm. No fracture or other feature present. Biofilm sampled and frozen in a 2 ml eppendorf tube. Est. SMTZ < 70 cm.
6/26/16	Pingo 5 SW ridge	GC	1070	326	67-69			x	x	Very small clear-to-yellow biofilm at 68 cm. No fracture or other feature present. Biofilm sampled and frozen in a 2 ml eppendorf tube. Est. SMTZ < 70 cm.
6/26/16	Pingo 5 SW ridge	GC	1070	326	71-73			x	x	Est. SMTZ < 70 cm.
6/26/16	Pingo 5 SW ridge	GC	1070	326	81-83			x		
6/26/16	Pingo 5 SW ridge	GC	1070	326	100-102			x		
6/26/16	Pingo 5 SW ridge	GC	1070	326	150-152			x		Very sulfidic around 160 cm.
6/26/16	Pingo 5 SW ridge	GC	1070	326	200-202			x		Sediment becomes dry, cakey, and more breccia-like below 190 cm.
6/26/16	Pingo 5 SW ridge	GC	1070	326	250-252			x		
6/26/16	Pingo 5 SW ridge	GC	1070	326	310-312			x		
6/27/16	Pingo 4 flare	GC	1081	102	22-24			x	x	Sampled very quickly (from deck to -80 In < 30 min).
6/27/16	Pingo 4 flare	GC	1081	102	48-50			x	x	Sampled very quickly (from deck to -80 in < 30 min).
6/27/16	Pingo 4 flare	GC	1081	102	55-58			x	x	Sampled very quickly (from deck to -80 in < 30 min). Gas pocket at 60 cm.
6/27/16	Pingo 4 flare	GC	1081	102	68-70			x	x	Sampled very quickly (from deck to -

										80 in < 30 min).
6/27/16	Pingo 4 flare	GC	1081	102	85-87			x	x	Sampled very quickly (from deck to -80 in < 30 min).
6/27/16	Outside Pingo area	GC	1082	48	10-12			x		Large carbonate caught by core catcher. Dropped most of the core (15 cm to end) on deck. Oops.
6/30/16	Outside snail patch, Yin Yang crater	ROV Push Core	1124	16	2-4			x	x	
6/30/16	Outside snail patch, Yin Yang crater	ROV Push Core	1124	16	6-8			x	x	
6/30/16	Outside snail patch, Yin Yang crater	ROV Push Core	1124	16	10-12			x	x	sulfidic sediments
6/30/16	Outside snail patch, Yin Yang crater	ROV Push Core	1124	16	14-16			x	x	rocky sediments towards bottom of core
7/1/16	Sponge sample scraped from shale slab	ROV claw grab	1130	N/A	0			x		
7/1/16	Raised feature SW of Yin Yang crater	BC	1133	22	0-2			x	x	rocky sediments
7/1/16	Raised feature SW of Yin Yang crater	BC	1133	22	2-4			x	x	rocky sediments
7/1/16	Raised feature SW of Yin Yang crater	BC	1133	22	6-8			x	x	
7/1/16	Raised feature SW of Yin Yang crater	BC	1133	22	10-12			x	x	
7/1/16	Raised feature SW of Yin Yang crater	BC	1133	22	14-16			x	x	
7/1/16	Raised feature SW of Yin Yang crater	BC	1133	22	18-20			x	x	sulfidic sediments

7.10 Biomarkers (H. Yao)

Foraminifera and Lipid Biomarker

The $\delta^{13}C$ of foraminifera provides both paleoceanographic and diagenetic information while δ18O provides environmental information in the past (e.g., water temperature and ice volume, Shackleton, 1987). Foraminifera in the surface and bottom seawater precipitate their shells from the DIC in the ocean and therefore inherit the isotopic signature from the ocean DIC pool. In this way, the variabilities of $\delta^{13}C$ from foraminifera shells suggest the fluctuation of ocean DIC $\delta^{13}C$.

Biomarkers are organic molecules carry information that incorporates microbial processes over a long period of time. Membrane lipids, due to its resistance to degradation, are the most important source of biomarker used to track its biological origin. To identify the AOM (Anaerobic Oxidation of Methane) communities, molecular techniques such as 16SrDNA clone libraries and fluorescence in situ hybridization (FISH) can achieve the goal. Investigation of lipid biomarker on the other hand can not only identify the microbial domain but also the carbon flow within such consortia by analyzing carbon isotope of the specific membrane lipids. Lipid biomarker in combination with foraminifera isotopic investigation can be used to reconstruction of the past methane emission events.

Another application of biomarker is the discovery of molecule IP_{25} (Ice Proxy with 25 carbon atoms), a mono-unsaturated HBI (Highly Branched Isoprenoid). IP_{25} is biosynthesized selectively by some Arctic sea diatoms. Studies have shown a positive correlation between the concentration of IP_{25} and satellite-derived

mean sea ice concentration in the Arctic area. Coupling the information from IP_{25} and other biomarkers can reveal more on the sea ice conditions to reconstruct paleo sea ice in the Arctic area.

Natural Products from bacteria and fungi

Natural products, or compounds isolated from biological sources, account for the vast majority of current pharmaceuticals. Many of these pharmaceuticals produced revolutionary medical advances at the time of their discovery, such as the antibiotics penicillin (isolated from Penicillium fungi) and tetracycline (isolated from Streptomyces). There are many chemically and biologically interesting compounds produced by under-explored microorganisms such as endophytic fungi and rare actinomyctes still awaiting discovery. The collaboration with Sandra Loesgen's lab (Oregon State University) is to aim at isolating bacteria and fungi from the Arctic Ocean sediment and water samples. And explore their chemistry for small molecules/natural products that are useful for human health applications: anti-cancer, antibacterial and anti-viral. Samples taken from CAGE 16-5 cruise will be used as a trial to start.

Sampling List:

Table 9: Sediment samples

Station Number	Sample Purpose	Resolution	Number of samples	Note
GC 1008	Lipid biomarker	5cm	22	
BC 1009	Natural Product	at surface	2	bag 1,2
ROV 1029	Lipid biomarker	2cm	22	blue push core
GC 1036	Foraminifera	5cm	55	
	Lipid biomarker	5cm, 10cm	40	
	IP25	5cm	55	
	Natural Product	at 1cm	2	bag 3,4
GC 1045	Lipid biomarker	10cm	13	
	Natural Product	at 1cm	2	bag 5,6
GC 1048	Lipid biomarker	5cm	61	
	Foraminifera	5cm	61	
GC 1049	Natural Product	at 1cm	2	bag 7,8
GC 1051	Natural Product	at 1cm	2	bag 9,10
	Lipid Biomarker	3cm	7	
Grab 1054	Natural Product	at surface	2	bag 11,12
MC 1058	Natural Product	at 3cm	2	bag 13,14
MC 1059	Natural Product	at 3cm	2	bag 15,16
MC 1061	Natural Product	at surface	2	bag 17,18

MC 1062	Natural Product	at surface	2	bag 19, 20
MC 1063	Natural Product	at surface	2	bag 21,22
MC 1064	Natural Product	at surface	2	bag 23,24
MC 1065	Natural Product	at surface	2	bag 25,26
GC 1068	Lipid Biomarker	10cm	29	
	Foraminifera	10cm	29	
GC 1069	Natural Product	at 3cm	2	bag 27,28
	Lipid Biomarker	10cm	22	
	Foraminifera	10cm	22	
GC 1070	Natural Product	at surface	2	bag 29,30
	Lipid Biomarker	10cm	33	
	Foraminifera	5cm	64	
GC 1081	Natural Product	at 3cm	2	bag 31,32
	Lipid Biomarker	10cm	10	
	Foraminifera	10cm	10	
GC 1082	Natural Product	at 3cm	2	bag 33,34
	Lipid Biomarker	10cm	4	
	Foraminifera	10cm	4	
ROV 1124	Lipid Biomarker	2cm	8	push core 1
	Natural Product	at surface	2	bag 35,36
ROV 1125	Natural Product	at 4cm	2	bag 37,38
BC 1131		whole core		
BC 1132		stored		
BC 1133				

Samples (foraminifera, lipid biomarker, IP_{25}) from GHP will be used for reconstruction of paleoenvironment in pingo area. Lipid biomarker samples are kept frozen immediately after sampling, foraminifera samples kept at 4 °C.

Table 10: Water samples for natural products extraction:

Station Number	Bottle Number	Depth (m)	Note
CTD 998	1	90	falcon tube 1,2
CTD 999	1	362.2	3,4
	10	25.1	5,6
CTD 1002	1	390	7,8

	12	4.2	9,10
CTD 1030	1	387	11,12
	12	1.3	13,14
CTD 1031	1	388.6	15,16
	12	5.3	17,18
Grab 1054		surface water	19,20
CTD 1085	1	349	21,22
	7	14	23,24
CTD 1093	1	335	25,26
	12		27,28
CTD 1109	1	339	29,30
	5	152	31,32

Samples will be analysed by Sandra Loesgen (OSU, Chemistry) for natural product/small molecules extractions. Samples for this purpose have taken duplicate, odd number samples are treated with 3-4 mL of filtered 50% glycerol, even number samples are kept frozen immediately.

Table 11: Carbonate samples

Station Number	Depth (cm)
GC 1051	14-17
	17-18
	25-26
	24-28
GC 1068	31-33
	121-129
	140-144
GC 1069	47-49
	53-58
	90-95
GC 1070	27-29
GC 1082	50
ROV 1029	sea floor
ROV 1077	sea floor

Carbonates collected are kept frozen, will be used for isotopic investigation and biomarkers analyses.

7.11 Sediment Geochemistry (W.-L. Hong)

Scientific objectives

The primary purpose of the porewater and sediment geochemistry program is to understand the fluid systems beneath the Storfjordrenna gas hydrate pingos and Bjørnoyrenna crater area. Sediments samples were also taken to quantify the different sulfur mineral species in the sediments.

Sample statistics and method

A total of 162 pore water samples were collected from 3 ROV push cores, 5 multicores, 9 gravity cores, and 3 box cores/grabs using 10 and 5 cm rhizons, previously soaked in distilled water. Fluids from gravity cores were extracted in a 4C refrigerated room, multicores and push cores were processed on deck, temperature ~6C. Most samples yield >10 ml of water, with a few ranging from 1 to 5 ml, which was collected in 20 ml acid washed syringes and subsequently filtered through 0.2 μm cellulose acetate in-line filters. Fluids were analyzed onboard for alkalinity and dissolved Fe^{2+} and subsampled as shown in Figure 20. Preliminary results of alkalinity and Fe^{2+} concentrations were shown in Figure 21. Photos and description of the gravity cores taken were summarized in Table 12.

Preliminary results

We can propose the depths of sulfate-methane-transition-zone (SMTZ) based on the results of onboard alkalinity titration, which were marked in Figure 2. These depths were determined at the depth where the highest alkalinity was measured. This is usually clear from the profile except for push core 1029. For this core, alkalinity slightly decreases between the depths of 15 and 21 cmbsf and increases again below 21 cmbsf. This may be due to the potential non-steady state condition of the fluid system around the seep which is evidential from the concave-up shape of the profile. For all the gravity cores we recovered from pingo#3 and #5, the depths of SMTZ are between 50 and 100 cmbsf, consistent with our previous observations. The only gravity core from pingo#3 show similar non-steady state alkalinity porewater profile as we observed from the other 3 gravity cores recovered during the two 2015 cruises. For the three gravity cores from pingo#5 which we were able to recover the whole sulfate reduction zone, no similar non-steady state profiles were observed. Based on such comparison, we can conclude the different methane supply and dynamics between the two pingos.

Results of on the onboard ferrous iron analyses can be used to indicate the strength of sulphide flux in the sediments. For sites with only slow sulfate turnover, such as GC1036, porewater is enriched of ferrous iron as only very few sulphide is present to react with iron. For sites with higher sulfate turnover rate, such as the push core 1029, ferrous iron depleted below 7 cmbsf indicating strong sulphide flux below such depth.

Table 12: Summary of the cores taken for sediment and porewater geochemistry

	Gravity cores	Multicores	ROV push cores/blade cores	Box cores/ Van Veen Grab
Prins Karls Forland	GC1008			
Storfjordrenna gas hydrate pingos	GC1036 (reference core) GC1045 (pingo#3) GC1048 (pingo #5) GC1051 (pingo #5) GC1068 (pingo #5) GC1069 (pingo #5) GC1070 (pigo#5) GC1081 (pingo#5)	MC1061 MC1062 MC1063 MC1064 MC1065 (pingo#3)	1029 (pingo#3)	
Bjørnoyrenna crater area			1123 1124	1120 1125 1133

Table 13: Summary of samples taken from each core

	Bottom water samples	Porewater samples	Sediment S samples	Sediment fungi samples
1008	1	10		
1029	1	14	22 (every 2cm)	1
1036		12		
1045		7		
1048		23		
1051		2		

1061		3		
1062	1	3		
1063	1	8		
1064	1	7		
1065		2		
1068		11		
1069		7		
1070		9		
1081		8		
1120	1	3		
1123	3	8	16 (every 2cm)	1
1124		6	12 (every 2cm)	
1125		2		1
1133		8		

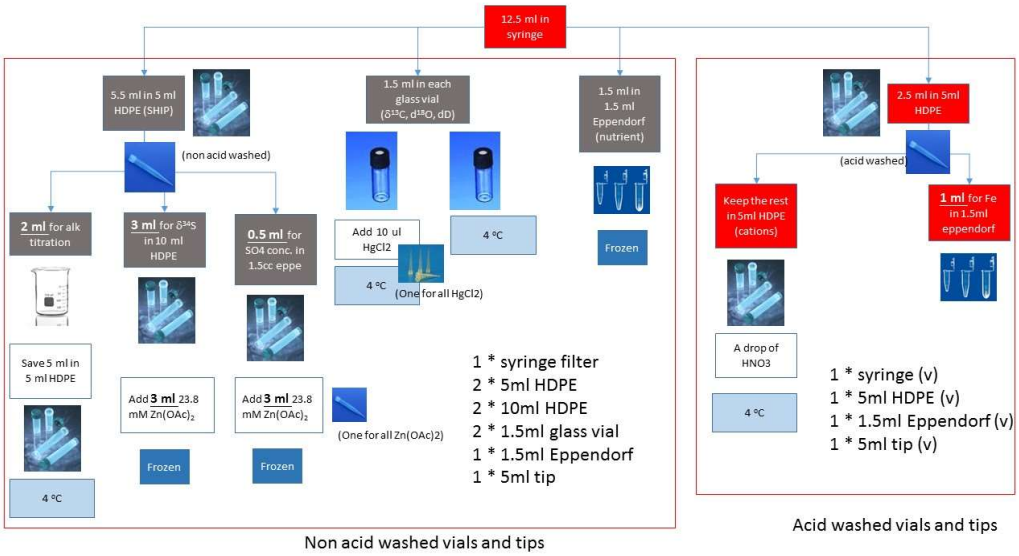
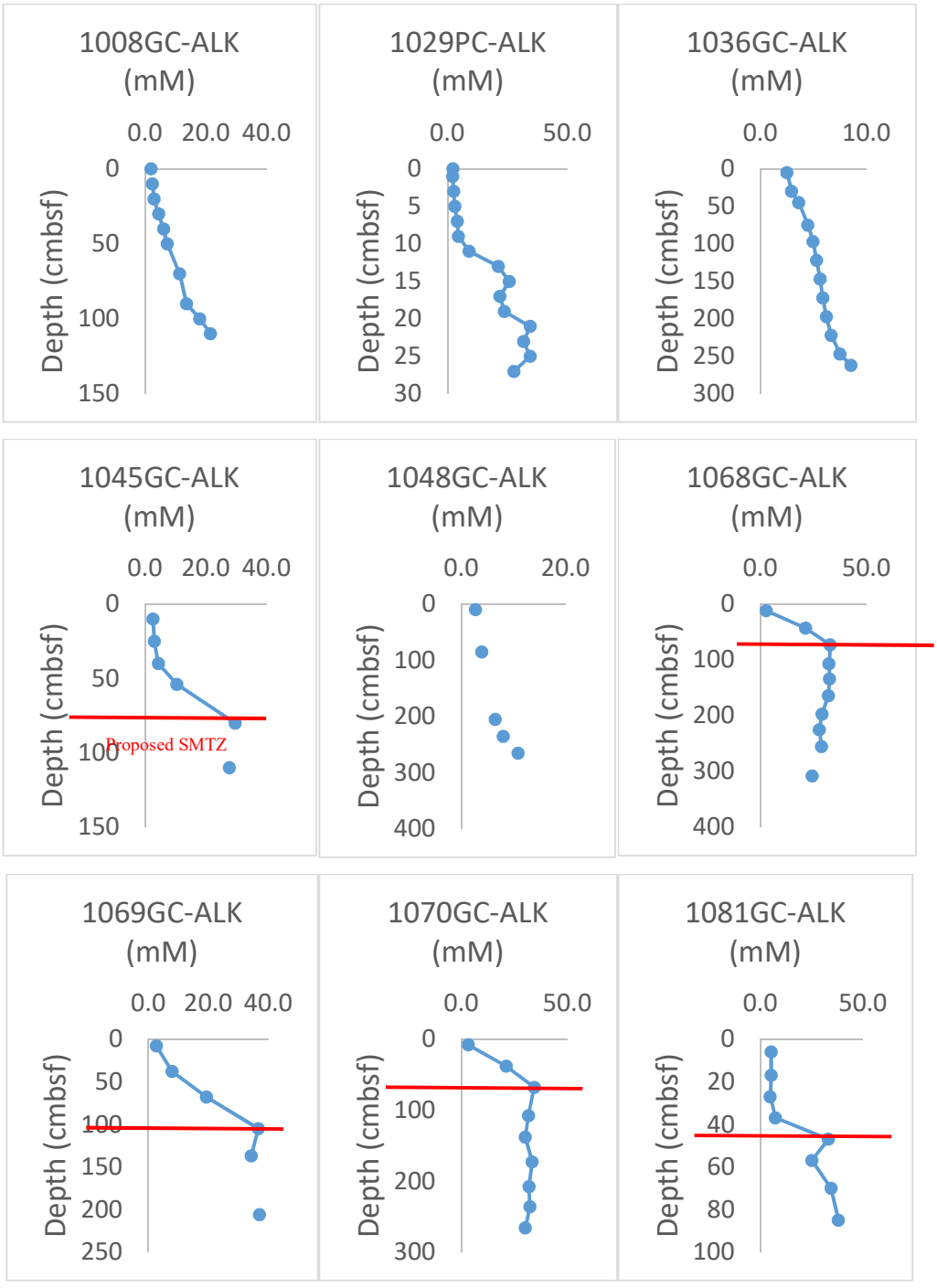
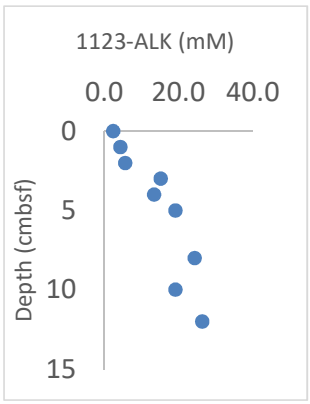
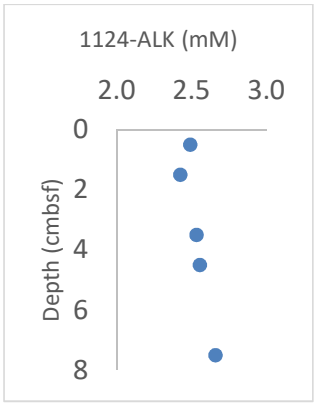


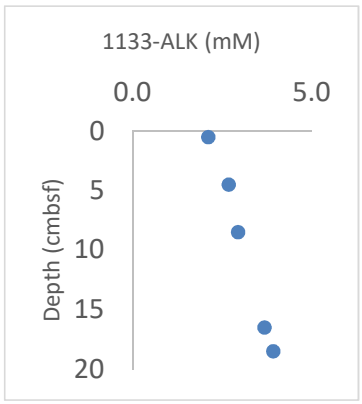
Figure 20: Flow chart for porewater subsampling

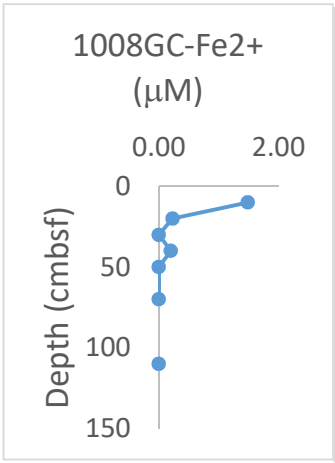
Figure 21: Results of on-board Fe^{2+} measurements

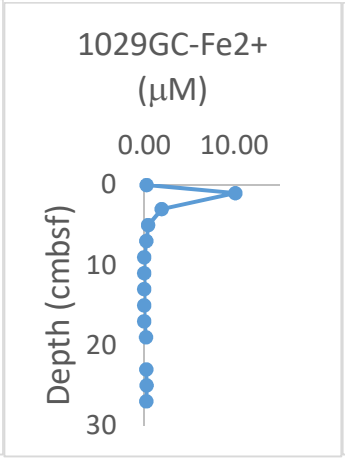


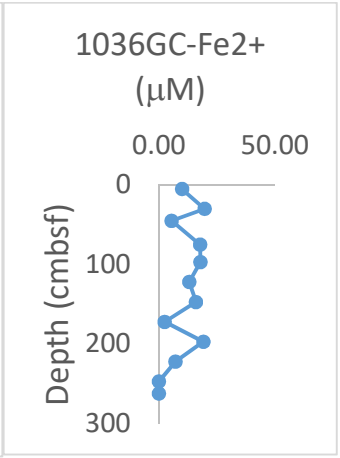

1123-ALK (mM)
0.0
20.0
40.0
Depth (cmbsf)
0
5
10
15

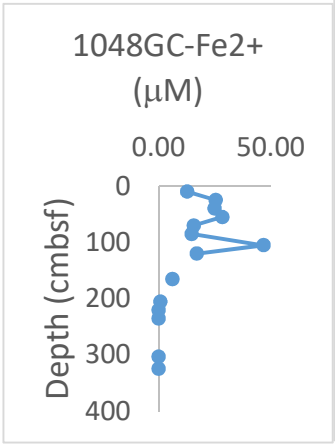

1124-ALK (mM)
2.0
2.5
3.0
Depth (cmbsf)
0
2
4
6
8

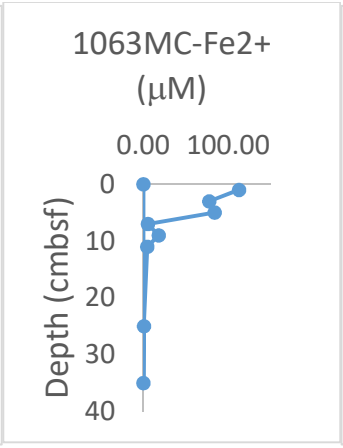

1133-ALK (mM)
0.0
5.0
Depth (cmbsf)
0
5
10
15
20

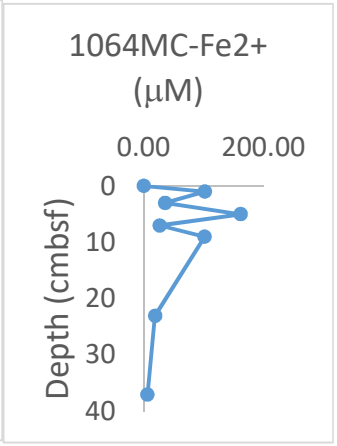

1008GC-Fe2+ (µM)
0.00
2.00
Depth (cmbsf)
0
50
100
150

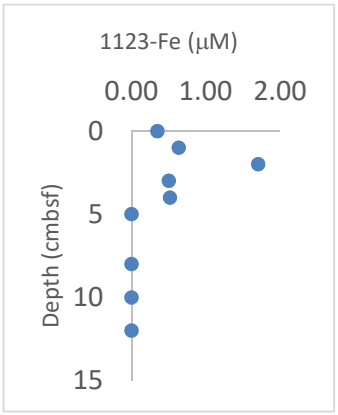

1029GC-Fe2+ (µM)
0.00
10.00
Depth (cmbsf)
0
10
20
30

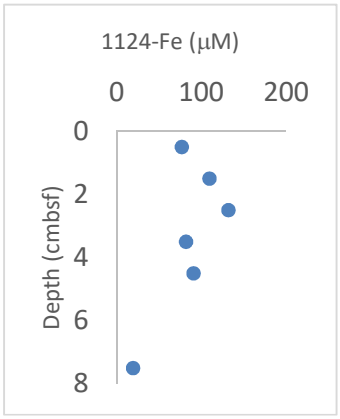

1036GC-Fe2+ (µM)
0.00
50.00
Depth (cmbsf)
0
100
200
300

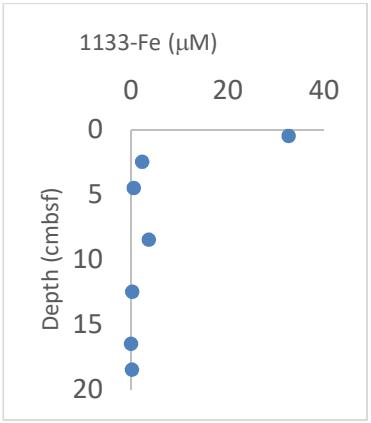

1048GC-Fe2+ (µM)
0.00
50.00
Depth (cmbsf)
0
100
200
300
400


1063MC-Fe2+ (µM)
0.00
100.00
Depth (cmbsf)
0
10
20
30
40


1064MC-Fe2+ (µM)
0.00
200.00
Depth (cmbsf)
0
10
20
30
40


1123-Fe (µM)
0.00
1.00
2.00
Depth (cmbsf)
0
5
10
15


1124-Fe (µM)
0
100
200
Depth (cmbsf)
0
2
4
6
8


1133-Fe (µM)
0
20
40
Depth (cmbsf)
0
5
10
15
20

7.12 Benthic Foraminifera (K. Melaniuk)

7.12.1 Sample collection for micropaleontology:

Surface sediments for analysis of distribution of living foraminifera from seep environments were collected from 3 investigated areas: Prins Karls Forland, Storfjordrenna Pingo, Crater area. In all stations methane emission from seafloor was observed. In order to obtain broad range of samples 4 sampling methods were used: Van Veen Grab, Box core, Multicore, and Blade core, the last one was taken during ROV diving.
In order to distinguish between living and dead foraminifera (empty shells) two staining methods were used: staining in Rose Bengal and labelling with CellHunt Green, all samples were preserved in formalin. In addition, from same of the station sediment samples for pore water and fluorescence *in situ* hybridization (FISH) analysis were taken. Samples for pore water and FISH were collected and proceed in collaboration with Wei-Li Hong and Friederike Gründger. All samples are listed in Table 14.

Table 14:Samples collected for living foraminifera

Station ID: CAGE 16-5		0-1cm		1-2cm	2-3cm				Sampling methods	Investigated area
	CHG	RB	CHG	RB	CHG	RB	PW	FISH		
100	x	x	-	-	-	-	-	-	box core	Prins Karls Forland
ROV 1029	x	x	-	-	-	-	-	-	blade core	Storfjordrenna Pingos
1054	x	x	x	x	-	x	-	-	grab #1	Storfjordrenna Pingos
1054	x	x	x	x	-	x	x	-	grab #6	Storfjordrenna Pingos
	x	x	x	x	-	x	x	-		Storfjordrenna Pingos
	x	x	x	x	-	x	x	-		Storfjordrenna Pingos
1059	x	x	x	x	-	x	x	x	multicore	Storfjordrenna Pingos
1060	x	x	x	x	-	x	x	x	multicore	Storfjordrenna Pingos
1062	x	x	x	x	-	x	x	x	multicore	Storfjordrenna Pingos
1063	x	x	x	x	-	x	x	x	multicore	Storfjordrenna Pingos
1064	x	x	x	x	-	x	x	x	multicore	Storfjordrenna Pingos
1065	x	x	x	x	-	x	x	x	multicore	Storfjordrenna Pingos
ROV1123	x	x	-	x	-	-	-	-	blade core 1	Crater area
ROV 1123	x	x	-	-	-	-	-	-	blade core 2	Crater area

7.12.2 Staining preparation:

CellHunt Green (CHG)

The CHG reagent solution was prepared in advance as follow: 1.4. ml od DMSO (not anhydrous) was added to 1mg of CellHunt Green (solid, stored in freeze at -20C) in a plastic vial as it came from the supplier. The CHG soltution was removed from the freezer, thawed approx. 30minutes before dissolving it, and shook it to dissolved. The CHG-DMSO mixture were added to sediment- filtered sea water samples in proportion 6µl to 10ml sample. It was mixted and stored on HPDE bottel (250ml), in cooling room in 4C. After incubation time approximatly 12h, 10ml of formaline (36%) was added. All activites were done under fume hood.

Rose Bengal (RB)

Rose Bengal were dissolved in filtered sea water approximatly 30minutes before sampling. RB mixture was added to sample, shook gently, and store in the cooling room in temerature 4C.

Pore water sampling for DIC measurements

In order to obtain porwater for DIC measurments, 3 Eppendorf vials (1.5ml) were filled with sediment from approximatly 4cm depth below surface, and centrifuged at 13,400 rpm for 2min. Pore water was filtered thought 0.2µm cellulose- acetate filters next 10 µlHgCl was added, mixture was added to 2 ml glass vials and stored in cooling room at 4C.

7.13 Planktic Foraminfera (J. Meilland, S. Ofstad)

7.13.1 Plankton net

Plankton net samples were collected using a Multinet (multi stratified plankton tow Hydrobios, type Midi) equipped with five nets (63µm mesh size).

Three stations were sampled at Prins Karls Forland, two of which have been previously sampled earlier this year. At the Pingo Site in Storfjordrenna Trough we sampled four stations, and re-sampled one station in Storfjorden grounding wedge on the transit to the Crater Area. We sampled eight stations in the Crater Area along a transect from east to west. The eight stations were last visited in April during CAGE 16-2 including four that were sampled at the exact same period in 2015.

At each collected station five depth intervals had been sampled in one dive, dividing the water column into the following depths intervals: 300-200m, 200-150m, 150-100m, 100-50m and 50-surface (crater area); 350-

250m, 250-150m, 150-100m, 100-50m and 50-surface (Prins Karls Forland and Pingo Site). The two deepest depth intervals varied slightly between the three sites due to depth variations.
The contents of each cast were sieved through 63 m sieves and placed in separate bottles, resulting in 80 bottles in total. Samples were preserved in absolute (99%) ethanol solution and buffered with Hexamethylenetetramine. Calcifying organisms including planktonic foraminifera, pteropods and bivalves will be studied from the collected samples. A particular interest will be given to their shell structure ($CaCO_3$) with regard to the ocean chemistry (DIC, CH_4 concentration, pH), with particular regard to ocean acidification. The small mesh size and coverage of the entire water column allows the analyses of other zooplankton groups (e.g. copepods, dinoflagellates, cladocerans), which provide additional information about water mass dynamics at Prins Karls Forland, Storfjordrenna Pingo Site, and Barents Sea Crater Area.

7.13.2 CTD

Water samples were collected from the CTD at two of the three plankton net stations at Prins Karls Forland. In Storfjorden water was collected from the CTD at all five plankton net stations, in addition to bottom water from a bladecore collected by the ROV. In the Barents Sea Crater Area, water was also collected from the CTD at all plankton net stations, in addition to three bottom water samples taken from three separate ROV dives. Nine water depths at the plankton net stations were sampled: bottom, 300m, 250m, 200m, 150m, 100m, 50m, 25m, and 5m. Sampling depths varied slightly between the three sites due to depth variations. Two drops of saturated mercury chloride were added to the samples to cease all biological activity. In total 135 bottles of water were collected. The water samples will be analysed for DIC, carbonate system parameters and pH.

7.13.3 Sediment

Surface sediment samples (upper 1 to 2 cm) were collected from Prins Karls Forland and Barents Sea Crater Area. At Prins Karls Forland the sediment was taken from a box core at station 1009, and a blade core from ROV station 1029. At the Crater Area a surface sediment sample was taken from a blade core from ROV station 1123. The samples are preserved using absolute (99%) ethanol solution and Rosa Bengal. At the Storfjordrenna Pingo Site we acquired a sediment core from the multicore at station 1059.
These samples will be sieved and analysed for planktonic foraminifera. It is important that we get a full picture of what is happening in the water column with regard to the planktonic foraminifera community, including after their lifecycle comes to an end. Planktonic foraminifera found in the surface sediment will be used to establish the flux of organisms from water column to seafloor. Fossilized planktonic foraminifera will be used for carbonate system reconstructions, as an attempt to quantify ocean acidification.

7.14 Photomosaic and habitat mapping (A. Sen)

Background and Goals:

Georeferenced, spatially explicit photomosaics can be used to characterize and map seafloor habitats fairly quickly and non-invasively. Though some of the study sites visited during this cruise have been studied for quite some time, images of the seabed are not particularly abundant. The use of an ROV makes it possible to target very specific locations on the seafloor for image and video surveys which can then be used within Geographic Information Systems to map the distribution of fauna and substrates. This information can then be used to study spatial relationships between animal groups and physical features or environmental characteristics, as well as associations between different types of species. In short, detailed analyses of community structure can be conducted with the use of photomosaics associated with navigation data. Often, in benthic communities, this type of research is typically conducted with downward facing cameras with the caveat and limitation that 3D structures are flattened out to two dimensions. However, the ROV for this cruise was equipped with two, overlapping stereo cameras, separated by about 40 cm in liner distance from each other, set at a 35 degree vertical tilt, which will make it possible to construct both 2 and 3D mosaics of the study sites and features of interest, particularly in locations where large structures rise above the seafloor, such as in the Yin-Yang crater-pingo complex. In addition to using the ROV's camera system for studying community structure through photomosaics, another goal was to use the system to image areas where sampling had been conducted. For example, all of the ship based sampling efforts, such as those through the use of box cores, gravity cores or multi cores, take place blindly. However, by guiding the ROV to locations where such sampling has taken place, it is possible to collect images of the sampling sites and get a record of the in situ conditions.

While a single snapshot of target sites is extremely useful in understanding and mapping features and fauna and obtaining an overview of local conditions at sampling stations, the beauty of the method lies in its repeatability. Precise navigation in conjunction with the deployment of physical markers on the seafloor makes it possible to return to the same specific mosaic site a later date, which means that temporal trends and community successional sequences can be studied. Therefore, another goal of the photomosaic component of this cruise was to establish a number of very specific areas as long term study sites, in order to study how the seafloor changes (both in terms of fauna and substrate) within Arctic seeps over time.

CAGE16-5 photomosaics:

Due to navigational issues and strong currents, fewer photographic surveys for photomosaics could be conducted than intended. At GHP 3, mosaic surveys in the true sense (overlapping images, lines in lawn mower fashion, with overlap between lines) could not be carried out at all, despite many attempts.

Therefore, photo transects were conducted instead. In total, 3 transects with 3-4 lines each were conducted. Both the navigation and the currents were more favourable during the imagery dive on GHP 5, therefore, image surveys for 3 mosaics were conducted there. Three mosaic surveys were also carried out at the pingo of the YinYang Pingo-Crater complex. However, two of these surveys were literally clouded over due to the presence of a large school of cod fish whose movement constantly stirred up sediment off the seafloor. Image surveys for mosaicking were attempted within the crater portion of the YinYang Pingo-Crater complex as well, but the same problem recurred. Subsequently, features that stood out on the multibeam map of the crater were visited and passes were made over and around the features, as opposed to conducting a typical mosaic based image survey.

Images obtained through the surveys will be blended together to produce seamless mosaics with a mosaic script for Matlab (courtesy Woods Hole Oceanographic Information Center), Matisse v3 (courtesy Aurelien Arnaubec, IFREMER Toulon) and AgiSoft's PhotoScan software, depending on the type of mosaic and images (2D/3D, good associated navigation, bad, associated navigation, etc). All visible fauna and habitat types will be marked and outlined within a GIS and community analyses will be conducted in PRIMER. Due to a suite of problems (navigation, currents, physical limitations of the ROV arm and ability to carry down markers), the mosaic sites were not marked specifically on the seafloor, therefore, returning to the locations for temporal studies might prove challenging. However, since cold seeps in general change very slowly, based on the images and visible structures, it is likely that mosaic sites will be possible to pinpoint again in the future and therefore, the prospect of conducting a time series analysis of the study sites still exists.

7.15 Benthic faunal ecology

7.15.1 Methane-fuelled trophic interactions and macrofauna associated to seep features (E. Åström)

Goal:

Collect fauna directly from seep-associated structures as microbial mats, sediment with bubbles, carbonate crust, i.e. bivalves, polychaetes, echinoderms, and cnidarians but also, if possible, crustaceans for food-web and tropic niches analysis. In addition, collect quantitative (density) and qualitative samples (fauna) for ecological community characterization outside and inside seep characteristic features; this includes biogeochemical variables as CH_4 concentration and sediment characteristics.

Background:

Stable isotopes are useful for constructing food web analysis and trophic interactions within benthic communities and for detecting the origin of digested carbon. In addition to $\delta^{13}C$, we can use stable isotope $\delta^{15}N$. Generally, ^{15}N is enriched by 3-4 % for each trophic level in the food chain, indicating the diet of an organism. Combining these tools, determining trophic interactions is possible.

By collecting organisms located in seep features, with aid of visual guidance from the ROV, we can ensure that these specimens are collected (and presumably affected) by seepage. Comparing with organisms not allocated close to seep activity, we can determine the influence of methane derived carbon and differences in trophic niches. The ROV also greatly enhances the capabilities of making small-scale density surveys of seep associated macrofauna in the sediment by placing tube-cores in seep-characteristic target areas.
Based on a real-time review of available photos and video from ROV dives, we can identify sites suitable for sampling, i.e. over a small depression, bubble stream, microbial mat, worm tuft mat or carbonate crust outcrop.

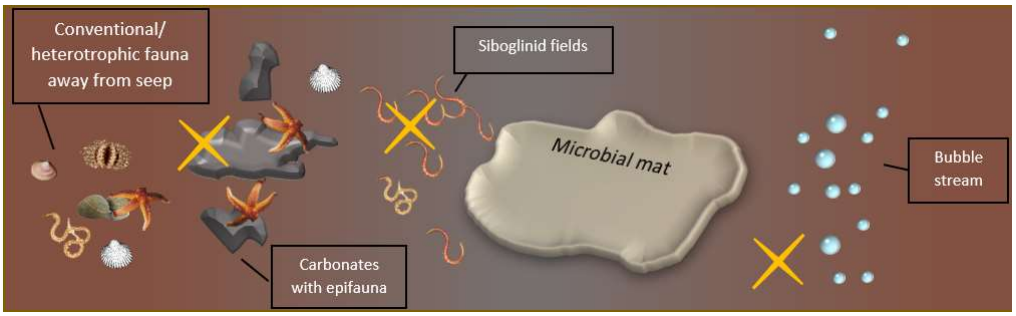


Figure 22: Sampling at "Big gas flare" at GHP 3 with the ROV. Biogeochemistry close to flare base. Quantitative fauna at Siboglinidae worm field. Carbonates sampled with ROV.

Analysis:

$\delta^{13}C$ and ^{15}N organisms will be kept frozen (-18° or lower). Dissecting specimens for endosymbiont extraction. Sieving carefully sediments for collecting retaining fauna (0.5 mm sieve). Keep organisms for reference collection (unusual specimens) in formaldehyde, others in ethanol (80%).

Expected results:

The combined result of small-scale sampling (quantitative and qualitative) will provide a unique view of an Arctic benthic seep system in detail. Both conventional and seep associated fauna can be studied from specific sites, which is impossible without visual guidance. The expected results will be the first ones of this kind (detailed and trophic interactions) from a high Arctic seep (known by todays date).
Quantitative faunal samples will be used to determine community structure analysis of the cold seep habitat at the gas Hydrate Pingos. This data together with environmental variables including CH4 measurements from sediment and water, TOC/grain size, chlorophyll a and benthic pigments, chlorophyll from water column combined with CTD-data will give an overview of the faunal composition at GHP 3 in comparison with control station further south of GHP. At crater area, Bjørnøyrenna, samples will be used in comparison with previous sampled material from 2014 and 2015. A summary of samples collected during this cruise for benthic faunal analysis is presented in Table 15.

Table 15: Summary of benthic faunal analyses.

Xg = from grab

Xc = from core

	CAGE_16-5	Boxcore	Bladecore	Grab	Muc	Muc	CTD	Grab control	CTD control	BR flare field	CTD	
		PKF390	GHP3_1029	GHP3:1054	GHP3:1061	GHP3:1063	GHP:1058	1075	1076	1120	1119	1133
Samples												
Benthic Fauna	*Quantitative Macrofauna, 0.5mm*	XBC	Xblc	X				X		X		X
Stable Isotopes	*sediment*			X	X	X		X		X		X
Stable Isotopes	*benthos*	X	X	X			$X_{flourmtery}$	X	X	X	X	X
Sediment Characteristics	*porosity*	X	X	X_{pasha}				X_{FG}		X_{Pasha}		X_{Pasha}
	chl/pigments surface sed	X	X	X			$X_{watercolumn}$	X	X	X		X
	grain size	X	X_{ngu}	X				X_{EA}		X		X
	TOC/PON	X	X_{ngu}	X_{EA}				X_{EA}		x		X
	CH_4		X_{pasha}	X_{pasha}				X_{FG}		X_{pasha}		X_{Pasha}

7.15.2 Siboglinid Biology (A. Sen)

Background and Goals: Prior benthic samples and images taken from the Pingo site and the Crater site revealed the presence of extremely dense patches of siboglinid worms. A characteristic feature of siboglinid worms is their lack of digestive system, mouth and anus, and subsequent lack of feeding activities. Instead, these worms host chemoautotrophic bacterial symbionts in a specialized organ located within the trunk of their bodies. The worms obtain the bulk of their nutrition from the sugars produced by their bacterial symbionts. Certain groups of sibiglinids have been studied quite extensively, such as the vestimentiferan worms that are very prominent at hydrothermal vents and cold seeps around the world. The worms found at our study sites are likely frenulate or monoliferan worms, which specialize in living in soft sediment, such as what is found at seepage areas within our study. Unfortunately, frenulates and monoliferans have not received the kind of attention rained on vestimentiferans, and the literature related to these animals is extremely scarce. However, they form the major and only, chemosynthesis based animal community at our Arctic seep study sites. Therefore, these siboglinids are an extremely important link between microbial, chemosynthesis processes and heterotrophic fauna, despite next to nothing being known about them.

A goal of the benthic study segment of this cruise was to collect siboglinid worms from the Pingo and Crater study sites, in order to investigate their biology and geochemical ties further. Collections will be used with information and results from other aspects of this cruise to really delve into the worms, their habitats and ecosystem functioning. For example, the photomosaics will provide the opportunity to map the locations of worm tufts and gain insight into the types of habitats and substrates they appear to prefer. Sediment cores among worm tufts will be used to characterize the environmental properties and local conditions in and among the worms.

Specifically, the collections and the worms were preserved for the following types of analyses and study aims:

1. **Transmission electron microscopy (TEM)**: This will provide insight into the arrangement of bacterial symbionts within the worm body, as well as the arrangement of blood vessels, glycogen stores (for low oxygen conditions), and general body plans. Additionally, electron micrographs will be used to measure minimum diffusion distances and surface areas, to figure out if the worms take up reduced chemicals for their bacterial symbionts through their plume, or through the posterior part of their bodies. Since sediment profiles indicate that free sulphide is not present in bottom water and does not appear in the sediment till a few centimetres deep, the current hypothesis is that they take up sulphide (or methane) through their posterior ends, while using their palps for oxygen and carbon dioxide uptake (ie, similar to Gulf of Mexico cold seep vestimentiferans, but different from hydrothermal vent vestimentiferans).
2. **Fluorescence in stu hybridisation (FISH):** This method will be used to target and visualize the specific locations of bacterial symbionts within the bodies of the worms.
3. **Genetics:** Since the species have not been identified, an aim of the worm collections is to examine the DNA of both the worms and the bacterial symbionts in order to identify species and holobiont combinations. Furthermore, this will also reveal whether the symbionts are sulphide oxidisers or methane oxidizers, or both.
4. **Hemoglobin:** Animals living in reduced habitats with chemoautotrophic symbiotic bacteria often have very specialized blood with unique hemoglobins that can bind both sulphide and oxygen, without them interfering with each other (sulphide rapidly oxidizes, making it unavailable to chemoautrotrophic bacteria when a lot of oxygen is present and sulphide binds more easily to animal hemoglobins, knocking out oxygen, which is why it is so toxic to animals). Studying the hemoglobins of the siboglinid worms will give us a better understanding of how the animals survive in their habitats and how they deal with a basic and important chemical problem in their lifestyle and environment.

At the Pingos, three different morphospecies were seen: ‘red siboglinid,’ ‘pinkish siboglinid,’ and ‘no palp/short palps siboglinid.’ At least five replicates were taken for each type of analysis for the three morphospecies (fewer for the ‘no palps/small palps’ morphospecies since it was much rarer than the other two).

At the pingo-crater complex, two morphospecies were seen: ‘long, red’ and ‘regular palps’. The ‘long, red’ morphospecies was extremely abundant and dominant, therefore, five replicates and more for vouchers and hemoglobins were collected for it. The ‘regular palps’ type was quite rare, therefore, only 4 replicates were collected, each for DNA, TEM and FISH. Whole, frozen individuals are needed to study hemoglobins (with multiple replicates) and it was not possible to obtain even one of the ‘regular palps’ type for haemoglobin

studies. Additionally, a number of other types of worms were seen and they were preserved opportunistically for DNA, TEM and FISH studies as well.

7.15.3 Meiofauna communities at Arctic cold seeps (A. Sen)

Bakground and Goals:

Meiofauna refers to the animals that are so small, that they literally live between the grains of sand and sediment. Officially, they are the animals that are smaller than 63 µm, but larger than 32 µm. Due to their small size, they are extremely susceptible to the conditions present within the sediment (for example, high levels of sulphide or low levels of oxygen) and therefore, form a link between the geochemical processes and biological processes in a given environment or habitat. No knowledge of a habitat or ecosystem is complete without an understanding of the meiofauna community. Not only are they important in their own right, as a community that is distinct from the more visible animal community, but they are also important because a number of larger benthic animals start their lives as tiny individuals, i.e., as meiofauna. Therefore, studying the meiofauna of a system can shed light on the larval stages and early life history of mega and macro faunal species. Our aim was to collect sediment cores from all the study sites and within a variety of habitats within the sites (bacterial mats, worm tufts, control sites) and study the first 10 cm of sediment (after which it oxygen levels are too low for animals) within those cores to identify the members of the meiofauna community. Community descriptions, indices of diversities and comparisons across habitats will be made and paired with geochemical profiles to make connections between physical conditions and the types of species present.

Meiofauna collections:

Sediment slices in general, were taken at the following sediment depths: 0-1 cm, 1-3 cm, 3-5 cm and 5-10 cm.

PKF site: One multi core sample was taken from a box core sample.

Pingo area: Half slices from a push core at GHP3, right next to a large flare and 4 small cores (equivalent to 2 push cores) from a grab sample at GHP3, five multi cores taken along a transect, starting from the top of GHP3 to south of GHP3.

Non methane site near Pingos (Control): 2 small cores (equivalent to 1 push core) from a grab sample.

Bjornoyrenna Flare Site 3: 2 small cores (equivalent to 1 push core) from a grab sample.

YinYang Pingo-Crater Complex: 1 push core from sediment near bacterial mat in the pingo, 1 blade core (only a third of the way filled) from a patch with white, fuzzy siboglinid worms.

8 Problems & action points

8.1 USBL

During calibration and testing of the ROV in Isfjorden at the start of the cruise, a critical failure was identified with the hull-mounted USBL transceiver. A new transceiver was sent on loan from the UK supplier on 17th June, arriving in Longyearbyen on 19th June. A side-mount for the transceiver was constructed in Longyearbyen the same day, and was tested that evening.

It has been speculated that the hull mounted transceiver may have become damaged during an extremely low-tide in Tromsø. During the next dry-docking this transceiver will need to be inspected and possibly replaced.

8.2 Internet

On-board internet has been significantly slower/non-existent compared to normal. This has impacted upon cruise operations, for example accessing weather/current forecasts, and sending emails for equipment troubleshooting. A ticket was lodged with the service provider by the ship crew during the cruise, but no performance increases were noticed. The CAGE engineers finally noticed that a switching cable had been changed during the installation of the replacement USBL system. This was fixed, and the ship internet was improved.

9 Logs

9.1 Event log

Date	UTC	Position		Event
16/6	08:30	Longyearbyen		Setup and calibration of ROV equipment on-board Helmer Hanssen
17/6	10:00	Longyearbyen		Depart Longyearbyen harbour
	11:10	78 19.07	15 13.50	Arrive at Isfjorden site for testing ROV operations
	16:50			Depart Isfjorden site, proceeding to Prins Karls Forland for CTD surveying. Replacement USBL transceiver ordered from supplier.
18/6	00:30	78 37.72	10 35.04	Arrive at Prins Karls Forland site.
	00:35	78 37.72	10 35.04	Begin first CTD transect; 6 stations across the shelf at 90m depth
	05:26	78 33.40	9 30.40	Begin “MASOX” CTD transect (5 stations at 390 m depth) in combination with 3 plankton net stations
	14:20	78 33.023	9 28.067	Begin sediment sampling at “MASOX” site: 2 gravity cores and 1 box core.
	17:03	78 34.913	09 23.39	Begin multibeam surveying at “MASOX” site (3 lines @ 120° swath)
	20:58	78 29.73	10 24.38	Begin CTD transect at Prins Karls Forland
19/06	01:45			Depart Prins Karls Forland location
	05:00	78 08.999	9 33.290	Arrive Isfjordrenna Trough Mouth Fan, for exploratory surveying. Begin 2 multibeam survey (2 lines @ 120° swath)
	06:34	78 08.501	9 32.627	Depart Isfjordrenna TMF for Longyearbyen
	14:00	Longyearbyen		Arrive at Longyearbyen to pick up replacement USBL transceiver
	14:45	Longyearbyen		Depart Longyearbyen for Isfjorden test site
	15:23	78 19.108	15 13.966	Arrive at Isfjorden site for testing new transceiver mount and ROV calibration/operations.
	20:55	78 18.634	15 10.634	ROV enters water for first time on test dive, down to sea bed.
20/06	06:20	Longyearbyen		Return to Longyearbyen in order to fix the side mount for the replacement USBL that broke during testing.
	21:00	Longyearbyen		Attach new USBL mount to outside of ship hull
21/06	06:00	78 19.070	15 13.500	Arrive at Isfjorden test site for USBL calibration and ROV testing
	08:32	78 18.634	15 10.850	ROV test dive and beacon retrieval.
	11:00	78 18.634	15 10.850	Depart Isfjorden for Storfjordrenna pingo site. CTD stations taken en route.
22/06	04:05	76 07.558	16 06.288	Arrive at Storfjordrenna pingo site. CTD for sound velocity profile. Start multibeam survey. EK60 is off. WCL logging.
	04:13	77.07.371	17 04.916	Started multibeam survey of 3 lines @ 120° swath over pingos.
	06:37	76 06.542	15 53.612	Finished multibeam survey
	07:50	76 06.189	15 57.689	Preparations for ROV dive over GHP-3 (mounting USBL; anchoring; loading apparatus into cage; CTD)

	11:00	76 06.390	15 58.206	ROV deployed for first reconnaissance dive above GHP-3 (station 1028)
	13:31	76 06.409	15 58.108	ROV retrieved back on board
	15:15	76 06.350	15 58.418	Re-anchored HH to the SE of GHP-3, rather than NE, for better stability with respect to currents. Reduced ping rate of USBL for improved ROV navigation.
	15:54	76 06.374	15 58.285	Equipment cage deployed over GHP-3
	16:59	76 06.397	15 58.157	ROV deployed to detach cage and collect sediment samples with push and blade cores.
23/06	00:10	76 06.375	15 58.002	ROV back on HH
	01:04	76 06.594	15.54.992	Start of CTD transect 1 (W-E) over Storfjordrenna pingos (5 stations)
	07:40	76 07.563	16 00.586	Start of CTD transect 2 (N-S) over Storfjordrenna pingos (4 stations)
	11:42	76 06.851	15 56.243	Start multibeam survey (3 lines), expanding coverage west of pingos
	15:19	76 06.516	15 40.545	End of multibeam survey and moved to position over GHP-3 for USBL calibration and ROV preparation.
	21:38	76 06.396	15 58.060	ROV deployed for third gas sampling dive over GHP-3 (station 1042).
24/06	00:32	76 06.516	15 57.979	ROV back on board – gas sampling failed over GHP-3
	02:28	76 06.421	15 57.967	Begin CTD, multinet and GC sampling programme over GHP-3, GHP-5 & GHP-2.
	11:15	76 06.403	15 58.148	Figure-8 track over GHP-3 beacon for USBL calibration, followed by circular tracks.
	12:44	76 06.410	15 58.034	Seven replicate grab samples over top of GHP-3 (station 1054)
	16:09	76 06.545	15 57.513	Continue USBL calibration above GHP-3.
	17:50	76 06.402	15 58.118	HH anchored in position over GHP-3 ready for ROV dive
	18:25	76 06.395	15 58.081	Repeat of ROV gas sampling dive over GHP-3
	19:39	76 06.393	15 58.065	ROV returned to surface with gas sample from flare and 4 niskin bottles for water at flare.
	22:41	76 06.388	15 58.062	ROV deployed for multibeam survey of GHP-3. Used chess board to measure bubble rate.
25/06	01:49	76 06.377	15 58.000	ROV returned, completed half line of multibeam. Stopped due to currents.
	03:04	76 07.030	15 59.670	Start sampling programme over GHP-3, including ADCP lines, fluorescence CTD and multicore transect (N-S).
	07:12	76 06.429	15 58.104	Begin multicore transect over GHP-3 (N-S)
	15:30	76 06.360	15 57.929	End of multicore transect (N-S). CTD station away from GHP-3 with 12 cylinders fired <1m from bottom.
	18:24	76 06.453	15 58.146	ROV deployed for stereo photo survey dive
	23:20	76 06.455	15 58.140	ROV back on board.
26/6	00:49	76 06.739	16 00.311	3 gravity cores over GHP-5. Good recoveries
	04:06	76 06.720	16 00.484	ROV deployed for another photo mosaic dive
	07:42	76 06.714	16 00.482	ROV back on board
	08:45	76 06.543	16 01.128	Start of EK60 survey: 3 lines over GHPs-1 & 5; 3 lines over GHP-3
	11:16	76 06.653	16.00.900	Start multibeam survey over GHPs 3 & 2 with narrower 60°

				swath. 4 lines
	13:16	76 04.541	15 58.369	Control GRAB station; 6 replicate samples
	18:14	76 06.447	15 58.142	ROV deployed over GHP-3 for carbonate crust grab with The Claw
	19:21	76 06.443	15 58.136	Carbonate crust successfully back on board with The Claw
	19:44	76 06.439	15 58.132	ROV deployed over GHP-3 with scoop net
	20:55	76 06.446	15 58.162	ROV back on-board after 5 scoop samples taken
	22:11	76 06.443	15 58.100	Triangle scrape over pingo 3
	23:40	76 07.012	16 02.605	2 gravity cores over GHP-4 and 1 outside pingos
27/6	1:57	76 05.553	16 00.663	2 narrow (60°) multibeam surveys over pingos 5,1 & 4; followed by expansion of wide (120°) swath survey west of pingo area
	06:35	76 06.442	15 58.201	ROV deployed over GHP-3 for multibeam survey
	09:25	76 06.444	15 58.354	ROV back on-board
	10:26	76 06.544	15 59.657	Leaving Storfjordrenna pingo area, collecting multibeam and chirp data south along Storfjordrenna GZW margin.
	12:51	75 50.370	16 37.905	Arrive at southern Storfjordrenna GZW for CTD and multinet sampling.
	14:34	75 50.341	16 37.861	Continued steaming towards Bjørnøyrenna Crater Area.
28/6	07:37	74 54.823	27 45.910	Arrive at Crater Area. First station a sound velocity profile CTD in “Yin Yang” crater (main crater of interest).
	08:23	74 54.568	27 44.877	Start multibeam survey of Yin Yang, 2 lines of narrow 60° swath.
	10:26	74 54.925	27 45.942	Anchored in position over Yin Yang, deploying USBL mount.
	12:04	74 54.965	27 46.072	ROV deployed over Yin Yang for multibeam survey
	17:44	74 55.080	27 46.156	ROV back on-board
	19:14	74 54.324	27 44.508	Start CTD transect SW-NE over Yin Yang
29/6	06:34	74 54.956	27 46.005	ROV deployed over Yin Yang to complete yesterday’s multibeam survey.
	07:49	74 54.955	27 46.007	ROV back on-board
	08:19	74 54.986	27 46.034	ROV deployed for photo mosaic survey and video reconnaissance
	16:01	74 54.978	27 46.053	ROV back on-board
	18:08	74 54.927	27 46.209	Begin CTD/multinet transect to west of Yin Yang
30/6	02:56	74 54.133	27 33.437	Grab core taken within weak flares
	07:35	74 54.991	27 45.665	ROV deployed for sediment sampling over Yin Yang pingo. Recovered 4 blade core samples
	09:06	74 54.978	27 45.733	ROV back on-board
	10:39	74 54.986	27 45.697	ROV redeployed for push core sampling over Yin Yang pingo. Recovered 5 push cores. Dropped push core frame when entering the water, but found it again on the sea bed.
	12:03	74 54.987	27 45.690	ROV back on-board
	13:45	74 54.986	27 45.694	Deployed ROV for another batch of 4 blade cores over Yin Yang
	16:00	74 54.988	27 45.688	ROV back on-board
	17:30	74 54.803	27 43.552	Multibeam patch test over Yin Yang
	22:34	75 01.605	27 22.882	New multibeam data collection NW of crater area. 3 lines
01/7	06:30	74 55.045	27 45.917	Back anchored in position over Yin Yang
	06:50	74 55.038	27 45 918	ROV deployed for gas collection over twin flares

	09:33	74 55.061	27 45.880	ROV back on-board
	10:15	74 55.035	27.45.919	ROV deployed for second gas collection over different flare
	11:57	74 55.049	27 45.892	ROV back on-board
	13:01	74 55.052	27 45.899	ROV deployed with The Bear Claw to pick up blocks
	14:15	74 55.052	27 45.881	ROV back on-board with rock sample
	14:57	74 55.045	27 45.909	ROV deployed for multibeam patch test and to collect an extra survey line
	17:15	74 55.043	27 45.899	ROB back on-board
	18:05	74 55.007	27 46.032	Box core sampling over Yin Yang. Bent box liner on third attempt
	21:26	74 55.216	27 45.509	EK60 survey on Yin Yang for gas flare mapping. 7 lines
02/7	00:57	74 55.398	27 48.135	Multibeam survey over Yin Yang with 60° swath
	06:57	74 55.040	27 45.994	ROV deployed for gas bubble flow rate measurements at Yin Yang
	08:12	74 55.051	27 46.002	ROV back on-board
	08:52	74 54.929	27 45.976	ROV deployed for photo mosaic survey in crater
	11:29	74 54.914	27 45.953	ROV back on-board
	12.40	74 54.873	27 45.924	ROV deployed for multibeam surveying over crater
	14:39	74 54.872	27 45.923	ROV back on-board. USBL mount being taken down before transit.
	16:43	75 01.937	27 29.750	New multibeam acquisition area northwest of main craters
	18:48	75 04.189	27 32.861	Completed data acquisition and started steaming to Longyearbyen. Storm forecast for return journey around southern Svalbard.
04/7	08:00	Longyearbyen		Arrive at Longyearbyen Coal Wharf

9.2 Station log

Cruise CAGE 16-5

16 June - 4 July 2016 Total stations: 150

Total ROV

Chief scientist: Michael Carroll dives: 23 (+2 test dives)

Area	Date	Cruise	Ship	Ship Station	Sampling device	N. of samples	Depth (m)	Lat	Long	UTC	Comment
Isfjorden	17. jun.	CAGE 16-5	HH	991	CTD	-	282	78 18.66	15 10.79	12:01	Test deployment
Isfjorden	17. jun.	CAGE 16-5	HH	992	CTD	8	282	78 18.66	15 10.78	12:40	Test deployment
Prins Karls Forland	18. jun.	CAGE 16-5	HH	993	CTD	8	75	78 37.72	10 35.04	00:35	CTD transect across PKF
Prins Karls Forland	18. jun.	CAGE 16-5	HH	994	CTD	8	118	78 36.45	10 26.43	01:14	CTD transect across PKF
Prins Karls Forland	18. jun.	CAGE 16-5	HH	995	CTD	8	126	78 34.95	10 18.00	02:13	CTD transect across PKF
Prins Karls Forland	18. jun.	CAGE 16-5	HH	996	CTD	8	150	78 34.26	10 13.20	03:00	CTD transect across PKF
Prins Karls Forland	18. jun.	CAGE 16-5	HH	997	CTD	8	92	78 33.68	10 08.54	03:43	CTD transect across PKF OS-2-site
Prins Karls Forland	18. jun.	CAGE 16-5	HH	998	CTD	8	110	78 33.18	10 06.06	04:28	CTD transect across PKF
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	999	CTD	8	364	78 33.40	9 30.40	05:26	CTD transect "MASOX"
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1000	CTD	8	386	78 33.364	9 29.460	06:34	CTD transect "MASOX"
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1001	PN	4	386	78 33.395	9 29.443	07:07	Multinet over flare
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1002	CTD	8	389	78 33.320	9 28.590	08:40	CTD transect "MASOX", heavy flares in the first 100m
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1003	CTD	8	398	78 33.273	9 27.894	09:40	CTD transect "MASOX"
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1004	CTD	8	405	78 33.165	9 26.817	10:55	CTD transect "MASOX"
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1005	PN	4	407	78 33.221	9 26.581	11:30	Multinet outside the flare
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1006	PN	4	392	78 33.718	9 28.003	13:00	Multinet inside flare zone
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1007	GC	1	392	78 33.023	9 28.087	14:21	40 cm recovery, smelly mud
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1008	GC	1	388	78 33.323	9 28.657	15:13	bullseye on strong flare; 116 cm recovery

Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1009	BC	1	389	78 33.333	9 28.615	16:03	bullseye on flare; good recovery
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1010	MB	3 lines		78 34.913	9 23.39	17:03	Multibeam and water column recording
Prins Karls Forland	18. jun.	CAGE 16-5	HH	1011	CTD	8	109	78 29.729	10 24.38	20:58	CTD western transect along shore
Prins Karls Forland	18. jun.	CAGE 16-5	HH	1012	CTD	8	114	78 35.91	9 59.05	22:00	CTD western transect along shore
Prins Karls Forland	18. jun.	CAGE 16-5	HH	1013	CTD	8	127	78 40.89	9 41.51	22:54	CTD western transect along shore
Prins Karls Forland	18. jun.	CAGE 16-5	HH	1014	CTD	8	93	78 73.53	9 58.03	23:35	CTD eastern transect along shore
Prins Karls Forland	19. jun.	CAGE 16-5	HH	1015	CTD	8	90	78 38.85	10 16.83	00:37	CTD eastern transect along shore
Prins Karls Forland	19. jun.	CAGE 16-5	HH	1016	CTD	8	78	78 32.617	10 41.655	01:48	CTD eastern transect along shore
Isfjordrenna TMF	19. jun.	CAGE 16-5	HH	1017	CTD	-	265	78 09.029	09 34.548	04:44	CTD (sound velocity profile)
Isfjordrenna TMF	19. jun.	CAGE 16-5	HH	1018	MB	2 lines	266	78 08.999	09 33.299	05:14	Multibeam and water column
Isfjorden	19. jun.	CAGE 16-5	HH	1019	ROV	-	272	78 18.634	15 10.634	20:55	ROV wet function test dive
Isfjorden	21. jun.	CAGE 16-5	HH	1020	CTD	-	278	78 18.642	15 10.736	08:10	CTD (sound velocity profile)
Isfjorden	21. jun.	CAGE 16-5	HH	1021	ROV	-	280	78 18.634	15 10 850	08:32	USBL calibration & beacon retrieval
Outer Bellsund	21. jun.	CAGE 16-5	HH	1022	CTD	8	168	77 31.888	13 10.858	17:17	CTD transect between Isfjorden & Storfjordrenna
Outer Hornsund	21. jun.	CAGE 16-5	HH	1023	CTD	8	121	76 53.481	14 37.929	21:45	CTD transect between Isfjorden & Storfjordrenna
	22. jun.	CAGE 16-5	HH	1024	CTD	8	85	76 25.596	15 54.407	01:30	CTD transect between Isfjorden & Storfjordrenna
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	1025	CTD	-	363	76 07.469	16 06.958	03:58	CTD (sound velocity profile)
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	1026	MB	3 lines	363	77 07.371	17 04.916	04:13	Multibeam survey - 3 lines over pingo area
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	1027	CTD	-	379	76 06.417	15 58.229	09:52	CTD (sound velocity profile); adjacent to GHP-3
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	1028	ROV	-	384	76 06.390	15 58.206	11:00	Reconnaissance dive over GHP-3 with video survey
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	1029	ROV	3 push cores, 3 blade cores, 1 carbonate crust	381	76 06.398	15 58.151	16:59	Sampling dive at GHP-3. Time-lapse camera deployed
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1030	CTD	8	389	76 06.563	15 54.830	01:20	CTD transect 1 (West-East)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1031	CTD	8	383	76 06.468	15 58.152	02:08	CTD transect 1 (West-East)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1032	CTD	8	387	76 06.393	15 59.909	02:48	CTD transect 1 (West-East)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1033	CTD	8	380	76 06.353	16 02.164	03:22	CTD transect 1 (West-East)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1034	CTD	8	387	76 06.217	16 04.730	04:31	CTD transect 1 (West-East)

Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1035	PN	4	387	76 06.220	16 04.862	05:00	Multinet East of Pingos
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1036	GC	1	394	76 06.471	16 04.663	06:40	GC to the East from Pingos
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1037	CTD	8	368	76 07.563	16 00.586	07:40	CTD transect 2 (North-South)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1038	CTD	8	379	76 06.885	16 00.163	08:35	CTD transect 2 (North-South)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1039	CTD	8	388	76 05.860	15 59.692	09:36	CTD transect 2 (North-South)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1040	CTD	8	385	76 05.187	15 59.738	10:32	CTD transect 2 (North-South)
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1041	MB	3 lines	384	76 06.851	15 56.243	11:42	Expand multibeam coverage to west
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	1042	ROV	0	379	76 06.396	15 58.060	21:38	Gas sampling dive over GHP-3. Hardware failure
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1043	CTD	10	389	76 06.421	15 58.056	02:24	CTD for multinet
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1044	PN	4	378	76 06.410	15 58.093	03:25	Multinet on GHP3
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1045	GC	1	387	76 06.347	15 57.959	04:56	Gravity Core south slope of GHP3
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1046	CTD	8	385	76 06.698	16 00.381	05:33	CTD on GHP5
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1047	PN	4	382	75 06.695	16 00.445	06:11	Multinet on GHP5
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1048	GC	1	387	76 06.737	15 59.845	07:07	Gravity Core north slope of GHP5
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1049	GC	0	382	76 06.699	16 00.378	07:44	Gravity Core south slope of GHP5. 1st attempt failed
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1050	GC	0	382	76 06.695	16 00.393	08:25	Repeat of 1049. Sediments in core catcher only.
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1051	GC	1	382	76 06.690	16 00.526	09:06	Third attempt over GHP5. c. 30 cm recovery
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1052	CTD	8	380	76 06.346	16 02.058	09:54	CTD on GHP2
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1053	PN	4	381	76 06.376	16 02.002	10:53	Multinet over GHP2
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1054	GRAB	7	377	76 06.410	15 58.034	12:44	7 replicate samples in same position over GHP3 flares
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1055	ROV	4 niskin / 1 gas sample	378	76 06.395	15 58.081	18:25	Gas sampling dive over GHP-3; 4 niskin bottles collected immediately as front loader filled
Storfjordrenna pingos	24. jun.	CAGE 16-5	HH	1056	ROV	100 m of MB	380	76 06.388	15 58.062	22:41	Multibeam survey over GHP-3. Bubble rate with chess board. 100m MB line, stopped due to currents
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1057	ADCP	2 lines	380	76 07.030	15 59.670	03:04	Two line ADCP survey over GHP3 and
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1058	CTD	2	380	76 06.422	15 58.091	04:45	CTD with 1 at bottom and 11 bottles at 20 meters (fluorescence max)
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1059	MC	2/6 tubes	376	76 06.429	15 58.104	07:12	Multicore transect over GHP3 (N-S)
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1060	MC	Miscast	377	76 06.412	15 58.101	07:49	Repeat of 1059 station location. Failed. Catcher not locked properly

Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1061	MC	6/6 tubes	377	76 06.413	15 58.097	08:24	Third attempt at 1059 station location.
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1062	MC	6/6 tubes	381	76 06.392	15 58.037	09:50	Multicore transect over GHP3 (N-S)
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1063	MC	6/6 tubes	384	76 06.367	15 57 997	11:06	Multicore transect over GHP3 (N-S)
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1064	MC	6/6 tubes	386	76 06.342	15 58.004	13:26	Multicore transect over GHP3 (N-S)
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1065	MC	5/6 tubes	386	76 06.315	15 57.981	15:03	Multicore transect over GHP3 (N-S)
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1066	CTD	1	386	76 06.360	15 57.929	15:30	Fired 12 cylinders <1m from bottom
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	1067	ROV	-	381	76 06.453	15 58.146	18:24	Photo survey dive at GHP-3
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1068	GC	1	384	76 06.739	16 00.311	00:49	GHP5. recovery 295 cm
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1069	GC	1	383	76 06.719	16 00.334	01:29	GHP5. recovery 227cm
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1070	GC	1	385	76 06.703	16 00.162	02:00	GHP5. recovery 326 cm
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1071	ROV	-	380	76 06.720	16 00.484	04:06	GHP5, Time lapse cam deployed for duration of dive, photo mosaic
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1072	EK60	6 lines	380	76 06.543	16 01.128	08:45	3 EK60 lines over GHP 1 & 5; 3 lines over GHP3
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1073	CTD	-	387	76 06.626	15 55.195	10:41	CTD (sound velocity profile)
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1074	MB	4 lines	387	76 06.653	16 00.900	11:16	Narrower 60° swath over GHPs 3 & 2
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1075	GRAB	6	385	76 04.541	15 58.369	13:16	6 replicate samples over control site outside pingos
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1076	CTD	1	384	76 04.571	15 58.306	15:45	12 bottles fired at 25 m
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1077	ROV	1	380	76 06.447	15 58.142	18:14	Carbonate grab dive at GHP-3
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1078	ROV	5 scoops	379	76 06.439	15 58.132	19:44	Scoop net dive at GHP-3
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1079	SCRAPE	1	377	70 06.441	15 58.100	22:11	Triangle scrape over GHP-3
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	1080	GC	0	369	76 07.019	16 02.605	23:40	GC 9 fail
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	1081	GC	1	369	76 07.022	16 02.593	00:19	GC 9, recovery 102 cm over GHP-4
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	1082	GC	1	385	76 06.825	15 56.742	01:13	GC 10, recovery 50 cm outside pingo area
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	1083	MB	4 lines	380	76 06.553	16 00.663	01:57	2 narrow 60° swath over GHPs 2 & 4; 2 wide 120° swath lines west of pingos
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	1084	ROV	5 lines	381	76 06.442	15 58.200	06:35	ROV based multibeam over GHP-3
Storfjordrenna	27. jun.	CAGE 16-5	HH	1085	CTD	8	349	75 50.374	16 37.763	13:00	Over flares at Storfjordrenna GZW
Storfjordrenna	27. jun.	CAGE 16-5	HH	1086	CTD	8	349	75 50 344	16 37.931	13:33	Repeat of station 1085 with different depths
Storfjordrenna	27. jun.	CAGE 16-5	HH	1087	PN	1	349	75 50.338	16 37.921	13:53	Over flares at Storfjordrenna GZW
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1088	CTD	1	352	74 54.823	27 45.910	07:37	CTD (sound velocity profile) in crater
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1089	MB	2 lines	337	74 54.568	27 44.877	08:23	Narrower 60° swath over Yin Yang

Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1090	ROV	Multibeam 5 lines	337	74 54.964	27 46.072	12:04	ROV based multibeam over Yin Yang. 600 m long lines; followed by short video reconnaissance
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1091	CTD	8	337	74 54.324	27 44.508	19:14	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1092	CTD	8	336	74 54.506	27 45.206	20:01	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1093	CTD	8	335	74 54.368	27 45.515	20:52	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1094	CTD	8	337	74 54.745	27 45.633	21:54	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1095	CTD	8	351	7454.82698	27 45.750	22:38	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1096	CTD	8	326	74 54.989	27 45.917	23:24	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	28. jun.	CAGE 16-5	HH	1097	CTD	8	326	74 55.022	27 46.252	23:56	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1098	CTD	8	347	74 55.259	27 46.662	00:35	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1099	CTD	8	336	74 55.495	27 47.119	01:12	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1100	CTD	8	336	74 55.726	27 47.470	02:07	CTD transect SW-NE over Yin Yang
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1101	CTD	9	332	74 54.928	27 50.643	02:35	CTD for multinet #9
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1102	PN	1	330	74 54.936	27 50.493	03:04	Multinet "#9"
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1103	CTD	9	336	74 55.086	27 47.731	03:55	CTD for multinet #11
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1104	PN	1	335	74 55.086	27 47.731	04:24	Multinet "#11"
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1105	ROV	1 line	330	74 54.956	27 46.005	06:34	Complete ROV multibeam survey from previous dive
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1106	ROV	3 photo mosaic areas	327	74 54.986	27 46.034	08:19	ROV with stereo camera and markers. Video reconnaissance over pingo & crater
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1107	CTD	9	328	74 54.927	27 46.209	18:08	CTD for Multinet
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1108	PN	1	350	74 54.928	27 46.209	18:44	Multinet
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1109	CTD	9	350	74 54.939	27 46.205	19:38	CTD for Multinet
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1110	PN	1	348	74 54.576	27 41.006	20:17	Multinet
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1111	CTD	9	348	74 54.405	27 38.766	21:05	CTD for Multinet
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1112	PN	1	351	74 54.382	27 38.730	21:45	Multinet
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1113	CTD	9	336	74 55.240	27 38.555	22:48	CTD for Multinet
Bjørnøyrenna Craters	29. jun.	CAGE 16-5	HH	1114	PN	1	336	74 55.199	27 38.360	23:10	Multinet
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1115	CTD	9	357	74 54.255	27 37.201	00:01	CTD for Multinet
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1116	PN	1	361	74 54.390	27 37.209	00:20	Multinet
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1117	CTD	9	335	74 54.656	27 32.261	01:29	CTD for Multinet
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1118	PN	1	335	74 54.656	27 32.261	01:42	Multinet

Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1119	CTD	1	335	74 54.656	27 32.261	02:21	All bottles fired at flurescence maximum
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1120	GRAB	6	335	74 54.133	27 33.437	02:56	Lots of weak flares
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1121	MB	1 line	334	74 54.151	27 33.292	04:26	1 line west of crater area
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1122	CTD	8	325	74 54.954	27 46.001	05:38	ctd @ Yin Yang
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1123	ROV	4 blade cores; water samples	338	74 54.991	27 45.665	07:35	Sediment & water sampling with blade cores without basket
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1124	ROV	5 push core; water sampes	337	74 54.987	27 45.697	10:39	Sediment sampling with push cores in frame
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1125	ROV	4 blade cores	338	74 54.986	27 45.694	13:45	Sediment with blade cores without basket
Bjørnøyrenna Craters	30. jun.	CAGE 16-5	HH	1126	MB	2 lines	335	74 54.803	27 43.552	17:30	Patch test
Bjørnøyrenna Craters	30. jun.	CAGE 16-6	HH	1127	MB	3 lines	338	75 01.605	27 22.882	22:34	New acquisition in northwest crater area
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1128	ROV	1 bottle	325	74 55.039	27 45.921	06:50	Gas collection over Yin Yang twin flares
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1129	ROV	1 bottle	328	74 55.035	27 45.919	10:15	Gas collection over different Yin Yang flare
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1130	ROV	1 shale slab	325	74 55.052	27 45.899	13:01	ROV deployed with the Bear Claw to pick up boulder
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1131	ROV	1 line	325	74 55.049	27 45.904	14:57	Multibeam dive for patch test & extra survey line
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1132	BC	-	325	74 55.008	27 46.034	18:03	Failed core, mostly stones and washed out mud
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1133	BC	1	325	74 54.975	27 45.937	18:51	Repeated with good recovery
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1134	BC	1	331	74 54.566	27 44.242	20:24	Lots of mud but damaged box with stone
Bjørnøyrenna Craters	1. jul.	CAGE 16-5	HH	1135	EK60	10 lines	335	74 55.216	27 45.509	21:26	Single beam echosounder survey for flare mapping, covering all of Yin Yang
Bjørnøyrenna Craters	2. jul.	CAGE 16-5	HH	1136	MB	7 lines	335	74 54.539	27 43.290	00:57	Multibeam over Yin Yang with new calibration & 60° swath
Bjørnøyrenna Craters	2. jul.	CAGE 16-5	HH	1137	ROV	-	326	74 55.040	27 45.994	06:57	Dive for gas bubble flow rate with chess board
Bjørnøyrenna Craters	2. jul.	CAGE 16-5	HH	1138	ROV		331	74 54.929	27 45.977	08:52	Photo mosaic survey and visual survey
Bjørnøyrenna Craters	2. jul.	CAGE 16-5	HH	1139	ROV	2 lines	342	74 54.873	27 45.924	12:40	ROV Multibeam survey of southernmost Yin Yang
Bjørnøyrenna Craters	2. jul.	CAGE 16-5	HH	1140	MB	2 lines	312	75 01.937	27 29.750	16:43	Ship multibeam survey 1.5 lines (complete area northwest area from stn 1127)

9.3 Line log

Cruise CAGE 16-5 16 June - 4 July 2016 Chief scientist: Michael Carroll			Total lines:	70							
Area	Date	Cruise	Ship	Line #	Device	SOL Lat	SOL Long	UTC	EOL Lat	EOL Long	UTC
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	1	MB	78 31.575	9 34.178	17:03	78 35.204	9 28.490	
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	2	MB	78 35.032	9 25.773		78 31.404	9 31.472	
Prins Karls Forland ("MASOX")	18. jun.	CAGE 16-5	HH	3	MB	78 31.303	9 28.882		78 35.231	9 22.395	19:49
Isfjordrenna TMF	19. jun.	CAGE 16-5	HH	4	MB	78 8.996	9 32.937	05:14	78 9.128	9 18.970	
Isfjordrenna TMF	19. jun.	CAGE 16-5	HH	5	MB	78 8.634	9 18.730		78 8.502	9 32.687	06:34
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	6	MB	76 07.345	16 04.736	04:13	76 06.247	15 56.508	
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	7	MB	76 05.741	15 57.861		76 06.839	16 06.086	
Storfjordrenna pingos	22. jun.	CAGE 16-5	HH	8	MB	76 07.779	16 03.473		76 06.754	15 55.404	06:37
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	9	MB	76 06.729	15 55.237	11:42	76 05.752	15 47.642	
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	10	MB	76 06.456	15 46.016		76 07.677	15 55.799	
Storfjordrenna pingos	23. jun.	CAGE 16-5	HH	11	MB	76 08.040	15 52.137		76 06.867	15 42.370	15:19
Storfjordrenna pingos	24 jun.	CAGE 16-5	HH	12	ROV	76 6.433	15 57.645	22:41	76 6.414	15 58.417	01:49	100m line over GHP3
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	13	ADCP	76 5.868	16 2.287	03:04	76 7.511	15 58.598		GHP3
Storfjordrenna pingos	25. jun.	CAGE 16-5	HH	14	ADCP	76 7.259	15 56.224		76 5.617	15 59.916	04:44
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	15	EK60	76 6.65251	16 0.89986	08:45	76 6.98586	16 0.12433	
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	16	EK60	76 6.96107	15 59.92325		76 6.62660	16 0.69036	
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	17	EK60	76 6.60865	16 0.48622		76 6.93504	15 59.72621	
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	18	EK60	76 6.42062	15 58.85241		76 6.50850	15 57.57383	
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	19	EK60	76 6.45852	15 57.49033		76 6.37064	15 58.76883	
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	20	EK60	76 6.31885	15 58.70985		76 6.40673	15 57.43142	10:33

Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	21	MB	76 6.44913	15 56.87298	11:16	76 6.37842	15 59.36642		
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	22	MB	76 6.37842	15 59.36642	11:39	76 6.44913	15 56.87298	11:50	Repeat of line 18 over GHP3 peak
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	23	MB	76 6.17998	16 1.31998		76 6.50432	16 2.74370		
Storfjordrenna pingos	26. jun.	CAGE 16-5	HH	24	MB	76 6.50432	16 2.74370	12:36	76 6.17998	16 1.31998	12:45	Repeat of line 20 over GHP2
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	25	MB	76 6.394	16 0.907	01:57	76 7.145	15 59.819		Pingos 5 & 1
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	26	MB	76 7.189	16 1.429		76 6.841	16 3.673		Pingo 4
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	27	MB	76 7.776	16 0.127		76 6.429	15 49.267		West of pingos
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	28	MB	76 7.516	15 42.892		76 7.884	15 46.034	04:14	West of pingos
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	29	ROV	76 6.359	15 57.800	06:35	76 6.494	15 57.900		Survey over GHP3
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	30	ROV	76 6.489	15 58.010		76 6.354	15 57.912		Survey over GHP3
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	31	ROV	76 6.349	15 58.020		76 6.484	15 58.121		Survey over GHP3
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	32	ROV	76 6.479	15 58.231		76 6.345	15 58.130		Survey over GHP3
Storfjordrenna pingos	27. jun.	CAGE 16-5	HH	33	ROV	76 6.340	15 58.241		76 6.475	15 58.341	09:25	Survey over GHP3
Storfjordrenna	27. jun.	CAGE 16-5	HH	34	SBP	76 5.925	16 0.653	10:31	75 49.543	16 37.614		Along Storfjord GZW
Storfjordrenna	27. jun.	CAGE 16-5	HH	35	MB	76 5.925	16 0.653	10:31	75 49.543	16 37.614		Along StorfjordGZW
Bjørnøyrenna Crater Area	28. jun.	CAGE 16-5	HH	36	MB	74 54.589	27 44.926	08:18	75 55.455	27 46.483	08:38	60° over Yin Yang
Bjørnøyrenna Crater Area	28. jun.	CAGE 16-5	HH	37	MB	74 55.700	27 47.757	08:41	74 54.548	27 45.374	09:01	
Bjørnøyrenna Crater Area	28. jun.	CAGE 16-5	HH	38	ROV	74 54.970	27 45.244	12:04	74 54.893	27 46.800		Over Yin Yang
Bjørnøyrenna Crater Area	28. jun.	CAGE 16-5	HH	39	ROV	74 54.861	27 46.777		74 54.938	27 45.221		Over Yin Yang
Bjørnøyrenna Crater Area	28. jun.	CAGE 16-5	HH	40	ROV	74 54.886	27 45.182		74 54.808	27 46.738		Over Yin Yang
Bjørnøyrenna Crater Area	28. jun.	CAGE 16-5	HH	41	ROV	74 54.959	27 46.848		74 55.036	27 45.292		Over Yin Yang
Bjørnøyrenna Crater Area	28. jun.	CAGE 16-5	HH	42	ROV	74 55.102	27 45.341		74 55.025	27 46.897	17:44	Over Yin Yang
Bjørnøyrenna Crater Area	29 jun.	CAGE 16-5	HH	43	ROV	74 55.103	27 46.778	06:34	74 55.167	27 45.507	07:49	Complete survey over Yin Yang
Bjørnøyrenna Crater Area	30. jun.	CAGE 16-5	HH	44	MB	74 54.151	27 33.292	04:26	74 54.737	27 32.188	04:36	West of craters
Bjørnøyrenna Crater Area	30 jun.	CAGE 16-5	HH	45	MB	74 54.802	27 43.543		74 54.802	27 48.914		Patch test
Bjørnøyrenna Crater Area	30 jun.	CAGE 16-5	HH	46	MB	74 55.120	27 43.662		74 55.114	27 48.894		Patch test

Bjørnøyrenna Crater Area	30 jun.	CAGE 16-5	HH	47	MB	75 01.659	27 23.015	22:34	75 07.035	27 35.328		Exploration NW of crater area
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	48	MB	75 07.001	27 37.375		75 01.380	27 24.523		Exploration NW of crater area
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	49	MB	75 01.066	27 25.777		75 04.242	27 33.049	02:59	Exploration NW of crater area
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	50	EK60	74 55.22142	27 45.52996	21:26	74 54.68739	27 45.29531		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	51	EK60	74 55.21775	27 45.65307		74 54.68372	27 45.41835		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	52	EK60	74 55.21408	27 45.77618		74 54.68006	27 45.54139		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	53	EK60	74 55.21041	27 45.89929		74 54.67639	27 45.66443		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	54	EK60	74 55.20674	27 46.02240		74 54.67272	27 45.78747		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	55	EK60	74 55.20307	27 46.14551		74 54.66905	27 45.91051		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	56	EK60	74 55.19940	27 46.26862		74 54.66538	27 46.03355		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	57	EK60	74 55.19572	27 46.39172		74 54.66171	27 46.15659		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	58	EK60	74 55.19205	27 46.51483		74 54.65804	27 46.27962		Flare detection Yin Yang
Bjørnøyrenna Crater Area	1. jul.	CAGE 16-5	HH	59	EK60	74 55.18837	27 46.63794		74 54.65436	27 46.40266	00:56	Flare detection Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	60	MB	74 55.41023	27 48.13813	00:57	74 54.15706	27 45.50962		Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	61	MB	74 54.21240	27 45.14597		74 55.47190	27 47.78536		Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	62	MB	74 55.51807	27 47.42386		74 54.27059	27 44.74136		Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	63	MB	74 54.32517	27 44.30983		74 55.57272	27 47.06057		Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	64	MB	74 55.61853	27 46.71551		74 54.37312	27 43.92876		Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	65	MB	74 54.44282	27 43.58529		74 55.66724	27 46.35969		Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	66	MB	74 55.71368	27 46.00002		74 54.50528	27 43.22033	03:43	Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	67	ROV	74 54.846	27 45.153	12:40	74 54.769	27 46.709		Southernmost Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	68	ROV	74 54.721	27 46.674		74 54.800	27 45.119	14:39	Southernmost Yin Yang
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	69	MB	75 01.968	27 30.271	16:43	75 06.376	27 40.065		NW of crater area
Bjørnøyrenna Crater Area	2 jul.	CAGE 16-5	HH	70	MB	75 06.572	27 38.308		75 04.113	27 32.674	18:48	NW of crater area

9.4 ROV observation log

Cruise CAGE 16-5
16 June - 4 July 2016
Chief scientist: Michael Carroll

Instrument room ROV observation log - secondary to log made from the deck container

Area	Cruise	Ship	Station	Date	UTC time	Observations
Storfjordrenna GHP-3	CAGE_16-5	HH	1028	2016.06.22	11:00	ROV deployed
	CAGE_16-5	HH	1029	2016.06.22	11:34	Bottom reached @ 380 m bsl. Start transect 01
	CAGE_16-5	HH	1030	2016.06.22	11:35	Small bacterial mat
	CAGE_16-5	HH	1031	2016.06.22	11:36	Pink anenome
	CAGE_16-5	HH	1032	2016.06.22	11:37	Pockmarks; anenomes
	CAGE_16-5	HH	1033	2016.06.22	11:39	Pink anenome; flat fish (plaice?)
	CAGE_16-5	HH	1034	2016.06.22	11:40	Anenomes; bivalve
	CAGE_16-5	HH	1035	2016.06.22	11:41	Large pink pom pom?
	CAGE_16-5	HH	1036	2016.06.22	11:43	Pink anenome & shrimp
	CAGE_16-5	HH	1037	2016.06.22	11:44	Pom pom, moved
	CAGE_16-5	HH	1038	2016.06.22	11:46	Snail; large shrimp (buried); pink pom pom
	CAGE_16-5	HH	1039	2016.06.22	11:49	Cod-type fish
	CAGE_16-5	HH	1040	2016.06.22	11:50	Sponge and pink pom pom; starfish; bacterial mats & worms
	CAGE_16-5	HH	1041	2016.06.22	11:51	Large bacterial mat, worms & carbonate
	CAGE_16-5	HH	1042	2016.06.22	11:55	large wormtuft
	CAGE_16-5	HH	1043	2016.06.22	11:59	Worm tufts and microbial mats
	CAGE_16-5	HH	1044	2016.06.22	12:01	microbial
	CAGE_16-5	HH	1045	2016.06.22	12:06	Tufts, pompom
	CAGE_16-5	HH	1046	2016.06.22	12:12	Hit sediment, turbid water
	CAGE_16-5	HH	1047	2016.06.22	12:17	Pom pom
	CAGE_16-5	HH	1048	2016.06.22	12:18	Bacterial mat & tufts; hermit crab? on mat

CAGE_16-5	HH	1049	2016.06.22	12:21	Pompom on bacterial mat; & starfish. Crater holes in mat.
CAGE_16-5	HH	1050	2016.06.22	12:24	Bacterial mat & tufts; skate/plaice? fish
CAGE_16-5	HH	1051	2016.06.22	12:34	Tufts and small bacterial mat
CAGE_16-5	HH	1052	2016.06.22	12:38	Bacterial mat and tufts
CAGE_16-5	HH	1053	2016.06.22	12:39	Trash? Skeleton?
CAGE_16-5	HH	1054	2016.06.22	12:41	Pompom amongst tufts
CAGE_16-5	HH	1055	2016.06.22	12:45	Pompom amongst tufts. Couple of fish
CAGE_16-5	HH	1056	2016.06.22	12:46	Series of holes amongst tufts
CAGE_16-5	HH	1057	2016.06.22	12:49	Carbonate & anenomes
CAGE_16-5	HH	1058	2016.06.22	12:52	Baterial mat and large carbonate crust
CAGE_16-5	HH	1059	2016.06.22	12:56	Many carbonate crusts and anenomes, corals
CAGE_16-5	HH	1060	2016.06.22	13:00	More carbonates
CAGE_16-5	HH	1061	2016.06.22	13:01	Bacterial mat
CAGE_16-5	HH	1062	2016.06.22	13:04	ROV ascending due to strong currents
CAGE_16-5	HH	1063	2016.06.22	13:26	ROV back to surface

Cruise CAGE 16-5 Instrument room ROV observation log - secondary to log made from the deck container

16 June - 4 July 2016

Chief scientist: Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations
Storfjordrenna GHP-3	CAGE_16-5	HH	1029	2016.06.22	16:59	ROV deployed. Cage deployed first with scoop and push core
	CAGE_16-5	HH	1029	2016.06.22	17:29	Observed gas bubbles on descent
	CAGE_16-5	HH	1029	2016.06.22	17:31	Hit sea floor at 376 m bsl; tufts; bacterial mat; shrimp
	CAGE_16-5	HH	1029	2016.06.22	17:32	Gas flare from carbonate crusts. Pulsing
	CAGE_16-5	HH	1029	2016.06.22	17:38	Anenome; large group of coral and carbonates
	CAGE_16-5	HH	1029	2016.06.22	17:39	Found beacon
	CAGE_16-5	HH	1029	2016.06.22	17:40	Black fish; located cage
	CAGE_16-5	HH	1029	2016.06.22	17:42	Detached cable from cage

CAGE_16-5	HH	1029	2016.06.22	17:44	2 small gas flares
CAGE_16-5	HH	1029	2016.06.22	17:47	Shrimp in flare Thyasira shell (Fishbone flare)
CAGE_16-5	HH	1029	2016.06.22	17:50	Pingo outcrop
CAGE_16-5	HH	1029	2016.06.22	17:50	skellet
CAGE_16-5	HH	1029	2016.06.22	17:51	intense bubble stream
CAGE_16-5	HH	1029	2016.06.22	17:52	Shrimp on bacterial mat
CAGE_16-5	HH	1029	2016.06.22	17:53	wormtuft
CAGE_16-5	HH	1029	2016.06.22	17:54	microbial mat
CAGE_16-5	HH	1029	2016.06.22	17:54	Tufts
CAGE_16-5	HH	1029	2016.06.22	17:55	Carbonate anemone field
CAGE_16-5	HH	1029	2016.06.22	17:56	Clarge piece of carbonate
CAGE_16-5	HH	1029	2016.06.22	17:57	Basket
CAGE_16-5	HH	1029	2016.06.22	18:04	Bubbles from above
CAGE_16-5	HH	1029	2016.06.22	18:06	TlC dropped at site
CAGE_16-5	HH	1029	2016.06.22	18:07	Bubbles
CAGE_16-5	HH	1029	2016.06.22	18:12	Blue pushcore
CAGE_16-5	HH	1029	2016.06.22	18:15	Bubblestream
CAGE_16-5	HH	1029	2016.06.22	18:19	Push blue core down, sediment dispersed
CAGE_16-5	HH	1029	2016.06.22	18:24	Retreived pushcore succesfully next to seep
CAGE_16-5	HH	1029	2016.06.22	18:33	Red pushcore
CAGE_16-5	HH	1029	2016.06.22	18:37	Red Pushcore down into sediment next to seep
CAGE_16-5	HH	1029	2016.06.22	18:39	Dropped pushcore
CAGE_16-5	HH	1029	2016.06.22	18:43	Red push core delivered to cage
CAGE_16-5	HH	1029	2016.06.22	18:47	White pushcore (with red markings)
CAGE_16-5	HH	1029	2016.06.22	18:52	Pushed white core into sediment next to seep
CAGE_16-5	HH	1029	2016.06.22	18:59	Lost core sediments trying to put into cage
CAGE_16-5	HH	1029	2016.06.22	19:02	Second attempt to collect sediment with white core
CAGE_16-5	HH	1029	2016.06.22	19:06	White pushcore delivered to cage
CAGE_16-5	HH	1029	2016.06.22	19:12	Collected blade core #3

CAGE_16-5	HH	1029	2016.06.22	19:20	Pushed blade core #3 into sediment next to seep
CAGE_16-5	HH	1029	2016.06.22	19:30	Delivered blade core #3 to cage
CAGE_16-5	HH	1029	2016.06.22	19:33	Collected red blade core
CAGE_16-5	HH	1029	2016.06.22	19:39	Pushed red blade core into sediment with tufts/worm tubes
CAGE_16-5	HH	1029	2016.06.22	19:54	Delivered red blade core to cage
CAGE_16-5	HH	1029	2016.06.22	19:59	Collected blue blade core #4
CAGE_16-5	HH	1029	2016.06.22	20:04	Blade core sampled
CAGE_16-5	HH	1029	2016.06.22	20:05	Blade core retrieved
CAGE_16-5	HH	1029	2016.06.22	20:11	Blade core delivered at basket
CAGE_16-5	HH	1029	2016.06.22	20:24	Took red scoop from basket
CAGE_16-5	HH	1029	2016.06.22	20:51	Picked up carbonate from seafloor with benthic scoop
CAGE_16-5	HH	1029	2016.06.22	20:55	Put carbonate into basket
CAGE_16-5	HH	1029	2016.06.22	21:00	Cable down to retreive basket
CAGE_16-5	HH	1029	2016.06.23	00:10	ROV back on HH

Cruise CAGE 16-5 Instrument room ROV observation log - secondary to log made from the deck container

16 June - 4 July 2016

Chief scientist: Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations
Storfjordrenna GHP-3	CAGE_16-5	HH	1055	2016.06.24	18:28	ROV deployed
	CAGE_16-5	HH	1055	2016.06.24	18:58	Reach 5m above sea bottom (373 m)
	CAGE_16-5	HH	1055	2016.06.24	19:16	Flare
	CAGE_16-5	HH	1055	2016.06.24	19:20	Flare - sampled gas into 4 niskin bottles immediately as front funnel filled
	CAGE_16-5	HH	1055	2016.06.24	19:22	ROV ascending to surface
	CAGE_16-5	HH	1055	2016.06.24	19:25	Bubbles continuously leaking from equipment (niskin bottles?)
	CAGE_16-5	HH	1055	2016.06.24	19:39	ROV at surface

Cruise CAGE 16-5
16 June - 4 July 2016
Chief scientist:
Michael Carroll

Instrument room ROV observation log - secondary to log made from the deck container

Area	Cruise	Ship	Station	Date	UTC time	Observations
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	18:24	ROV deployed
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	18:50	Bottom reached @ 375 m bsl. Start transect 01
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	18:51	worm fields
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	18:52	bacterial mat
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	18:55	worm fields
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	18:58	worm fields
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	18:59	close up worms
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:04	Mark of multicorer
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:07	worm fields
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:07	marker dropped
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:30	Carbonates?
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:32	Many shrimps in worm fields
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:40	cod and carbonate
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:46	Male skate
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	19:48	Carbonates and worm fields
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:12	Picking up marker
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:17	Camera? Time lapse?
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:17	Bubblestream
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:34	marker dropped. Start of video survey
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:44	worm field & bacterial mat
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:45	bubbles
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:47	family of shrimps in worm field. Bacterial mat closeby
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:53	a lot of shrimps on bacterial mat
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	20:54	mound with carbonate crusts & shrimps on

Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:06	close up of shrimps, spider
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:12	box core hole next to carbonates
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:18	Carbonates with white crust
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:32	Mound with shrimp zip tie on top
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:35	End of video survey?
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:38	bacterial mat mound
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:40	trash
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:44	A flat fish
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:45	Two multicore footprints
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	21:48	big fish; core sediment debris
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:00	white fish
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:16	grab core hole?
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:18	large mound with bacterial mats & tube worms
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:21	same white fish
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:30	Collection of shells in gully
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:32	four fish,
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:33	spotted flat fish
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:45	bacterial mat surrounded by extensive tube worms
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:52	blade core site next to flare; back at time lapse camera
Storfjordrenna GHP-3	CAGE_16-5	HH	1067	2016.06.26	22:54	grabbed timelapse camera and started ascent

Instrument room ROV observation log - secondary to log made from the deck container

Cruise CAGE 16-5
16 June - 4 July 2016
Chief scientist: Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations
Storfjordrenna GHP-3	CAGE_16-5	HH	1077	2016.06.26	18:14	ROV deployed
Storfjordrenna GHP-3	CAGE_16-5	HH	1077	2016.06.26	18:39	Bottom reached @ 377 m bsl

Storfjordrenna GHP-3	CAGE_16-5	HH	1077	2016.06.26	19:00	Found crust and picked up with claw
Storfjordrenna GHP-3	CAGE_16-5	HH	1077	2016.06.26	19:21	ROV back on board with crust
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	19:44	ROV deployed
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:07	Bottom reached @ 377 m bsl
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:10	First scoop on normal sediment
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:13	Second scoop into bacterial mat and worm tufts
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:18	Third scoop into bacterial mat
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:20	Closeup of tufts; fourth scoop into tufts
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:22	Bubbles
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:25	Flare (where previous blade cores sampled)
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:27	Fifth scoop near flare
Storfjordrenna GHP-3	CAGE_16-5	HH	1078	2016.06.26	20:55	ROV back on-board

Instrument room ROV observation log - secondary to log made from the deck container

Cruise CAGE 16-5
16 June - 4 July 2016
Chief scientist: Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	12:04	ROV deployed
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	12:34	Bottom reached @ 377 m bsl
Yin Yang	CAGE_16-5	HH	1090	2016.06.28		Multibeam survey started
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	16:28	Large bacterial mats
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	16:33	Lot of mushrooms and anenomes
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	16:39	3 cod
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	16:48	Cable - fishing debris??
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	16:50	Bacterial mat
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	16:54	Bubbles
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	16:56	Lots of shrimps
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	17:01	Anenome field
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	17:10	Carbonate crust?

Yin Yang	CAGE_16-5	HH	1090	2016.06.28	17:15	Anenome field
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	17:21	Many bacterial mats
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	17:25	More bacterial mats
Yin Yang	CAGE_16-5	HH	1090	2016.06.28	17:27	Rov ascending

Cruise CAGE 16-5 Instrument room ROV observation log - secondary to log made from the deck container

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Chief scientist: Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	08:19	ROV deployed
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	08:40	Bottom reached @ 327 m bsl. A lot of cod
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	08:47	Small bacterial mats (this area will be reserved for sampling)
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	08:50	Small bacterial mats
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	08:52	Bacterial mat with anenome & shrimp
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	08:55	Bacterial mat and blocks and anenomes
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	09:02	Dropped marker
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	09:31	Small bacterial mat
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	09:34	Rope
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	09:53	Large bacterial mat (part of photo survey)
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	09:57	Haddock fish
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	10:20	More fishing debris
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	10:22	Bacterial mat (Finished first mosaic area)
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	10:25	Back at marker
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	11:20	Gave up disentangling markers. Small corals? on rocks
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	11:22	Large school of cod constantly obscuring camera view
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	11:37	Large boulders next to precipice
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	11:54	Bubbles
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	11:58	Small bubble stream in bacterial mat

Yin Yang	CAGE_16-5	HH	1106	2016.06.29	12:19	2 bubble streams in bacterial mat (Finished 2nd survey)
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	13:23	Pink jellyfish Periphylla periphylla
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	13:28	Bubbles
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	13:29	Bubble stream
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	13:32	Two bubble streams
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	13:37	Bubbles
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	13:59	Collection of corals on rocks, red fish amongst them
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	14:01	Starfish
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	14:49	Flat fish among corals on rocks. In crater now @343 m
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	14:52	Flat rock collection
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	15:04	Large slab
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	15:10	orange fish; elephant ear, near slabs
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	15:15	Big elephant ear
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	15:17	Sponges closeup
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	15:21	Cracked boulder 2-3m?
Yin Yang	CAGE_16-5	HH	1106	2016.06.29	15:37	Ascending

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Chief scientist: Michael Carroll

Instrument room ROV observation log - secondary to log made from the deck container

Area	Cruise	Ship	Station	Date	UTC time	Observations
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	07:35	ROV deployed
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:00	Bottom reached @ 327 m bsl next to large bacterial mats
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:08	Picked up red-red blade core
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:13	Blade core into bacterial mat @330 m. Not much penetration
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:17	Red-red core into box
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:17	Picked up yellow-black blade core

Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:20	Blade core into same bacterial mat. Slightly more penetration
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:22	Yellow-black core into box
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:23	Picked up blue-red blade core
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:27	Blade core into same bacterial mat. Little penetration
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:30	Second attempt for sediment collection. Bubbles came out
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:34	Picked up yellow-white blade core
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:38	Blade core into adjacent white tufts
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:42	Blade core into box
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:44	Captured a starfish
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	08:48	Ascending with blade cores
Yin Yang	CAGE_16-5	HH	1123	2016.06.30	09:07	Back on board

Cruise CAGE 16-5 Instrument room ROV observation log - secondary to log made from the deck container

16 June - 4 July 2016

Chief scientist: Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	09:37	Dropped push core frame from surface!
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	09:49	Searching for push cores; dead fish
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	09:53	Found push cores!
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:07	Picked up unmarked push core
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:11	Attempt into same mat as used by blade cores. No recovery
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:15	Second attempt into another mat. Bubbles but no recovery
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:17	Third attempt outside mats. Much better penetration, some recovery
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:20	Delivered 1st core to frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:21	Red taped liner stuck in frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:23	Picked up core
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:26	Attempt into white tufts outside bacterial mat. Slightly more

						recovery
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:29	Delivered 2nd core to frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:30	Picked up core "15"
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:35	Attempt into white tufts. Recovered sediments and disturbed bubbles
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:36	Lost sediments. Marker came off
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:40	Second attempt with same core
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:43	Lost sediments again
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:44	Third attempt with same core into white tufts
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:47	Lost sediments again over frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:53	Fourth attempt with third core. Recovered sediment with worms
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:57	Delivered 3rd core to frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	10:59	Picked up red taped liner "9"
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:02	Rocvered sediment
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:04	Dropped sediments
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:06	Recovered sediment outside white tufts. Poor recovery
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:08	Dropped sediments
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:09	Third attempt amongst white tufts next to bacterial mat
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:12	Delivered 4th core to frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:14	Picked up core
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:20	Attempt into bacterial mat. Bubbles released
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:21	Sediment dropped out
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:24	Second attempt outside bacterial mat
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:27	Delivered 5th core to frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:37	Hooked on to frame
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	11:39	Ascending
Yin Yang	CAGE_16-5	HH	1124	2016.06.30	12:03	Back on board

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Area	Cruise	Ship	Station	Date	UTC time	Observations
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	13:45	Entered water - zarges box upside down during descent
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:05	ROV at bottom @329 m
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:21	Box set on ground
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:28	Pick up yellow-black blade 2
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:41	Sampled within white tufts. Broken?
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:45	Returned to box
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:46	Picked up red-red core 3
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:48	Sampled within same white tufts. Not much penetration
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	14:49	Knocked over zarges box
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	15:14	Returned red-red blade 3 to box
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	15:15	Picked up red-black core 1
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	15:18	Penetrate new white tufts. Some sediments collected
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	15:22	Picked up yellow-white core 4
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	15:23	Resonable penetration amongst white tufts. Spider.
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	15:26	Returned core 4 to box
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	15:40	Caught handle and ascending
Yin Yang	CAGE_16-5	HH	1125	2016.06.30	16:00	Back on board

Instrument room ROV observation log - secondary to log made from the deck container

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Chief scientist: Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations

Yin Yang	CAGE_16-5	HH	1128	2016.06.30	06:50	ROV deployed
Yin Yang	CAGE_16-5	HH	1128	2016.06.30	07:20	Searching for the twin gas flares
Yin Yang	CAGE_16-5	HH	1128	2016.06.30	08:21	Fired niskin bottle for collection
Yin Yang	CAGE_16-5	HH	1128	2016.06.30	08:54	Filled with gas to marker
Yin Yang	CAGE_16-5	HH	1128	2016.06.30	09:10	Ascending

Instrument room ROV observation log - secondary to log made from the deck container

Cruise CAGE 16-5
16 June - 4 July
2016
Chief scientist:
Michael Carroll

Area	Cruise	Ship	Station	Date	UTC time	Observations
Yin Yang	CAGE_16-5	HH	1129	2016.06.30	10:15	ROV deployed
Yin Yang	CAGE_16-5	HH	1129	2016.06.30	10:35	On sea floor @324m, searching for flare
Yin Yang	CAGE_16-5	HH	1129	2016.06.30	10:45	Collecting gas
Yin Yang	CAGE_16-5	HH	1129	2016.06.30	11:36	Gas below marker
Yin Yang	CAGE_16-5	HH	1129	2016.06.30	11:41	Ascending

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Instrument room ROV observation log - secondary to log made from the deck container

Area	Cruise	Ship	Station	Date	UTC time	Observations
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	08:52	ROV deployed
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	09:12	On sea floor @345m
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	09:18	Dropped marker
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	09:27	Start photomosaic survey. Already a lot of fish
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	09:39	Stacked big slabs

Yin Yang	CAGE_16-5	HH	1138	2016.07.02	09:57	Lots of swimming shrimp
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	09:58	Big slab boulders
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	10:02	Group of stacked boulders with many anenome and sponges
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	10:05	Navigating around boulder; elephant ears
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	10:12	Wire cable of ROV - retreating round boulder
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	10:20	Ascending to sort out cable tanglement
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	10:48	Close-up of biology on same slabs
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	10:58	Close-up of large elephant ear sponge
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	11:00	Ascending to 312 m
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	11:06	Back onto boulders
Yin Yang	CAGE_16-5	HH	1138	2016.07.02	11:11	Ascending to 303m and to surface

10 References

Berndt, C., T. Feseker, T. Treude, S. Krastel, V. Liebetrau, H. Niemann, V.J. Bertics, I. Dumke, K. Dünnbier, B. Ferré, C. Graves, F. Gross, K. Hissmann, V. Hühnerbach, S. Krause, K. Lieser, J. Schauer, and L. Steinle. 2014. Temporal Constraints on Hydrate-Controlled Methane Seepage off Svalbard. Science **343**: 284-287.

Knittel, K., and Boetius, A.: Anaerobic Oxidation of Methane: Progress with an Unknown Process, Annu. Rev. Microbiol., 63, 311-334, 2009.

Niemann, H., Steinle, L., Blees, J. H., Krause, S., Bussmann, I., Treude, T., and Lehmann, M. F.: Toxic effects of butyl elastomers on aerobic methane oxidation, Limnolog and Oceanography: Methods, 13, 40-52, 2015.

Pernthaler, A., and J. Pernthaler. 2007. Fluorescence in situ hybridization for the identification of environmental microbes. Methods in Molecular Biology **353**: 153-164

Reeburgh, W. S. 2007. Oceanic methane biogeochemistry. Chem. Rev. **107**: 486-513

Steinle, L., Graves, C. A., Treude, T., Ferre, B., Biastoch, A., Bussmann, I., Berndt, C., Krastel, S., James, R. H., Behrens, E., Boning, C. W., Greinert, J., Sapart, C. -J., Scheinert, M., Sommer, S., Lehmann, M. F., and Niemann, H.: Water column methanotrophy controlled by a rapid oceanographic switch, Nat. Geosci., 8, 378-382, 2015.

Treude, T., Boetius, A., Knittel, K., Wallmann, K., and Jørgensen, B. B.: Anaerobic oxidation of methane above gas hydrates at Hydrate Ridge, NE Pacific Ocean, Mar. Ecol.-Prog. Ser., 264, 1-14, 2003.

11 Appendix:

Additional cruise report from the AMOS ROV team with additional perspective on the ROV operations.

NTNU

Norwegian University of
Science and Technology

Centre for Arctic Gas Hydrate, Environment and Climate (CAGE) Cruise

Pedro De La Torre

June 15th to July 5th 2016

Contents

0.1 Cruise information

0.1.1 Cruise Participants

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Table 1: participants

0.1.2 Research sites

Data collection and sampling were performed in three main sites: Prins Karls Forland area located to the west of Svalbard, Pingos area roughly southwest and the Craters area roughly southeast of the archipelago. These sites were selected due to their geological relevance and biochemical activities already reported.

The cruise occurs in the middle of the summer with the equinox happening in the first week and no sunset due to the latitude of the research areas. Overall, the weather was suitable for research with two days of cloud free, sunny skies and the rest 100% cloud covered. Only a pair of nights with slight rain. Besides from the last day of the cruise, were winds exceeded 15m/s, most of the cruise remainded relatively calm under 10m/s and waves no larger than 1m.

The waters surrounding the vessel were visited by humpback whales, white nose dolphins, seagulls and sea frigates among others.

Figure 1: Research vessel Helmer Hanssen that belongs to the University of Tromsø, as seen from the starboard aft side

0.1.3 Equipment

Research Vessel

The expedition was on board the research vessel Helmer Hanssen from the University of Tromsø. It is shown on picture 1. Captain Per Kristian and his crew . Some members of the crew that I had the chance to work with are: Jan Rual, Eivind, Nils, Petter, Ronny and Ingu Ida.

The ROV and its different enabling parts were installed as shown in the diagram on figure 2. An anchor was taken on board specifically for the purpose of enabling Helmer Hansen to hold a constant position. It was successfully tested at the beginning of the cruise. Additionally, a 12m long pole was installed on the port side of the ship. The transponder head was installed on one end of the pole and then submerged and located under the vessels hull. The ROV was deployed from the starboard side. This arrangement worked effectively during the whole cruise.

ROV

NTNU provided a Sperre Subfighter 30K remotely operated vehicle for the survey. It is shown in figure 3. The payload of the ROV depended on the type of activity to be done in each dive. The following list indicates some of the instruments used to deliver scientific data to the research team.

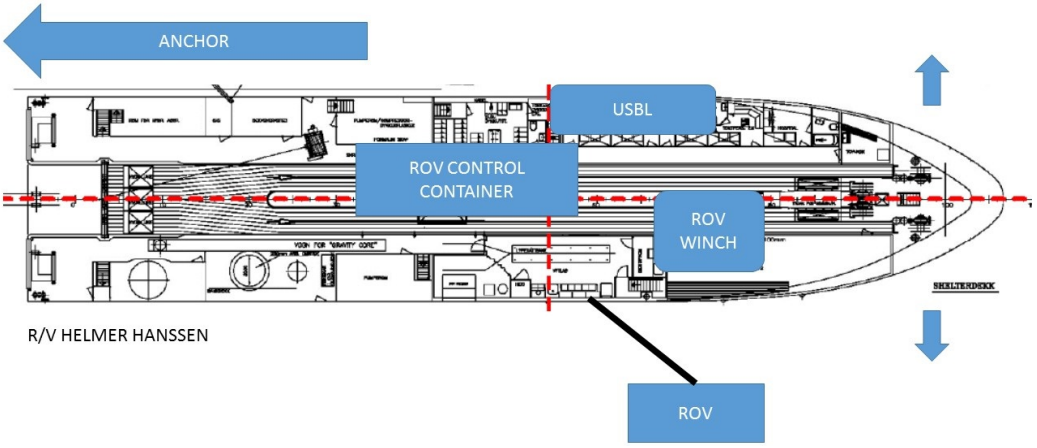

Figure 2: Installation diagram for the 30k ROV on RV Helmer Hansen. The ship anchored from the aft. The USBL was installed with a pole on the port side for every dive. The winch at the center let cable out to the ROV on the starboard side while the control room was located one deck under it.

- A gas sampler: a metallic funnel that when placed over gas flares consentrates the gas into a plastic bottle which then is transferred to a pressurized metallic sampling bottle activated remotely by the ROV operator.
- Picking claw: a longitudinal actuator opens and closes a three finger claw capable of grabbing a carbonate crust or a slab and bring it to the surface.
- Niskin bottles: a frame with 4 niskin bottles collected water at specific sites selected by visual reconaisance of the area. The mechanism consisted in triggering the four bottles at the same time with an actuator and a string to each bottle.
- HD camera. The high definition camera provided quality video useful to identify the water column and seafloor features of the research sites.
- Norbit Multibeam. The ROV-based multibeam provided high resolution acoustic imaging of the area. In combination with the software hypack, the surveyor is capable to geolocate the data gathered and identify prominent features from it.
- Phins intertial navigation system. This high precision INS provided feedback on motion to the multibeam to create high quality acoustic data.

- Valport pressure sensor. The main measurement of depth on the ROV.

- Workhorse doppler velocity log. The DVL measures the altitude at which the ROV swims and the speed at which it moves. In combination with NTNUs AUR lab control system software, it enables the ROV to hold position, maintain a constant altitude of follow a preprogramed pattern,

- Raptor Arm. On the ROV, this 7 degrees of motion actuator enables the ROV team to take or bring objects to or from the bottom or use instruments to collect samples.

- Applied Acoustic Systems Easy Track ultra short base line positioning system. the USBL system was used to reveal the position of the ROV with respect to the vessel during a dive.

- Multiple push cores rack. Enabled the ROV to bring a maximum of six push cores in one single dive. Buoyancy was adjusted to minimize its weight.

- Multiple blade-core box. Provided means to transport up to four blade cores in a single dive without the large weight that the provided transport cases had.

Figure 3: The remotely operated vehicle 30k on Helmer Hanssen's deck with the gas sampler and the claw for geological research.

0.2 Daily Reports

0.2.1 160615 - Arrival to Longyearbyen

F. Volden, S. Nornes, B. Krogh and I arrived at Longyearbyen around 1300h. We met M. Carroll at the airplane. We then took a taxi to RV Helmer Hanssen that was in the Pole Position port at Svalbard. ROV containers were laying outside of HH. The boxes that I had shipped a few days ago were already inside. We mobilized the control room and winch and ROV containers. Then we visited Longyearbyen for a pair of hours. Dinner at 1800h with cruise participants. Back to HH to setup ROV. Fixed the connectors for the power cable (125A, 220V). We powered the ROV and got video in the control room. However, we were not able to communicate with the ROV through the yellow control panel on the pilots seat. We started looking for the source of the problem. We stopped around 23h with more work to be done.

0.2.2 160616 - Setup and debugging of a control panel error

S. Nornes and F. Volden began activities by testing the control panel (refer to the picture 4). I installed the INS, multibeam, and adjusted the DVL on the ROV. Then proceeded to software setup together with B. Krogh. We

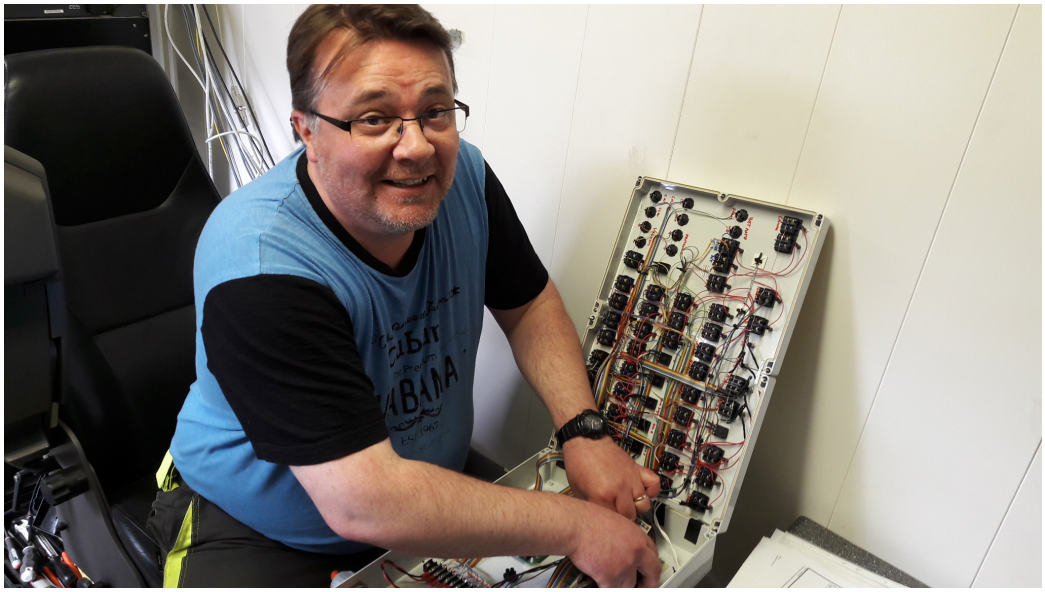

Figure 4: F. Volden debugs the ROV control panel to find the reason why it is not working.

setup the Phins sensors input and output, multibeam and the network to the ship and the ROV to be fed to Hypack for the survey. The control panel issue was narrowed down to a failure in the electronics card. A new one was ordered from Sperre AS. The bracket for the multibeam was also sent to the Pole Position headquarters. The ROV was nonoperational, however activities continued to set the rest up until our first scientific meeting at 2000h. We had a safety talk with Nils from HH.

0.2.3 160617 - Testing of new equipment for the ROV

We received both the new card and multibeam mounting bracket early in the morning. The new card did not fix our control issue. Frode and I continued debugging the controller issue while Stein set the stereo cameras and AUR lab control system up. Operational meeting with crew and M. Carroll about ROV operations. After a thorough debugging session, the issue was believed to be located somewhere between the pilots control and the connection to the remote controller. The problem was fixed, nevertheless, the exact cause could not be determined.

The team proceeded to test the ROV's arm. During the first three attempts, the Raptor arm draw over 60A of electrical current and the electrical safety switch triggered. This was fixed by running the hydraulic pump for at

least 5min and letting the newly changed oil run in the system. Then the gas sampler and the pick up claw were tested for functionality interoperabitilty with the ROV. Buoyancy floats were installed on them to reduce some of their weight in the water. The ship-based USBL system was reported faulty. ROV test deployment was postponed at least for two days. Daily meeting at 2030h. Gravity coring and additional CTD sampling were setup while the USBL spare part that was ordered arrived.

0.2.4 160618 - found the bug

After breakfast we had a brief meeting in the instrument room. The plan was to do CTD stations, core sampling, box core and multinet sampling throughout the day at Prins Karl Forland site (as shown in fig 5) . Then I found S. Nornes in the control room with the ROV turned on. The control problem persisted. So, we set ourselves to the task of finding the source of the problem and fix it. F. Volden also joined. After several hours of testing every single wire, with a modification to the control system that showed when the microcontroller sent strings to the ROV, S. Nornes discovered a cable that looked in good shape but was loosely connected and hampered communication with it. After welding it properly, a new connection for the control system was installed and the ROV, including the arm where successfully tested. Scientific activities were ongoing and continued the whole day. ROV team continued to check the overall status of our instruments. A photo of S Nornes (6) shows him working hard on the ROV, from the vehicle's own camera.

0.2.5 160619 - dive 1 and first positioning trial

We came to Longyearbyen's port early in the morning but there were no ports available for docking. Bjørn Runar and team went on shore to pick up a new USBL head from the airport. A 12m long pole was improvised from laminate metal to install the USBL under the ships hull. It was made with around 10 aluminum profiles bolted to each other. A wooden beam was installed across at one end of the pole, and another one 3m under the first to ease installation of the long pole on the ships side.

After the instrument arrived, HHs crew and ROV operators worked to install the USBL safely. The Easy Track processing unit was brought into the ROV container because the cable was not long enough to reach the instrument room. With the main crane the crew fixed the pole to the port side and minimized motion with 4 ropes: 2 on each side of the pole tied it towards the bow and two towards the aft.

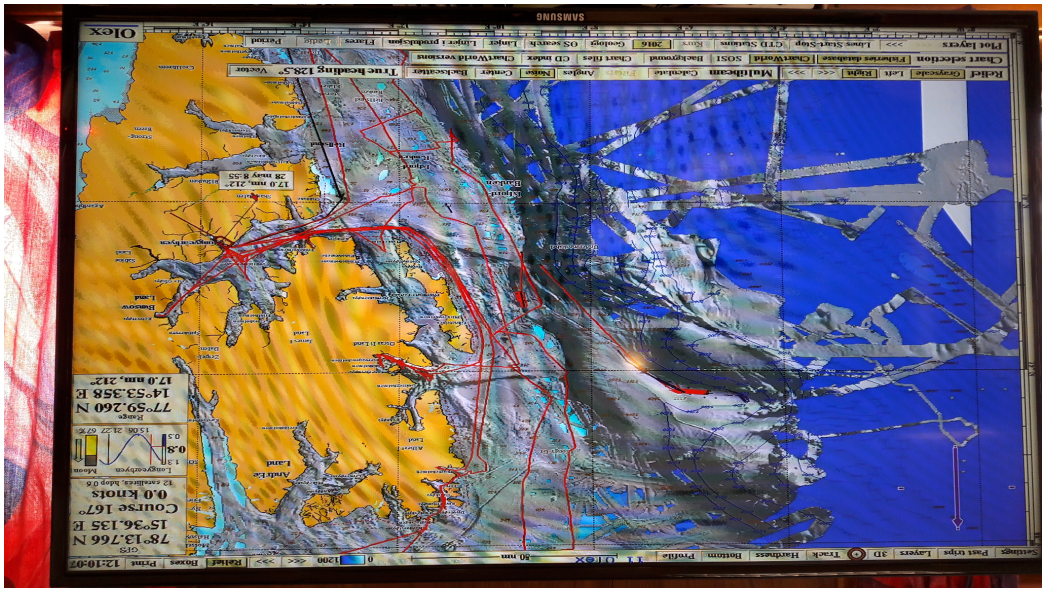

Figure 5: Prins Karl Forland research site where coring and CTD samples were taken.

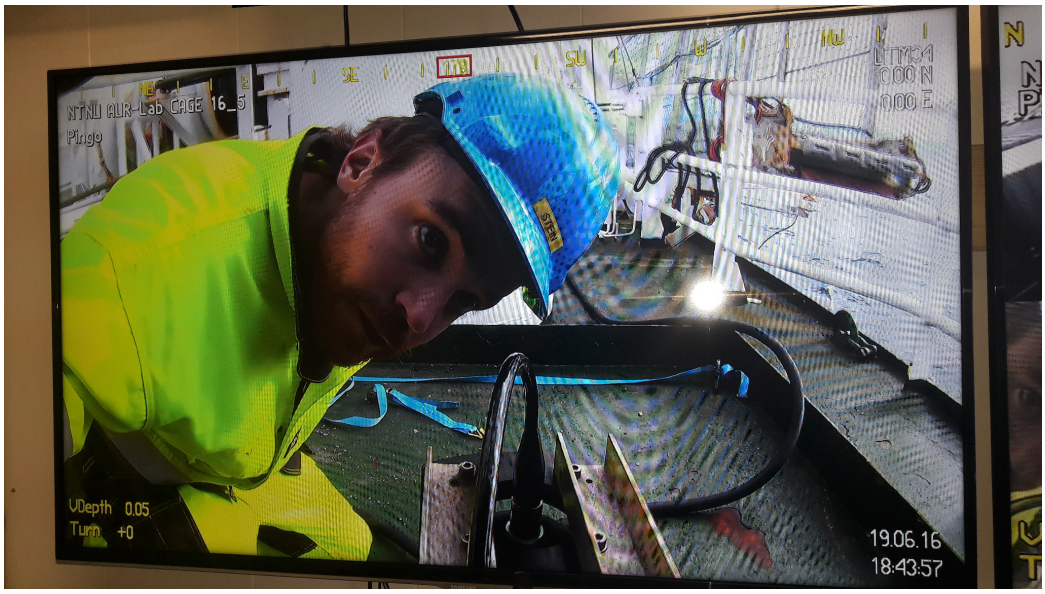

Figure 6: Stein getting the ROV ready for operation.

The ROV was then prepared and set in the water (dive 1) to install an acoustic beacon for calibration of the USBL. F. Volden pilot, S. Nornes copilot, P. De La Torre winch and arm man. During the descent, at approximately 200m, some of the ROV systems, including the HD camera, pan and tilt and the arm, lost power. Additionally, the acoustic beacon installed on the ROV lost communication for almost the whole ascent. Careful winch handling and ROV compass navigation were necessary to bring the ROV back on board. The performance of the USBL did not meet the navigation requirements of the ROV and compromised the safety of its operation by increasing the risk of umbilical entanglement in the propellers. The pole broke when it was being removed to be fixed. The crew's decision was to go back to port to find material to design a fit solution to the USBL installment.

0.2.6 160620 - standby for USBL frame

HH came into Longyearbyen approximately at 0800h. Bjørn and crew went on land looking for material useful to install the USBL. They identified a pair of square steel pipes 6m long each. They also ordered a pair of brackets to hold the pipe to the ship. It took the whole day for everything to be delivered and brought on board. In the ROV, S. Nornes worked on getting the positioning string distributed to the Phins and Navipack. One problem faced was that Phins did not identify the USBL when Navipack did because of a format conflict, i.e. georeferenced vs ship-based reference. I worked in the ROVs cabling. Some of the lines going out from the main instruments cylinder were stressed by either other cables or by the way they had being tied against the frame. Then, we installed the blue cover on the ROV to protect it from coal dust blowing from land. I walked to the city and back to buy a beanie that protects against the wind. During the night HHs crew welded the pole brackets against HH port side and installed the pipe with the acoustic positioning system.

0.2.7 160621 - Successful dive 2 and beacon recovery

At 0600h the USBL was installed and the calibration process for the USBL started, leaded by B. Krogh. The ship drove a triangular path around the acoustic beacon that was left in the bottom by the ROV on 160619. Following this activity, the ROV was set in the water to pick up the transponder (dive 2). Same ROV crew setup as on dive 1. The dive was effective and did not report errors. Visibility was low, approx 2m. The beacon was brought on board in good shape. HHs crew proceeded to uninstall the USBL pole so that we could begin transit to the station which would take about 19h.


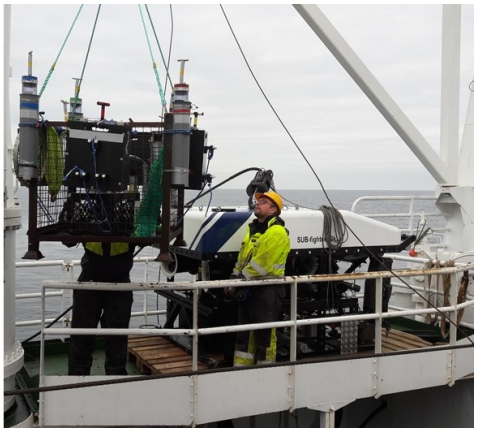

Figure 7: The cage was well equipped with blade cores, push cores and nets, four of each, a time lapse camera and markers.

0.2.8 160622 - dense sampling

Arrived to Pingos site at 0600h. Ship-based multibeam until 1000h. Dive site defined around a pingo and gas flares. Scientists and ROV equipped the sampling basket with 4 push cores, 4 blade cores, one time lapse camera, 4 nets and two markers. Picture 7 illustrates the fully equipped basket.

The first ROV dive (dive 3) was a reconaissance dive to identify features in the seabed. The dive revealed sandy substrate with potential for coring and biological sample taking.

For the next dive (dive 4) the basket was first sent to the bottom at 380m with the scrape winch. Then the ROV followed. First, the ROV disconnected the cable from the basket and the basket cable was retrieved. The ROV took the time lapse camera out and set it in an area with high bacterial and worm activity. 3 push core samples were taken and two blade cores around the largest identified flare, west from the sampling site.

The basket's cable was sent down, this time with a transponder attached to it, a 4kg weight, a 10m long "'stinger"' line and a ROV-hook open at the end. It was challenging and risky to find the end of the cable on the bottom with the vehicle. However, the basket was hooked and retrieved without any line entanglement :). ROV proceeded to ascend. USBL navigation was unstable in the order of 50m to 100m and the ROV surfaced in front of HH. ROV back on deck around 0200.

0.2.9 160623 - Gas sampling

Multinet and CTD stations during the early morning. The ROV was equipped with gas sampler. It was installed in the bow, tied to the lower bow frame beam and the Raptor held it by the T-handle. Two Niskin bottles were installed to the starboard side of the 30k. The rope-based triggering system made it risky to be deployed, so water sampling was postponed. (Dive 5) Navigation with around 75% of screen blocked by the funnel. Landed ROV for first sampling attempt: stirred bottom. Second attempt hovering, and missed the flare afterward. Final attempt hovering 2m to 3m above the flare. The funnel filled up with gas in a matter of seconds. The valve was opened and closed, and started immediate ascent. ROV on deck at 0300h. Then, J. Faust confirmed that the gas sample was lost and only water was brought on board :(. Multinet and gravity cores followed the ROV dive.

0.2.10 160624 - gas 2 and multibeam

A leak was found in the pipeline following the actuator operated valve before the sampling bottle. The fittings were reinforced with PVC tape. The pipeline was pressurized to find out if there were more leaks. A second leak was found. This one was sealed with Loctite after cleaning it with rust-removing spray. The gas sampler was installed in the same configuration to the ROV. A frame with capacity for four Niskin bottles was developed and installed on the outside of the ROV port side, as shown in fig 8. This version had minimized the ropes length and the bottles were triggered with an actuator. ROV was deployed at 2200h (Dive 6). The flare was found and sampled with higher time efficiency than the previous attempt. The Niskin bottles triggered successfully on top of the gas plume. A stereo camera was used to observe them triggering. Gas and water samples were successfully brought on board around 0000. J. Faust was very happy to hear the pressure release as the sample cylinder was released. (see figs 8and 9).

0.2.11 160625 - Photomosaic Pingo 3

The team proceeded to equip ROV with the multibeam, adjust pressure compensator and ROV buoyancy. ROV in water at 0100 (Dive 7). First, we found the flare and landed next to it to record the bubble stream with a chess pattern on the background for about 5min. We then moved on to find the time lapse camera and leave the checkboard frame with it. It was down there when the team found out that the checkboard floated, so the multibeam survey continued with the board held by the raptor. Strong westward current

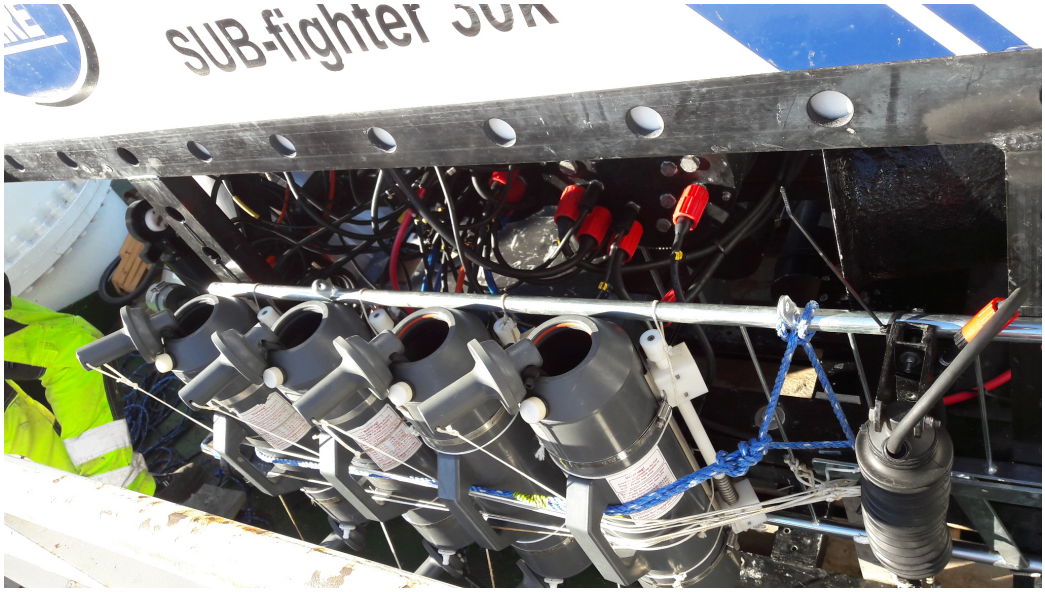

Figure 8: A four-Niskin bottles module installed on the port side of the ROV and triggered with a linear actuator.

Figure 9: Johan celebrates his gas sample

pushed the cable under the ship!. 30m transect in 1 hour. Ascent started at 0230h. Multibeam data, and chess board recovered succesfully.

Box core and multicore sampling ongoing in the morning. Dive briefing: anchored ship heading south. ROV deployment (dive 8) on starboard with photomosaic sampling area located within 150 to 200m away from the ship. Objectives: deployment of two markers, followed by photomosaic and retrieval of camera.

The ROV was set in the water at 1800h (dive 9), after the niskin bottles and multibeam were removed and the stereo cameras installed for photomosaic of Pingo 3. Strong current from the east did not allow the area to the east of the Pingo to be photographed. An alternative area south from it was selected. The visibility was poor and the cameras had problems with focus. Automatic altitude control worked successfully but it was not possible to follow a pattern due to a combination of poor positioning from the USBL and strength of the current. During the scan, evidence of box core, multi core, blade core and ROV landings were discovered on the muddy bottom. After approximately 4 hours of looking for a suitable site and scanning it, ROV proceeded to pick up the time lapse camera. ROV was back on deck at 0100h.

0.2.12 160626 - Photomosaic Pingo 5

The time lapse camera was tilted inside its pressure cylinder and the captured video reveals current and only 10% of the screen some floor activity. It was decided to deploy it again.

The ROV was back in water at 0600h (dive 10) at Pingo 5(76◦ 6.70073'N 16◦ 0.35962'E). Low current at bottom and better visibility with respect to the previous dive. The timelapse camera deployment followed by 3 photomosaic areas located at east, west and south somewhere in a radius of 20m from the center. Bacterial mats, a *Peryphila peryphila*, wolffish (steinbit), cod (torsk), haddock (hise), halibut (kveita) and plaice(like a flounder). In addition, large crusts were identified. After retrieving the camera, the ROV was back on deck at 0930h. Debriefing: setup claw and prepare nets. Preparation for the dive began after ship based multibeam around 1900h. The claw was fixed at the beam of the ROV and the arm was used to control and adjust its position. 45kg of weight were removed from the chasis. In the next dive (dive 11), a crust was collected from the "'anemone garden"' at Pingo 3 and brought on board after a 90min dive. The ROV was then equipped with a net to scoop the soft bottom in search for worms and other types of living specimens (dive 12). Four scoops were taken from different sites and brought on board. A Sen and E. Åstrom showed me pictures of the worms

that are no thicker than 0.5mm. A dive for multibeam was planned for next days morning.

0.2.13 160627 - multibeam pingo 3

ROV at 380m at 0830h for multibeam (dive 13). two hours dive = 4.5 100m long transects with one of them perpendicular to all the others. B. Krogh to analyze the data. ROV on deck at 1100h and secured for the sea. Cruise to crater site began after recovering USBL.

0.2.14 160628 - multibeam crater

HH reached the crater site at 1000h and continued with a ship-based-multibeam. The data revealed a site with a crater and a pingo next to it and the mission for the ROV was set to swim transects with the multibeam and then a video survey of it. ROV in the water (dive 14) after an early lunch and back on board by dinner time. The 6h dive revealed steep walls, areas with large biodiversity including abundance of anemones and bacterial mats. It was difficult to find gas flares, at least not like those in the Pingo 3 area. However, some gas releases were observed during the dive. The cruise continued with a plan for 10ctds and multinets.

0.2.15 160629 - photomosaics crater

We had prepared the ROV for photomosaics early in the morning after breakfast, as planned the previous night. However, we had to install the multibeam again to repeat one of the lines from the previous survey. B. Krogh requested it. After a brief dive for the acoustic survery (dive 15), the ROV was brought on board and equipped for photomosaics. Three markers were carried down (dive 16) with the arm to be set in the photographed area. The three markers were set together in the bottom, at the ridge of the "'Ying Yang"' site, as S. Nornes named it. The three photomosaics were driven by S. Nornes using a combination of altitude control and autonomous navigation. In the meanwhile, the blade-core and push-cores deployment systems were being prepared. The dive was almost 6 hours long. Many fish in the bottom of the ocean made it difficult to photomosaic the area. Additionally, the release system of the multiple marker system did not work and the markers could not be separated from each other even after a dense 30min of knot untying attempts with the arm.

0.2.16 160630 - multiple coring instruments

The ROV touched water around 1000 (dive 17) equipped with the modified Zarges box that contained four blade cores (see fig. 10). This happened after the last multinet of the cruise was retrieved. In the bottom, the first attempt to obtain sea floor sediments revealed a thin layer of soft material followed by a hard one that could not be penetrated. The core triggered itself without getting a good sample, but only an idea of the substrate faced by the team. The second attempt scratched a dark bacterial patch from which snails were discovered. Samples three and four collected around 10cm of sediment. The newly designed blade-core transport box allowed a smooth set of each individual sample in its space.

The second dive (dive 18) was for push-core sampling. Several tests were made to find an appropriate distribution for the buoyancy on a rack that contained six push core cylinders. An open hook was installed on the bow boom of the ROV to hold the weight of this rack which was about 66kg dry and around 10kg in water. The rack was in addition equipped with a Tbar to hold it stable with the arm. The problem was that the arm held the frame higher than it was planned, so when the ROV touched the water, the frame unhooked from the ROV. The claw was opened and thenegatively buoyant frame sank. The ROV dove fast to the bottom and using the sonar and careful navigation the frame was found in good shape and with all the cores in place. Several push cores had to be repeated because the penetrable layer had so soft sediments that they fell out from the cylinder before being set into its transport cylinders. However, some cores were obtained from white, black and brown sediments indicating snail presence, sulfates and untouched (control samples) areas, respectively. Notewhorthy, four Niskin bottles collected water before each of the two dives for blade and push core dives.

The third and final dive of the day (dive 19) was set for blade cores again. A newly installed safety string prevented the blade cores from falling out of the box. This was a risk noted in the first dive. The string proved itself useful immediately as the ROV touched the water. The transport case capsized and all the bladecores would have fallen out if such a string had not been installed. The descent continued with the capsized transport case and sat correctly at the bottom.

In this dive the first blade core triggered only on one side before the triggering line snapped. the second one seemed not to penetrate deeply before it was triggered. Only the fourth blade core looked like it had a good sample in it. The transport case tipped on its side during the dive and it needed to be accommodated properly. The samples were brought on board

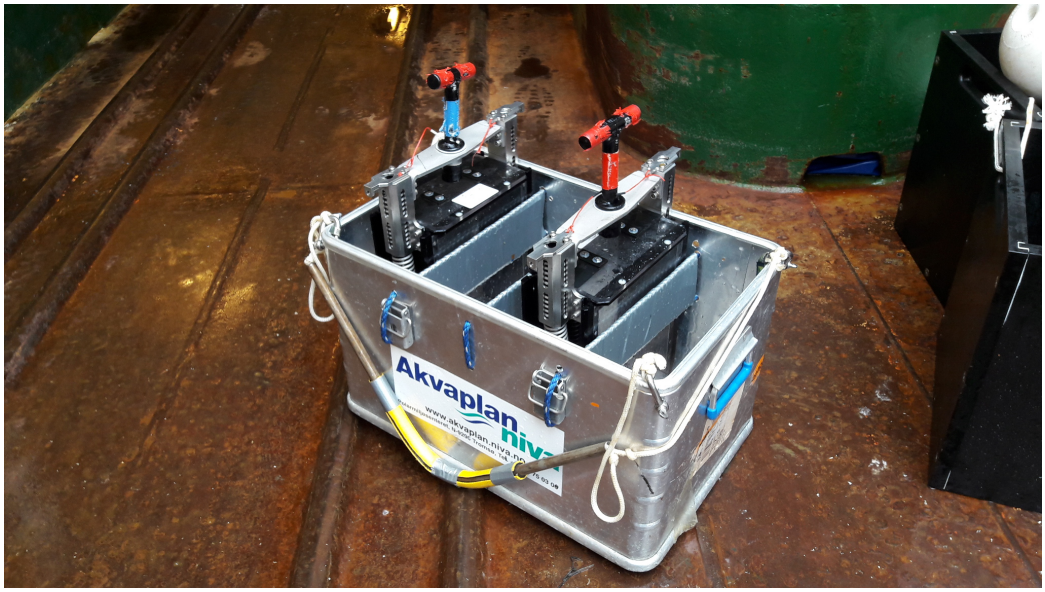

Figure 10: The blade core transport case with capacity for four samplers at a time.

and Scott and Helge confirmed that there was good material for research in them, despite how much agitation these samples went through during the dive and on their way up.

0.2.17 160701 - gas, core and multibeam patch test

Early morning was assigned for calibration of the ship based multibeam. The gas sampler was set into the ROVs boom and the arm held it away from the chasis. ROV held position over the gas flare (dive 20) with the DVL-based dead reckoning and altitude control of 1m. One hour was necessary to collect enough gas for the bottle. Additionally, 4 niskin bottles of water were sampled on top of the flare immediately after the gas was collected. A second dive (dive 21) was done to fill up the second bottle with gas and 4 more niskins for the plankton ecologists. After lunch, the ROV was equipped with the claw. The ROV was driven into the bottom of the crater to collect a squared slab of around 50cm by side (dive 22). It had some macrofauna useful for the biologists on it. The complexity of this operation was related to the slabs being flat and therefore difficult for the three fingers of the claw to grab. The final dive of the day (dive 23) was a patch test calibration for Hypack and the multibeam. A set of lines were flown with the ROV accounting for distance and heading. Altitude control was used for the purpose.

Figure 11: The pushcore rack was hung from the hook at the ROVs boom and then the arm held it from the Tbar installed for this purpose.

0.2.18 160702 - checkboard, photomosaic and multibeam

Diving (Dive 25) today began with the chess board in the arm of the ROV. The site of the flares was reached without major trouble. The ROV landed next to a sandy area from were a small amount of gas was released from time to time. It kept there for about 15min. Then the ROV was moved to a second site. This one was characterized for having more than only one spot from were gas was being released. The board was set as background as a reference for bubble size and quantity measurements from the HD video. The second dive was dedicated to a photomosaic of the bottom of the crater (dive 26). A marker was installed in the photographed area. Large features were identified from the recently revealed data for the ROV-based multibeam . From the the actual survey these features were confirmed to be large rocks. In addition to the zig-zag pattern, these rocks were filmed all over. The umbilical cable got around one of these rocky aggregations. It was carefully released with no major consequences. Finally, the ROV was equipped with the multibeam, to run a pair of transect lines at the furthest south point of the crater. They were covered in a couple of hours (dive 27). Before starting the ascent, the umbilical cable was sent all out and coiled in carefully. ROV was back on board at 1700h. Packing activities were ongoing on deck during dives both for the ships crew and scientific teams.

0.3 Conclusion

The CAGE cruise (University of Tromsø) from June 15th to July 04th 2016 studied three areas in the area surrounding Svalbard: Prins Karls Forland, Pingos, and Craters site. Traditional sampling methods, and use of modern technology resulted in a multidisciplinary research approach to these sites.

Niskin bottles for water sampling, multiple coring methods and trawling for seafloor sediments collection, multi-nets for plankton, acoustic and video surveys were used to analyze the areas of interest. Twenty seven dives with NTNUs remotely operated vehicle "'30k"' provided high definition video of the seafloor and water column, high resolution multibeam surveys, seafloor sediment, crusts and slabs, water and gas samples, a diversity of micro and macro fauna specimens and overall provided an insight into the geological features known as the pingos and the craters that is new to the scientific world. This material provides evidence that furthers our understanding in various fields of science.

The experiences obtained from the methods and techniques used to study these sites are of high value for possible future cooperative research within the teams described. The equipment reports no major damages, however, rutinary maintenance will be necessary after the demanding set of activities to which it was exposed. The cruise concluded with no personal injuries.