RV Kronprins Håkon (cruise no. 2019708)
Longyearbyen – Longyearbyen
19.09. – 16.10.2019

Photo: Ana Hilario

Edited by

Stefan Bünz[1] and Eva Ramirez-Llodra[2]

with contributions from all HACON cruise participants

[1] UiT The Arctic University of Norway

[2] Norwegian Institute for water Research

16.10.2019

PREFACE

The HACON cruise is a major component of the FRINATEK HACON project, which aims at investigating the role of the Gakkel Ridge and Arctic Ocean in biological connectivity amongst ocean basins and global biogeography of chemosynthetic ecosystems. The HACON study area is centered in the Aurora seamount and Aurora vent field. During the ChEss-Census of Marine Life programme (2000-2010), the Gakkel Ridge was identified as a key study area to contribute to the global biogeographic puzzle for hydrothermal vent communities (Ramirez-Llodra et al., 2007). Although the environmental, technological and economic challenges of working at great depths in complex topographic terrain under Arctic ice has constrained exploration and investigation of the Gakkel Ridge for decades, each research cruise to this remote region provides new information to better understand the composition and functioning of the Gakkel Ridge and its associated communities. The AMORE 2001 expedition located the Aurora vent field through the detection of the buoyant plume and the dredging of an extinct sulphide chimney (Edmonds et al., 2003). In 2014, the Polarstern (PS86) 2014 cruise observed the first black smoker in the Aurora vent field during an OFOBS (Ocean Floor Observation and Bathymetry System) transect conducted on the last day of a 5-week cruise. Only 1 image and less than 1 min of video of the black smoker could be gathered at the time (Boetius et al., 2014).

The FRINATEK programme funded by the Norwegian Research Council provides the necessary funding framework from which to develop high risk-high gain projects that, if successful, can greatly advance science and move forward the frontiers of science and knowledge in challenging deep-sea environments. It is in this framework that the HACON project is being developed. In Sept-Oct 2019, the HACON cruise, investigated the Aurora seamount and vent field situated at the western end of the Gakkel Ridge, providing additional data on the system and its communities. This cruise, as previous ones into the Arctic Ocean, has faced many challenges. For reasons external to the project, a decision was made only a few days before mobilisation that prevented the ROV Ægir from joining the cruise as originally planned. The WHOI NUI hybrid ROV/AUV was on board, but technical failures resulted in the vehicle not reaching the vent site at 3 occasions. This was followed by physical obstruction from sea ice to the study area, when a large ice floe stayed stationary over the vent site, not allowing for a final NUI dive to sample the hydrothermal vents. Nevertheless, the cruise has been a success. Four OFOBS dives had transects over the vent field, with 3 of the dives producing excellent images. We have now information on 3 different black smokers from the Aurora vent site. The systematic analysis of the video and stills data from the OFOBS transects will provide new knowledge on the biological communities of the vent fauna, and the imagery data together with the water column and benthic samples will greatly increase our understanding of the composition and functioning of the Aurora seamount and vent field. The results will also provide an excellent basis from which to return to Aurora for additional investigations and sampling.

In addition to the science conducted on board, the HACON cruise been a great success in terms of national and international collaboration amongst teams with different expertise, from physical oceanography to geology and geochemistry, ecology and engineering. The excellent collaborative atmosphere on board has facilitated the sharing of samples amongst groups and the development of technological solutions on board to address some of the challenges. These activities have strongly strengthened existing collaborations, as well as establishing new collaborations, amongst many of the teams from the different national and international institutions. The cruise has also provided a unique opportunity to several early career postdocs (4), PhDs (3) and MSc (1) students to further develop their skills, at the same time that they greatly contributed to the cruise with their dedication, knowledge and enthusiasm. The cruise also benefited from the presence of additional collaborators interested in the Arctic Ocean from different perspectives. Colleagues from NASA-JPL joined the cruise to sample the sea ice in a project related to developing methodology for the search of life in outer space. In parallel, colleagues from National Geographic Magazine and the Avatar Alliance Foundation were on board to gather material for communication projects related to the HACON investigations and related activities form WHOI and NASA-JPL.

Table of Contents

1 PARTICIPANT LIST

Stefan Bünz	CAGE, UiT	Chief Scientist
Eva Ramirez-Llodra	NIVA & REV Ocean	Co-Chief Scientist
Lissette Victorero	NIVA/UAVR	Deep-Sea Ecology
Benedicte Ferre	CAGE, UiT	Water Column, Oceanography
Giuliana Panieri	CAGE, UiT	Micropaleontology
Pierre- Antoine Dessandier	CAGE, UiT	Micropaleontology
Dimitri Kalenitchenko	CAGE, UiT	Ice, Water Microbiology
Fatih Sert	CAGE, UiT	Water Column, Oceanography
Hans Tore Rapp	UiB	Marine Ecology & taxonomy
Ida Steen	UiB	Microbiology
Eoghan Reeves	UiB	Fluid Geochemistry
Eva Maria Meckel	University of Oldenburg/UiB	Fluid Geochemistry
Achim Mall	UiB	Microbiology
Pedro Ribeiro	UiB	Marine Biology
Håkon Dahle	UiB	Microbiology
Francesca Vulcano	UiB	Microbiology
Tina Kutti	IMR	Benthic Ecosystems
Christopher German	WHOI	Geochemistry
Kevin Hand	NASA-JPL	Ice coring, Astrobiology
Andrew Klesh	NASA-JPL	Ice coring, Robotics
Autun Purser	AWI	Marine Biology, Ecology
Ulrich Hoge	AWI	OFOBS Engineer
Ana Hilario	UAVR	Marine Ecology
Sofia Ramalho	UAVR	Marine Ecology
Mike Jakuba	WHOI	ROV Operations
Andy Bowen	WHOI	ROV Operations
Stefano Suman	WHOI	ROV Operations
Daniel Gomez-Ibanez	WHOI	ROV Operations
Chris Judge	WHOI	ROV Operations
Molly Curran	WHOI	ROV Operations
Victor Naklicki	WHOI	ROV Operations
Sig Vågenes	NORMAR, UiB	ROV Operations
Patrick Vågenes	NORMAR, UiB	ROV Operations
Luis Lamar	Avatar Alliance Foundation	Director of photography
Nadia Drake	NGM	Writer

CAGE, UiT: Centre for Arctic Gas Hydrate, Environment and Climate, UiT Arctic University of Norway
NIVA: Norsk Institutt for Vannforsking / Norwegian Institute for Water Research, Norway
UiB: University of Bergen, Norway
IMR: Institute of Marine Research, Norway
WHOI: Woods Hole Oceanographic Institution, Woods Hole, USA
NASA-JPL: NASA Jet Propulsion Laboratory, California Institute of Technology, USA
AWI: Alfred Wegener Institute, Germany
UAVR: University of Aveiro, Portugal
NORMAR, UiB: Norwegian Marine Robotics Facility, University of Bergen
NGM: National Geographic Magazine

2 INTRODUCTION AND OBJECTIVES

Eva Ramirez-Llodra & Stefan Buenz

Forty years after the discovery of hydrothermal vents, research into these unique habitats and their ecosystems is still in the exploratory phase. These recent discoveries have changed the way we understand life on Earth, have challenged knowledge of the origin of life and are now fuelling exploration for extra-terrestrial life in our solar system. To date, only 10% of the global ridge system has been investigated (Ramirez-Llodra et al., 2010), yielding an inventory of just over 500 confirmed active hydrothermal vent sites and estimates of 1300 (±600) existing vents globally (Beaulieu et al., 2015). However, new estimates suggest that the number of active vents on fast- and intermediate-spreading ridges may be 3 to 6 times higher (Baker et al., 2016), forecasting a wealth of discoveries to come.

The remote Arctic Gakkel Ridge, though briefly investigated in regions by previous exploratory cruises, remains largely unexplored and ecosystems in this northerly, under-ice region, largely unknown. In 2001, Edmonds and colleagues (2003) obtained first evidence of hydrothermal venting in the Gakkel Ridge (83-86°N), previously predicted to host an extremely low number of active sites, due to the ultra-slow spreading nature of the ridge. In 2007, the AGAVE expedition provided evidence of explosive volcanism at 85°N, supporting growing evidence that ultra-slow spreading ridges host unique modes of crustal accretion and tectonic extension (Sohn et al., 2008). In 2014, the Polarstern cruise PS86 to the Aurora seamount (Fig. 1) observed, for the first time, black smokers on the Gakkel Ridge (82°53'N, 6°15'W) (Boetius et al., 2015). Although the autoecology of many of the more than 400 vent species described to date has been unravelled, the biogeography of vent fauna remains poorly understood, with 11 distinct biogeographic provinces thus far identified (Rogers et al., 2012). Tectonic dynamics influences biogeography across geological time scales, but a number of physical factors play key roles in determining the distribution of species, operating within the lifetime of individuals, particularly during the planktonic larval phase (Hilario et al., 2015). Pioneer phylogeographic studies of vent fauna from Loki's Castle on the Arctic Mid Ocean Ridge (AMOR, Fig. 1) suggest that its fauna has evolved through local adaptation and by migration from Atlantic cold seeps and Pacific vents (Pedersen et al., 2010). These initial results lead to questions on the role of the deep Arctic Ocean in driving regional and across-basin connectivity and in shaping global biogeography.

Data from the PS86 cruise (Boetius et al., 2014) shows that the Aurora seamount (4300-3850 m depth) has steep vertical basalt walls, encrusted by filter feeders, intermixed with lower angle, sediment draped steps and sledges. The top of the seamount is flat and sediment covered. Identified fauna on the Aurora seamount was characterized by high abundance of sponges and anemones on the hard substratum and at least 2 species of shrimp. Ophiuroids, swimming polychaetes and crustaceans (potentially isopods) were also observed. The active sites were colonized by bacterial mats and small white organisms (potentially limpets and/or other small gastropods) and a low density of individuals of an unidentified shrimp species, similar in appearance to those observed at the Loki's Castle vent field in the AMOR

The HACON cruise was designed to conduct a multidisciplinary survey of the Aurora seamount centred around the identified black smokers in 2014. The scientific goal was to obtain visual and physical samples of the different habitats on the seamount to better understand hydrothermal vent communities on the Gakkel ridge and abyssal communities of an Arctic seamount, to assess the sphere of influence of the Aurora vent field across the seamount and adjacent seafloor regions.

The proposed research addresses major scientific questions and technological challenges that will yield a better understanding of the structure and functioning of our planet and large-scale connectivity patterns, in the current framework of changing oceans.

The specific objectives of the cruise included the following:

1. Conduct OFOBS bathymetry and video transects over the Aurora seamount, particularly targeting the Aurora hydrothermal vent, to identify habitats and biological communities from background to vent environments.
2. Characterise and sample the water column and hydrothermal plume with the CTD and Niskin bottles.
3. Sample the water column plankton using a WP2 plankton net for food-web analyses.
4. Sample the seamount using coring equipment (gravity core, box core and multicore) for geological, geochemical, micropaleontological, microbial, meiofauna and macrofauna analyses of sediments.
5. Conduct high-resolution bathymetry of the vent field with NUI (Nereus Under Ice) on ROV or AUV mode.
6. Sample the hydrothermal vent fluids and fauna with NUI on ROV mode.
7. Collect a series of ice cores to investigate how biogeochemical signatures from the ocean water column overlying the Aurora hydrothermal field might be transmitted upward into the overlying ice for inter-comparison with similar samples collected above the Polaris vent-site in 2016 as part of an on-going NASA PSTAR project between WHOI and NASA-JPL.
8. Communication project in collaboration with National Geographic Magazine and the Avatar Alliance Foundation.
9. Recovery of oceanographic moorings of the Nansen Legacy Project (UiB and NPI)

A full list of all equipment deployments and sampling is provided in Appendix 18.1, with subsampling described in Appendix 18.2.

3 GEOLOGICAL SETTING OF THE AURORA SEAMOUNT

Christopher German

The Aurora hydrothermal field sits in the westernmost segment of the Gakkel Ridge within the Western Volcanic Zone (Michael et al., 2003) which extends for 220 km from 7°W to 3°E. The spreading rate here is 14.5-13.5mm/yr and the ridge axis floor at 4200m depth is bounded by steep normal-fault rift valley walls and punctuated by a series of axial volcanic ridges and smaller volcanic mounds that rise up hundreds of meters above that axial floor depth (Michael et al., 2003). The Aurora field was first located associated with one such volcanic mound as part of the InterRidge two-icebreaker AMORE expedition in 2001. At 82°53’N, 6°15’W a small volcanic mound measuring ~1.5-2km in extent rises approximately 400m from the seafloor at a saddle-point where the rift-valley narrows from ~20km to ~15km wide. A dredge from S to N across this volcanic mound in 2001 recovered components of an extinct sulfide chimney in addition to abundant pillow basalts and in situ sensor data from a MAPR instrument attached to that dredge revealed clear evidence for a particle-rich lens, consistent with a nearby source of active black smoker venting, at 2800-3400m water depth (Edmonds et al., 2003).

During a return cruise to the site aboard the FS Polarstern in 2014 (Boetius et al., 2014a) CTD profiling coupled with water column sampling and CH4, TDMn and He-isotope anomalies revealed clear evidence for ongoing hydrothermal activity including strong evidence from CH4:TDMn ratios of ultramafic influence in the underlying vents (Boetius et al., 2014b, German et al., 2017). Buoyant plume signals intercepted with the CTD during that cruise suggested at least one source of venting was situated toward the south/southwest of the shallowest summit of the Aurora seamount and OFOS deep-tow camera tows from North to South across that summit revealed deep rifts through the thickly sediment seafloor surrounding the base of the volcanic mound. Those firsts were observed striking approximately E-W (across axis) immediately south of the summit of the mound on at least two OFOS tows. These paired observations (CTD, seafloor imaging) led to first imaging of an active vent at ~3900m depth at a Posidonia position of 82°53.83’N, 006°15.32’W (Figure 3.1).

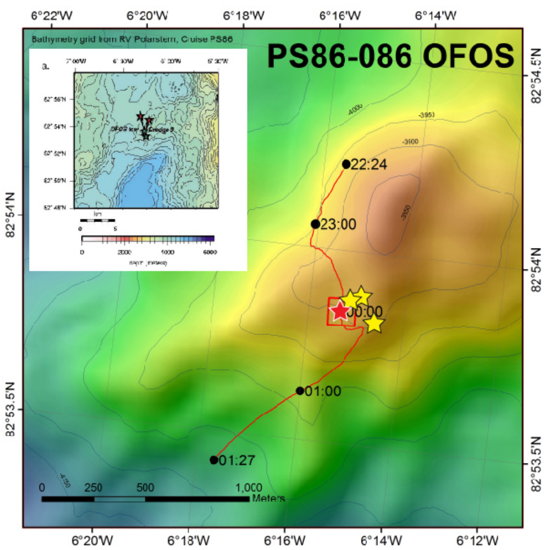


Figure 3.1. Map showing the track-line of OFOS Station No.86 during FS Polarstern Cruise 86 (2014) that first imaged a site of active venting at Aurora (red star). Also shown are locations where extinct chimneys were also identified on that cruise (Boetius et al., 2014a). Inset: map showing the location of the dredge track across the mound, close to the center of the axial rift valley, that first revealed the Aurora site to be hydrothermally active during the 2001 AMORE cruise (Edmonds et al., 2003).

4 NARRATIVE OF THE CRUISE

Stefan Buenz & Eva Ramirez-Llodra

Note: Given times in this narrative are local times. Log sheets are in UTC.

Tuesday, 17th September

The team from WHOI is able to start mobilizing NUI during the afternoon and set up workspace in the main hangar.

Wednesday, 18th September

WHOI team continues to mobilize NUI.

Thursday, 19th September

Official start of HACON expedition, scientific party comes on board at 09:00. Mobilization of equipment for teams from NIVA, UiB, UiT, IMR and UAVR. The remainder of the scientific party arrives in Longyearbyen at 14:00. All equipment on deck. Scientific teams set up laboratories. Departing from Longyearbyen at 22:00, transiting to the mooring sites north of Svalbard.

Friday, 20th September

On transit to mooring sites north of Svalbard. Further preparation of labs and instrumentation during transit.

Saturday, 21st September

Arrival at mooring site W1 at 06:00. Few small ice bergs in area drifting through southward with relatively high velocity. Acoustic releaser is ranged three times from different positions and is located close by at ~200 off star board. Conduct a CTD station at 07:15 including water samples. 08:30 release command is sent to releaser. A floatation surfaces after about 3 min, it is recognized as the bottom float of the mooring, no signs of the top floatation which as anchored very shallow below sea surface. Ship moves in position and recovers bottom floatation and releaser, unfortunately the rest of the mooring is lost. It had likely been ripped off the bottom floatation due to sea swell and/or ice bergs dragging on the top float. 09:00 transit to mooring site W2. At mooring site W2 at 10:10, identify mooring on MB water column, ship positions itself 150m NW of the mooring site. 10:15 CTD station at W2. 10:50 Acoustic release of mooring, surfacing 2 min later. 12:05 mooring W2 safely on board. Transit to W3 passing through denser coverage of ice. 13:10 Arrival at W3, W3 located using MB under an extensive area of ice floes. Move out of ice and conduct CTD at 13:00. CTD finished at 14:30. Reposition ship at northern end of ice drift and wait until drift passes by W3 mooring. Mooring clearly visible in MB. Release mooring at 15:20, all three flotations surfaced after ~10 min. Recovery completed at16:45. Transiting to INTAROS position further East. 20:20 arrival at mooring. A bit lucky that site is free of ice as a tight ice cover is 1 nm further east. 20:25 mooring released and surfacing within 1 min. Recovery finished at 21:05. CTD station including water samples conducted afterwards and finished at 23:05. Transiting to mooring station on Yermak Plateau.

Sunday, 22nd September

Arrival at mooring site on Yermak Plateau at 14:10. Mooring cannot be detected on MB at given location. Conduct a CTD with water sampling at station. Ranging the releaser during CTD station without response. 15:10 start ranging again but 20+ attempts are without response. Move to another position, acoustic responses come irregular with ranges of 2500 ±500 m. Trying to triangulate from 4 further positions, also turning the ship on each site. Only one of the positions gives few ranges of 2000 – 2500 m and a couple more ranges larger than 6000m. No consistency in range values, very difficult to predict possible position. We do not take the risk of simply releasing the mooring when we do not know its actual position, that is in case it is actually still in this area. Give up on the search at 18:00. Heading back to Longyearbyen to pick up the AWI stuff.

Monday, 23rd September

Arrival in Longyearbyen at 14:30, anchoring in harbor area. AWI container emptied at dock and transported to vessel using KPH work boat. Equipment on board at 17:15. Start a wet test with NUI at 21:00.

Tuesday, 24th September

NUI test completed at 00:30 with only minor problems. Leaving Longyearbyen at 01:00 for our transit to Aurora.

Wednesday, 25th September

On transit, at the ice margin at ~02:00. Preparation of sampling equipment and labs. Occasional thicker ice and ice ridges make progress difficult at times. At 22:00 still 85 nm to Aurora.

Thursday, 26th September

On transit through the ice. Ship's uses satellite images to find small water ways through the ice. Nonetheless, the ship turned around multiple times in hopes of finding better passage somewhere else. As of 22:00 we are still 40 nm away from Aurora. Sunny blue skies today, everyone is enjoying wonderful experience in this icy landscape.

Friday, 27th September

On transit to Aurora making much better progress today using small water ways between the ice. Sunny weather and -10°C again today.

Saturday, 28th September

Arrival at Aurora Seamount at 09:10. 09:30 start CTD (259) with water sampling. CTD wire will be inspected during downcast. Several scratches and rifts need repair along the wire. Further inspection with NASA's blue mini-ROV in the moonpool. CTD wire bends sharply around lower block in moonpool. Crew adds another small block to keep wire in steady place avowing scratching. Further repairs during downcast to 4000 m. Water sampling during upcast. CTD cast finally finished at 21:00. Relocating for OFOBS deployment.

Sunday, 29th September

Relocating to NW of vent field based on assumption of drift direction (SW, 210°) observed in the afternoon and evening (01:00). A large opening in the ice helps significantly. Drift pattern changed to SE (140°), so relocate again to NW of Aurora. Start of OFOBS deployment at 03:00, OFOBS in water at 03:20. Several instrument failures and change of drift direction lead to termination of video transect. Relocating of vessel for deployment of NUI. NUI in water at 09:40. Several small problems also cause termination of the NUI dive. Slow drift NW across Aurora. Conduct two multi corers and one gravity core between 13:00 and 23:00. Start CTD on top of active Aurora vent.

Monday, 30th September

Shortly after commencing the CTD, the CTD wire gets trapped on the outside of the winch and heavily damaged. CTD aborted. CTD wire breaks and rosette falls down the moonpool during recovery but fortunately after moonpool doors had been closed. Mounting CTD on 12-bottle rosette in CTD hangar. NUI start pre-launch check at 04:00, and NUI launches into water at 06:30. NUI descends as normal and parks 70 m above seafloor at 10:45 when communication is lost. All attempts to recover communication or to release NUI from weight fail. Navigation data from the USBL show later that NUI descended to the seafloor after loss of communication with a speed of 13 m/min. While confirming NUI position at seafloor, CTD measurements and water sampling are conducted at 14:00 and 16:10. We relocate to deploy OFOBS in a position to drift across the Aurora Seamount.

Tuesday, 1st October

OFOBS deployed shortly after midnight. Testing initially ok, however, during downcast current spikes indicate potential shortcuts on the Edgetech Sonar system. OFOBS aborts videostation at 2000 m and is recovered. We are on a drift heading ENE and passing the top of Aurora Seamount to the South. The NUI team is regularly checking on NUI's location at the seafloor in hopes that they can release the weight, or it's being released by itself after complete corrosion of burnwire that keeps weight attached. At 04:40 a gravity corer is deployed SE ~500 m of the top of the Aurora Seamount. 06:00 gravity corer recovered 2.5 m of sediments. Relocate ship again west of Aurora and continue ranging NUI. CTD station 263 at 10:45 during a drift ENE. 14:00 CTD finished, relocating again westward. No way through the ice, we have to retreat to a relatively wide waterway heading SW-NE and 3 km south of Aurora Seamount. At 19:15 group of 6 people leaving vessel for taking ice cores. Simultaneously, the box corer is deployed. Ice group returns at 20:30 with 6 ice cores. Box corer returns with full box at 22:00. OFOBS deployed at 23:00 for video survey.

Wednesday, 2nd October

00:15 OFOBS at bottom SE of Aurora Seamount. Video Survey drifting ESE and then E. 04:00 start recovering OFOBS, and back on deck at 05:30. Relocating back west of Aurora. Ice drift changing from initially NE to E and later slightly SE with drift speed decreasing to almost zero and taking us eastward on a line approximately 2 km south of Aurora seamount. CTD station including water sampling at 11:00 and multicorer at 14:45. Multicorer back with 5 full liners at 17:15. Relocating to an open water way north of Aurora as ice drift predictions are changing to a SW drift. Access to the Aurora Seamount is difficult. Work continues with a plankton net cast to 3300 m at 21:40.

Thursday, 3rd October

Plankton net cast concludes at 2:15. Gravity corer taken between 03:20 and 05:30. Deploying OFOBS for video survey over vent. At 06:50 news comes that NUI is ascending in the water column, released after 72 h by corrosion of burn-wire. OFOBS station aborted. NUI ascends with about 13-15 m/s and comes up under a thin, new ice sheet in an opening between ice floes. At 12:15 NUI is hooked up on a crane and taken aboard. Analysis later revealed a switch failure that produced a short cut, which led to the shut down of the battery packs. OFOBS deployed at 13:30 for a slow drift southward across the known vent field. Open water or thin ice allows the vessel to make small changes to its position during the drift. Shortly after 20:00 we re-discover the known vent site from a Polarstern expedition in 2014. The OFOBS drift reveals that there are at least two more vents in close vicinity.

Friday, 4th October

The OFOBS drift last for more than 12 hours and finishes at 02:00. We conduct two CTD stations with water sampling in hopes to sample water from the plume directly on top of the vent sites, however, ice drift is not in favor. A gravity core is taken at 09:30. Ice drift allows another OFOBS visual survey over the main vent site at 13:00. However, the drift passes slightly east of the active smokers but still adds valuable imagery to understanding the full extent of this vent system. A multicorer is taken at 19:30 at the site where the OFOBS drift finished. We relocate to the southern water lead as ice drift direction changed to a NW direction.

Saturday, 5th October

A box corer is taken 100 m east of the vent site at 08:00. We make another attempt at conducting a CTD station with water samples over the plume. Unfortunately, also this time ice drift changes abruptly to the east and misses the vent with several hundreds of meters. Another NUI dive was planned for today but continuous changes in ice drift make it difficult to identify a good launch location. Ice drift is now rather south and we relocate again to the water lead bordering north of the ice floe. Ice drift conditions do not allow launching NUI, so we take 2 more gravity cores in the middle of the ridge valley north of the Aurora Seamount. Relocate for OFOBS survey.

Sunday, 6th October

At 01:30, OFOBS is launched for a visual survey starting ~7 km north of the seamount and heading SE. OFOBS survey finished at 08:15. Relocate for NUI dive 19, which then launches at 12:15. Strong drift North partly due to gale winds from the South. Communication problems occur at 1000 m depth, full communication with NUI partly lost, delaying descend, and together with the strong drift ultimately lead to abortion of the dive. NUI back on deck at 15:30. Strong drift northward puts the Aurora Seamount beneath another ice floe. We relocate around the ice floe to the south to be in better position for further activities. Gravity corer taken at 21:15 followed by CTD cast no. 268. Both these stations are approximately 12 km to the SSW of the Aurora Seamount. The CTD cast detects an unusual high plume signal given the distance to the seamount.

Monday, 7th October

Another CTD station starts 10 km further East on a small seamount structure at the flank of the ridge valley. The CTD stops at 1500 m due to problems with the wire and is aborted after several hours. Ice drift this morning allows access to the Aurora Seamount. Two successful OFOBS dive pass directly over the vent and provide further visual imagery of the terrain and fauna around and at the vent site. The OFOBS dives are concluded at 18:00. At 19:45, a multicorer is taken at the end of the drift about 1 km East of the Seamount.

Tuesday, 8th October

We conduct a plankton net over the night. In the morning, we search for possibilities to deploy NUI but ice drift is not in our favor and the Aurora Seamount is difficult to access underneath a huge ice floe that is drifting very slowly to the East. The ice work team from JPL is on the working boat this morning undertaking a survey of the underside of the ice using their blue mini ROV. In the afternoon, the ice work team is out on ice taking 5 more ice cores. We conduct another plankton net cast in the evening starting at 20:20.

Wednesday, 9th October

Two box cores are taken over night. Drift speed has also increased over night and in the morning we relocate to the western margin of the ice flow anticipating that we may be able to deploy NUI when the Aurora Seamount gets within reach. Unfortunately, ice drift is very slow; a large ice flow is covering the Seamount. Over the course of the afternoon and evening we conduct three short plankton net casts and take two more box cores. Shortly before midnight (23:00), we start a CTD cast with water sampling.

Thursday, 10th October

At 02:00 we conduct a plankton net cast from 2000 m water depth, followed by a box core (06:00), a gravity core (09:30) and another plankton net from 1000 m. Ice drift is still extremely slow and provides no opportunity for NUI to get in reach of the Aurora Seamount. As this is the last day of activities at the seamount, NUI uses an open water lead to descend to 4000 m and grabs some live and dead sponges using manipulator and blade corer.

Friday, 11th October

NUI is safely recovered at 03:30. Gravity corer taken at 04:15. We move approximately 10 nm SW closer to the steep terrain at the flanks of the rift valley and deploy OFOBS at 08:45. A CTD cast at 13:00 concludes all activities at the Aurora Seamount and we start to sail south back to Longyearbyen.

Saturday, 12th October

Open water leads provide fast progress southward. At 05:00, we take a gravity core approximately 70 nm south of Aurora Seamount in the Lena Trough. Another gravity core taken 60 nm further SE in the eastern half of the Lena Trough. Steaming further south towards the inside corner high at the intersection of the Lena Trough and the Spitsbergen Fracture zone. Still, many open water leads enable fast progress back towards Longyearbyen providing time for reconnaissance opportunities in this unexplored basin.

Sunday, 13th October

Shortly after midnight we arrive at the southern Lena Trough area and conduct a CTD and gravity core station. Thereafter, we start mapping the inside corner high as much as ice conditions allow. Mapping is temporarily paused for two OFOBS dives (13:00 and 23:45) along the steep flanks of the rift valley. However, in both cases changes in ice drift shorten the dives.

Monday, 14th October

After the OFOBS recovery, we continue on a multibeam transect eastwards towards a small basin between Lena Trough and Yermak Plateau. At 08:00, we conduct another CTD in 3100 m water depth. This cast is temporarily halted by repairs to the CTD winch. At 12:30 we continue eastward towards the ice margin. We pass the sea ice margin at 22:30 and continue southward.

Tuesday, 15th October

02:00 We take two gravity cores outside the ice edge at about 1100 m water depth before continuing southward towards Svalbard. With a few hours to spare we stop at a shallow (100 m) gas seepage site west of Prins Karls Foreland and conduct three CTD stations, and OFOBS dive and a hydro-acoustic transect. During the OFOBS dive, we take images of a CAGE seafloor observatory. Work here concludes at about 22:00 and we head back to Longyearbyen.

Wednesday, 16th October

We arrive in Longyearbyen at 08:00 and start demobilization. Demobilization is finished at 15:00. The HACON expedition concludes.

Ursus maritimus, by Alexander Eeg.

5 SCIENTIFIC EQUIPMENT ONBOARD RV KRONPRINS HAAKON

Stefan Buenz

5.1 Hydroacoustic systems

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

Among the hydroacoustic systems, the following were used extensively during the HACON 19 cruise:

1. Simrad Kongsberg EA 600 – 12kHz single beam echosounder
2. Kongsberg EM 302 multibeam echosounder and SBP 300 Sub-Bottom Profiler

5.1.1 Kongsberg EA 600 –12kHz single beam ekkolodd

The EA 600 single beam echosounder operates up to four high power transceivers simultaneously. Available frequencies span from 12 to 710 kHz. A variety of highly efficient transducers is available to suit all your operational needs from extreme shallow water to a depth of 11.000 meters. Major applications of this echosounder is to identify the depth and finding high-reflective objects in the water column. During this cruise, we operated the echosounder at 12 kHz as this frequency provided best bottom detection. Higher frequencies were notably affected by sea ice under the hull and hence did often not detect bottom.

5.1.2 EM 302 and SBP 300

The EM 302 multibeam echo sounder has an operating frequency of 30 kHz and is designed to perform seabed mapping with high resolution and accuracy to a maximum depth of more than 7000 m. Beam focusing is applied both during reception and transmission. EM 302 is equipped with a function to reduce the transmission power in order to avoid hurting mammals if they are close by.

The system has up to 432 soundings per swath with pointing angles automatically adjusted according to achievable coverage or operator defined limits. With dual swath (two swaths per ping) the transmit fan is duplicated and transmitted with a small difference in along-track tilt. The applied tilt takes into account depth, coverage and vessel speed to give a constant sounding separation along track. In dual swath mode, 2 swaths are generated per ping cycle, with up to 864 soundings. The beam spacing is equidistant or equiangular.

The transmit fan is split in several individual sectors with independent active steering. This allows stabilization, which compensates for the vessel movements: yaw, pitch and roll. Each transmit sector has individual beam focusing.

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

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

During the cruise, the multibeam bathymetry data was processed and cleaned using QPS Qimera Software. An initial grid surface with a resolution of 15 m was produced for the perimeter of the Aurora Seamount. However, high noise levels merit further processing to improve map quality.

5.2 Oceanographic systems

Physical and chemical measurements are measured in the water column from a CTD/rosette. The CTD model is a Seabird 911 plus mounted on a 12 or 24 10-liters Niskin bottles carousel and was brought close to the seafloor. The CTD is coupled with different types of equipment such as oxygen sensor, transmissiometer and fluorimeter. Two lowered acoustic Doppler current profilers (RD Instruments 300 kHz Workhorse LADCP) were mounted on the rosette, one looking upward and one looking downward. They recorded velocity data during all CTD casts at a ping rate of 1 Hz. The instruments were transferred from the 24-bottles rosette to the 12-bottles rosette after the first one became unusable because of the winch (see narrative). The configuration of both instruments was set to narrowband to extend the beam range, and recording in 15 8 m-cells. In order to improve velocity accuracy in the water column the rosette was stopped for 5-10min at several depths during a few casts to remove noise when lowering the winch

5.3 Attributed Sensors

5.3.1 GPS/Navigation, Motion Reference Unit

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

5.3.2 USBL HiPaP

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

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

6 HULL-MOUNTED HYDROACOUSTIC SURVEYS

Stefan Buenz

6.1 Introduction and objectives

The EM302 multibeam system acquired bathymetric data during the whole cruise with a minor exception of some periods where the vessel was breaking ice. Under these conditions, ice floats along the bottom of the hull and interferes with the hydroacoustic systems making data unusable. However, many of the drift deployments (e.g. OFOBS, CTD) across the Aurora Seamount provided a huge amount of bathymetric data.

In the water depth at Aurora (~4000 m), multibeam coverage on either side of the vessel can potentially be high (about 3-4 times the water depth). However, due to the lateral extent of the Aurora Seamount to a few kms, the coverage was limited to about 40 degrees on either side of the vessel to increase seafloor resolution. Over a period of two weeks at Aurora, the multibeam system acquired billions of overlapping soundings. About two thirds of the data were immediately rejected during initial data screening as they contained too much noise from scattering, ice interference or false depth measurements. Still, the remaining data was good enough in order to produce a much better seafloor map of the Aurora Seamount than what previously was available. However, data cleaning and editing was time-consuming and was only completed after the cruise so that the new data was not available for survey planning during the cruise. It will however be very useful to better understand the surface morphology and geological setting of the Aurora Seamount and it will be valuable to integrate with results from all other experiments. The map presented in this report is a first version of the processed multibeam data. There is still considerable noise and some artefacts in the data and further processing will improve the map.

6.2 Multibeam Echosounder EM302

The new multibeam data shows the Aurora Seamount in much greater detail (resolution of 15 m) than previously mapped (Figure 6.1). The seamount stands about 200-300 m high above the seafloor of the Gakkel Ridge valley. It has a soft conical structure and it is elongated predominantly in SW-NE direction, following roughly the direction of the ridge valley. The summit of the seamount lies at slightly below 3800 m water depth and has a small crater feature just east of it. However, this part has not been found to be active (black smoker), neither during this cruise nor during a previous investigation onboard RV Polarstern in 2014 (Boetius et al., 2015). It is along one of the small ridges extending towards the SW flanks, where multiple black smokers have been observed (see chapter 8). Some of the ridges extending away from the summit in south and west direction have rather steep flanks, whereas the topography is smoother towards the north and the east where one can identify 2-3 slabs that look like lava flows.

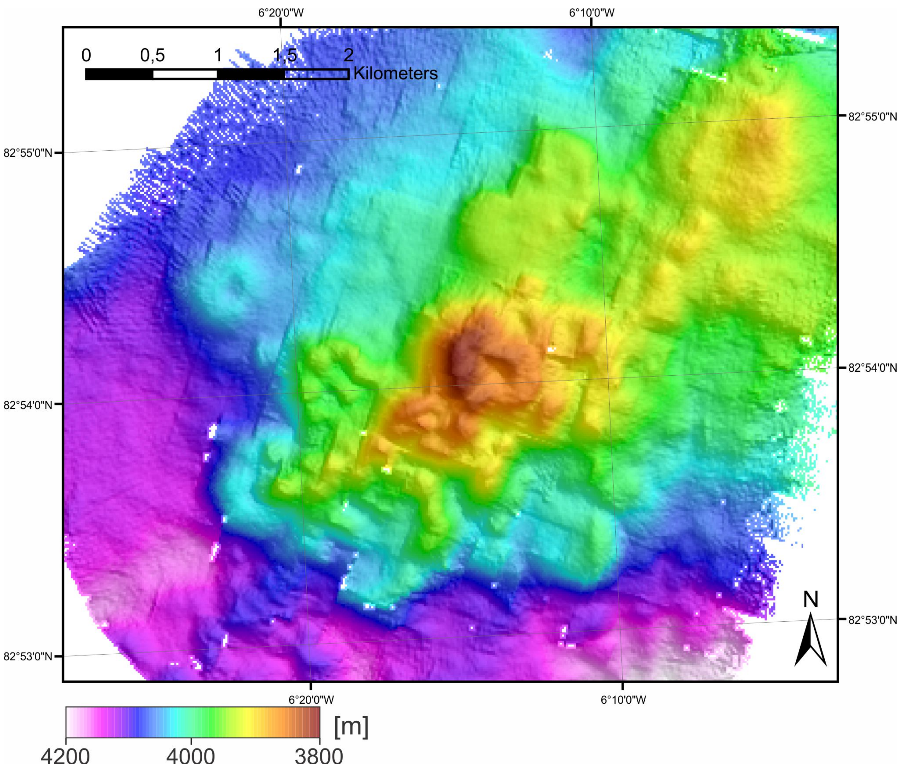


Figure 6.1. Seafloor bathymetry and structure of the Aurora Seamount obtained from multibeam surveying during the HACON cruise.

7 WATER COLUMN

Benedicte Ferre, Fatih Sert, Dimitri Kalenichenko, Eoghan Reeves, Kevin Hand, Håkon Dahle, Tina Kutti

7.1 Introduction and objectives

Mixing and spreading of a hydrothermal plume can be identified from the water mass properties inside and outside the Aurora hydrothermal plume, provided by the CTD on-board the R/V Kronprins Haakon and mounted on the NUI. Water samples were performed during CTD casts (Figure 7.1) for geochemical properties of the water column, analysed directly after sampling or later on in different partners' lab. Current velocity and direction in the water column and close to the seafloor were obtained from the ADCPs mounted on the NUI and on the ship. The rosette was also equipped with two LADCPs, one looking up and one looking down. The current information will be used to constrain the biophysical model developed in task 4.1.

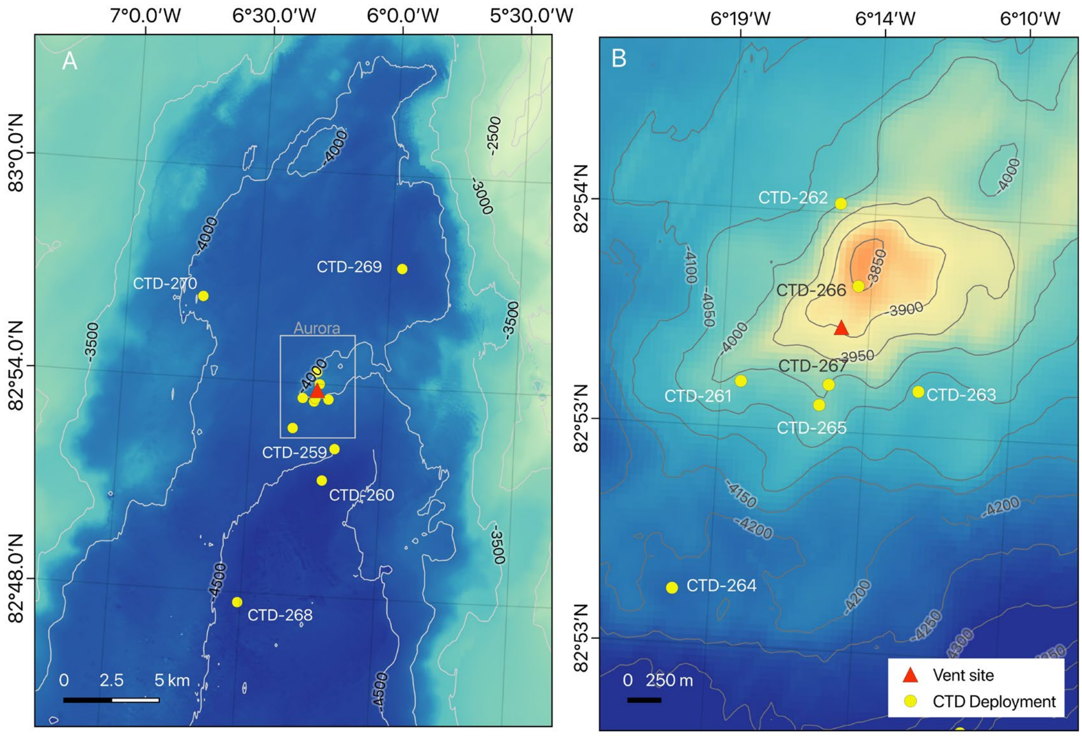


Figure 7.1. General map (left) and zoomed area of the Aurora seamount with CTD stations indicated by yellow dots. The targeted vent site is represented by the red triangle.

7.1.1 Geochemistry

Composition of the dissolved organic matter (DOM) in the abyssal ocean is known to be refractory and considered primarily unavailable for organisms. Yet, hydrothermal vents and surrounding environments are rich in terms of biodiversity and provide source for many different chemosynthetic organisms and hydrothermal fauna. For such organisms, reduced carbon (such as methane) and DOM would be the main carbon source and they might have an adaptation to utilize refractory DOM and modify the composition in the deep-sea environments. Additional to the microbial modification, DOM composition around the hydrothermal vents are expected to be thermally and/or chemically altered. The extent of these modifications are unknown in many deep-sea hydrothermal vents and our objective is to reveal compositional changes of DOM under the influence of hydrothermal input in the Aurora Hydrothermal vent in the Gakkel ridge, Arctic Ocean. Collected DOM composition data will be also compared with other methane receiving water (cold-methane seepages) areas around Svalbard archipelago.

With this study, we focussed on DOM composition and nutrient profiles along with the other biological measurements in the Aurora Hydrothermal vent in the Gakkel ridge. Composition of DOM were determined by solid phase extraction from 1 L sea water samples for high-resolution mass spectrometry (FT-ICR-MS). Additionally, dissolved methane (CH4), dissolved organic carbon (DOC), coloured-DOM, stable oxygen isotope (δ18O-H2O), total and dissolved inorganic nutrients (nitrate, phosphate, silicate, ammonia), dissolved inorganic carbon (DIC) and δ13 C-DIC and chlorophyll-a were sampled for the characterisation of water column around the Aurora hydrothermal vents. Geochemical properties of the water column also included δ13C-CH4 and CO2. In addition, water sampling was used to characterize the microbiological communities in the water masses surrounding the Aurora vent site, including the hydrothermal plume.

7.1.2 Carbon flux to the seafloor

Deep-sea dwelling benthic organisms are dependent on organic carbon produced in the sun-lit surface of the ocean. Around hydrothermal vents chemoautotrophic bacteria also fixate carbon, which can likewise fuel the benthic food-chain. Together with other data collected during the cruise (i.e. sediment and benthos) the filter and zooplankton data will be used to address the following questions: 1) What are the basal organic carbon and nitrogen sources on which meio- and macrofaunal species rely? 2) How much organic carbon is available at the seafloor and what´s the quality of this material? Is the vertical flux of carbon to the seafloor limiting benthic biodiversity and secondary production? And, 3) Does the functional complexity, based on stable isotope analysis and fatty acid markers, vary between sampled sites?

7.2 Oceanography

The Arctic Ocean is characterized by three distinct water layers, i.e. Arctic surface water, Atlantic Water and Deep Water. Each of these layers presents different water masses and properties. The different water masses around the seamount are represented in Figure 7.2 and described here. The Arctic surface water contains mainly Polar Mixed Water (down to 200 m water depth), characterized by low temperature because of the ice cover, with seasonal and geographical salinity variation freezing or melting of sea ice as well as input from shelf water from river runoff. A strong halocline precedes the Arctic Atlantic Layer down to ~900 m water depth, highlighted by a temperature maximum in all profiles (up to 1.4°C).

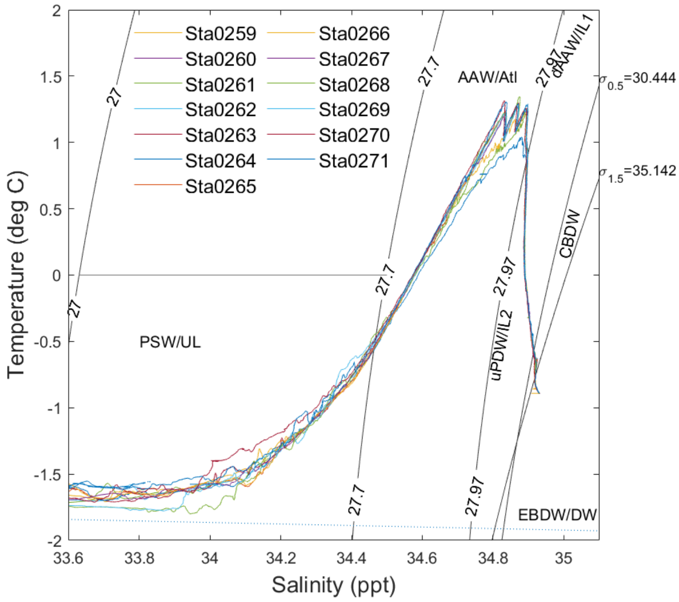


Figure 7.2. Temperature-salinity diagram of all stations taken at Aurora, along with categorized water masses in the Arctic. PSW/UL: Polar Surface water/Upper Layer; AAW/Atl: Arctic Atlantic Water/Atlantic water; uPDW/IL2: upper Deep Water/Intermediate Layer; CBDW/DW: Canadian Basin Deep Water/Deep Water; EBDW/DW: Eurasian Basin Deep Water/Deep Water. Each color represents one CTD down cast. Isopycnals are indicated and delimitates water masses see Marnela et al., 2008 for water masses classification).

ADCP data from the ship and the NUI will be interpreted at a later stage. An example of data from the LADCP mounted on the CTD/rosette is presented in Figure 7.3, keeping in mind that all data set need filtering for ship drift, descent speed and potential rotation.

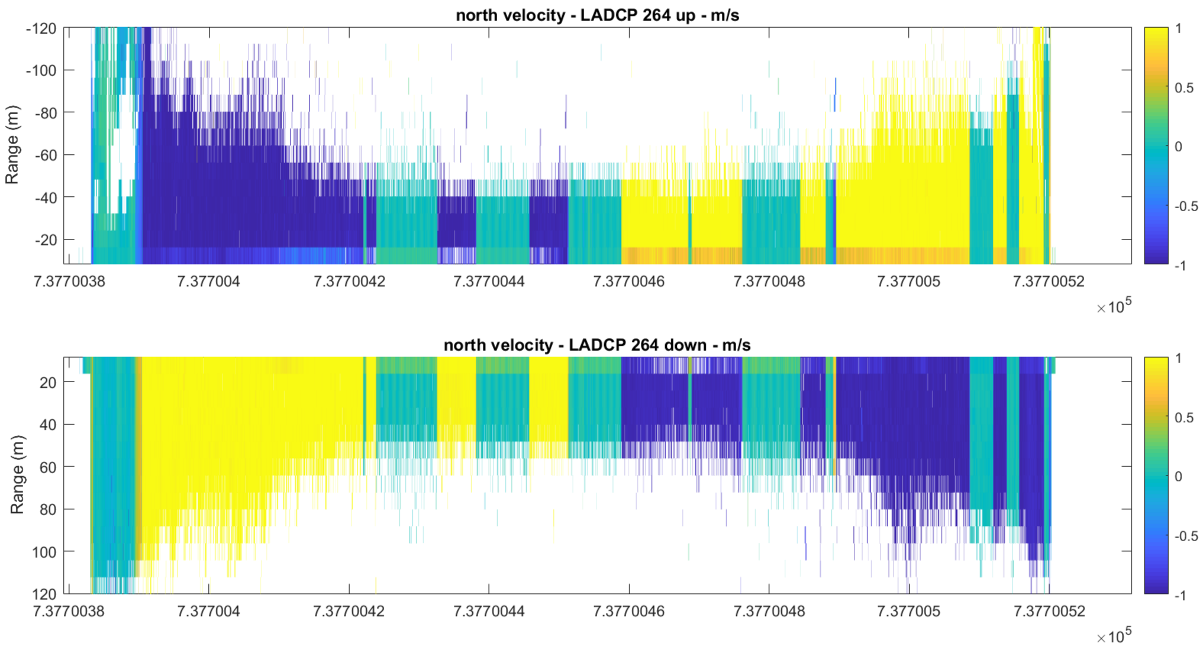


Figure 7.3. Current velocity from the upward (up) and downward (down) looking ADCP. Example for the 264-file taken on 02.10.19. Note that the data is not filtered for drifting, descent and potential rotation of the rosette. The CTD was stopped at a few depths to have 10 min of stable data.

7.3 Water column / plume geochemistry

Water was first collected from the Niskin bottles for methane concentration. Then 2 L of seawater were taken into 1 L glass bottles for filtration and subsampling. Samples were kept in +4 °C cooling room if immediate filtration is not possible. $\delta^{18}O$, DIC and C^{13}-DIC were directly sub-sampled from unfiltered water samples. Filtration was carried out by glass filtration towers on GF/F filters for chlorophyll *a*, and nutrients, DOC and colored dissolved organic matter (CDOM) were sampled from the filtrate water. One liter of filtrate water was acidified to pH 2 with concentrated hydrochloric acid and separated for solid phase extraction (SPE).

Methodology for SPE of DOM is modified from Dittmar et al. (2008). Briefly, styrene diviniyl benzene polymer type of cartridges (Bond Elut, PPL, ENV) were conditioned by 6 ml of methanol and rinsed respectively by12 ml of milliQ, 6 ml of methanol and 12 ml of pH2 milliQ water. Acidified seawater samples were then flushed through the conditioned cartridges. After the sample, cartridges were rinsed by 12 ml pH 2 milliQ water. 2 ml of methanol were used for final elution of the sample. Samples will be kept in -20 °C freezer until analysis date.

CTD casts 259-260, 262, 263, 265, 269 and 271, both on the periphery of the Aurora hydrothermal plume, and in background waters away from the seamount, were sampled for dissolved CH_4 using the procedure followed in German et al. (2010). In some casts, but not all, Niskins were fired in duplicate at each depth. Briefly, as soon as possible after recovering the CTD on board, 100mL samples were taken for N_2 headspace-extraction gas chromatography (with Flame Ionization Detection) using 120mL syringes (E. Reeves). Simultaneously, ~250 ml samples were also taken for CH_4 $\delta^{13}C$ (to be analyzed on board by a Picarro cavity ring down spectrometer instrument, K. Hand) by direct filling from Niskins into preevacuated rubber-stoppered serum vials. Background CH_4 values of 0.5 nM were typically detectable, with 0.3 nM representing the minimum detection limit for such sample sizes.

CTD casts 259-260 were also sampled at selected depths for total dissolvable Fe and Mn (E. Reeves). Water from Niskin bottles was withdrawn into 100 ml acid-cleaned HDPE bottles (flushed 2-3 times for rinsing, then filled with sample) then immediately acidified with 500uL of ultra-pure (distilled) nitric acid. Near bottom water samples were also taken from CTD259-260 for Alkalinity, pH (25°C) and dissolved inorganic carbon (DIC). As for sediment porewaters, Alkalinity was determined on board using a Metrohm 888 Titrando Tiamo autotitrator, performing a Gran-style titration using 0.1N HCl with automatic end-point detection (cross-checked with values computed using the classical Gran function approach). pH (at 25 °C, 1 atm) was measured potentiometrically onboard using a Ag/AgCl combination reference electrode. Samples for DIC were taken directly from Niskin bottles into pre-evacuated 60mL serum vials (previously poisoned with $HgCl_2$) for onshore analyses.

7.4 Microbiology

7.4.1 Targeted microbial communities

Eight samples for analyses of viral communities were obtained from six CTD stations and covered the range of 15-4000 m water depth (Appendix 18.2). Virus concentrates were obtained from 20-40 L of seawater pre-filtered through 5 µm and 0.45 µm meshed filters in order to remove bigger particles, zooplankton, phytoplankton and most prokaryotes. The filtrate was then concentrated down to 40 mL using a QuixStand benchtop system with a 100,000 NMWC Hollow Fiber Cartridge (GE Healthcare Life Sciences). Aliquots of 1.2 ml were immediately snap-frozen in liquid nitrogen and stored at −80 °C. Seawater samples fixed with 1% glutaraldehyde will be used to determine prokaryotic and viral abundances through flow cytometry. Results from this work will contribute to the biological characterization of the Aurora site. Moreover, from comparisons with other available data, they can shed light on the latitudinal influence on shifts in viral community structure.

7.4.2 Water column microbial communities

To include microbial communities in the entire water column, seawater was collected at stations to sample a maximum of 6 depths per station (Appendix 18.2). Depths were chosen for sampling based on characteristics of the water column as profiled by the downcast of the CTD. We attempted to sample the hydrothermal plume and the bottom water. However, at many stations the decrease of beam transmission was broad and unstable.

DNA and RNA

Samples for DNA and RNA were collected by filtering up to 5 liters of seawater onto a 5 µm polycarbonate filter and a 0.2 µm Sterivex cartridge (Millipore) using a peristaltic pump. This method gives us access to two distinct size fractions of the microbial community. Filters were stored in RNAlater buffer (Ambion) at -80ºC. Both DNA and RNA will be extracted upon return to UiT; the first represents simple presence of the cell or gene, while the second indicates the community's capacity for protein production, sometimes conceptualized as the “active community” since it excludes cysts and dormant cells.

Because RNA in particular degrades at ambient temperature, filtering was stopped after a maximum of three hours, meaning that sometimes less than 5 liters was filtered.

Flow Cytometry (FCM)

FCM is more accurate than microscopy to count cells in the “pico” size range (0.2–2 µm), and can include some functional information such as prokaryote versus eukaryote cells and the presence of photosynthetic pigments. FCM samples were taken from each station and depth and fixed with 0.5% glutaraldehyde in duplicate. After a short incubation at ambient temperature in the fixative or buffer, samples were frozen and stored at -80°C

Methane oxidation rate (MOX)

Samples for methane oxidation rates were collected in the plume and in the reference station (Table 1). The oxidation of methane by microorganisms involved the transfer of the methane’s hydrogen to a water molecule. To measure the methane oxidation rate, we incubate the water samples (20mL hexatuplates) for 3 days with tritiated methane. After this incubation period, half of each hexatuplate were bubbled with nitrogen to remove the remaining radioactive methane. Back at Tromsø University we will measure the total activity of the bubbled triplicate ($3H_2O$) versus reference triplicate ($3H_2O + C_3H_4$) for each sample and calculate the methane oxidation rate.

7.5 Carbon flux to the seafloor

To study the relative importance of particulate food derived from different carbon fixation pathways for Aurora Seamount benthos, seawater from Niskin bottles released at the surface (15 m), at intermediate depth (3000-3800) and at the bottom (10 m above the sea-bed) was sampled to measure the quantity and quality of suspended particles. On-board 8 to 10 liters of water from each site and depth was filtered onto pre-combusted Whatman glass fiber filters (0.8 µm) and stored at -20°C for later analysis of total particulate organic carbon and nitrogen, carbon and nitrogen stable isotopes and fatty acid composition. In all, 46 sea-water samples were collected from CTD 259, 262, 264, 265, 266, 267 and 271.

Secondary production of zooplankton in the water column can likewise fuel the benthic food web as sinking detritus (faeces and dead or dying specimens) or through vertical migration. To gain a better understanding of these processes, zooplankton communities in the water column around the Aurora seamount were sampled using a WP2 net (180 µm mesh size). In all, 8 hauls were carried out in haphazardly selected locations (dependent on ice conditions and drift) with 3 hauls sampling the water column from 0-3300 m depth (Håv 118-120), 3 hauls sampling the water column from 0-100 m depth (Håv 121-123) and 2 sampling the water column from 0-2000 m depth (Håv 124 & 125). Onboard the plankton catches were sorted under dissecting microscope to lowest possible taxonomic levels and partly frozen for analysis of C and N stable isotopes and fatty acid composition, partly dried (at 40°C for 48 h) for biomass determinations. A representative number of jelly fish were preserved in ethanol for later identification on land. Juveniles of 2 polychaete taxa were caught in the nets. These were also preserved in ethanol for later taxonomic analysis. Abundance wise the zooplankton catches were completely dominated by Calanoid copepods, in particular in the upper water layer (0-100 m). In the hauls from 0-2000 jelly fish were introduced and composed a large part of the wet biomass of the catches. In hauls sampling from 0-3300 m salps occurred in high numbers. In deep hauls shrimps were caught on 4 occasions. One net sampled a large (15 cm) *Tomopteridae polychaete*. This taxon had earlier been observed on the OFOPS video records.

Basal sources of OM at the vent

photosynthesis-derived OM from the surface of the ocean and local primary producers. The local primary producers can use either the Calvin- Benson-Bassham (CBB) cycle, the reductive tricarboxylic acid (rTCA) cycle or methanotrophs to bind carbon. They yield contrasting stable carbon isotope signals. Can we separate them or get an estimate of how dominant the different forms are?

The δ13C signatures of local primary producers depend on the isotopic values of their carbon sources in combination with their isotopic fractionation during carbon fixation.

Vertical CTD (SBE 911plus) and rosette water sampling casts were carried around the vent. Seawater was collected from the Niskin bottles. A minimum of 10 liters of water was filtered onto pre-combusted Whatman glass fibre filters (0.8 μm) which were folded in two and wrapped into pre combusted aluminium foil and stored at -20 °C until analysis.

8 OFOBS VISUAL SURVEYS AND SIDE-SCAN SONAR IMAGERY

Eva Ramirez-Llodra, Autun Purser, Christopher German, Ana Hilario, Sofia Ramalho, Hans Tore Rapp, Pedro Ribeiro, Lissette Victorero, Ullrich Hoge, Stefan Buenz, Giuliana Panieri

8.1 Technical description

The Ocean Floor Observation and Bathymetry System (OFOBS) (Purser et al., 2018) is a towed underwater camera sled equipped with both a high-resolution photo-camera (iSiTEC, CANON EOS 5D Mark III) and a high-definition video-camera (iSiTEC, Sony FCB-H11). The cameras are mounted on a steel frame (140L x 92W x 135H cm), together with two strobe lights (iSiTEC UW-Blitz 250, TTL driven), three laser pointers at a distance of 50 cm from each other that were used to estimate the size of seafloor structures, four LED lights, and a USBL positioning system (Posidonia) to track the position of the OFOS during deployments. For the duration of cruise no. 2019708 however, the ship Kongsberg transponders were used in place of the Posidonia system for USBL positioning. Positioning information is further augmented via input from an onboard IXBLUE inertial navigation system (INS) with DVL input.

The sidescan bathymetry sonar is an interferometric Edgetech 2205 AUV/ROV MPES (Multi Phase Echosounder) with two sidescan frequencies (230 kHz & 540 kHz) for different range and resolution achievements. The transducers additionally hold a bathymetric receive array to calculate bathymetric 2.5D data in the range of the 540 kHz sidescan sonar with around 800 data points per ping. A forward acoustic camera gives ~20m warning of approaching obstacles in front of the OFOBS sled.

During deployments, the OFOBS is lowered to ~1.5 m above the seafloor then towed by the ship / ice drift at speeds of up to 0.8 kn. Ideal deployment speed is 0.4 kn, and for the majority of deployments made during this cruise, drift was slower. Every 20 seconds a 26 megapixel still image of the seafloor is taken by the device, and there is the option to additionally take 'hotkey' images of features of interest.

8.2 Introduction and objectives

The Aurora seamount was investigated with a previous version of OFOS (Ocean Floor Observation System) during the Polarstern PS86 cruise in 2014. The transects provided images of the seafloor form the seamount, and a few frames of the only black smoker observed at the time. The system used in the HACON cruise (OFOBS) is an updated version of the towed equipment, which includes bathymetry and higher-resolution cameras. The aim of the OFOBS dives was to conduct high-resolution bathymetry and video/photo surveys over the Aurora seamount, centered around the known location of the black smokers visualized during PS86 in 2014. Six successful dives were conducted on and around the seamount (Figure 8.1). The bathymetry will provide essential information to better understand the distribution of different habitats within the seamount and to locate different vent chimneys for future dedicated sampling. The video and high-resolution photographic transects have gathered a dataset for habitat mapping and community analyses of the Aurora seamount and hydrothermal vent field.

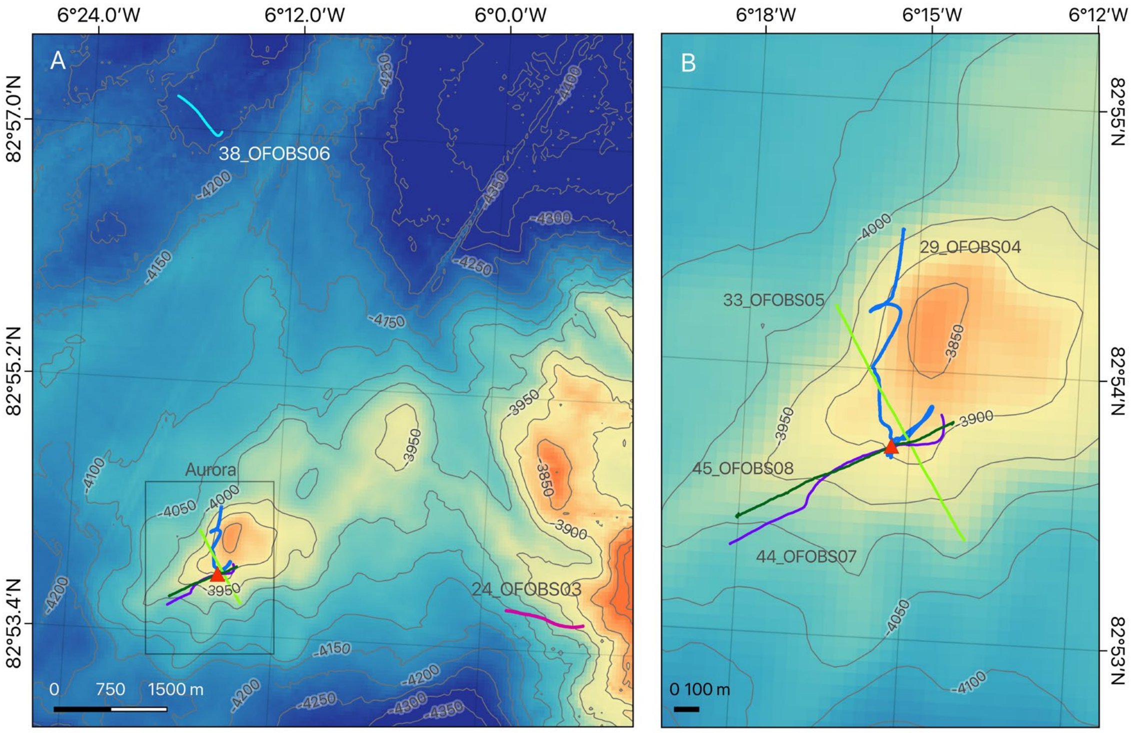


Figure 8.1. Map showing all OFOBS dives around Aurora (A) and detail of the transects conducted over the Aurora seamount (B).

A short description of each dive is provided below. The times are in UTC.

8.3 OFOBS 1 – 29/09/2019

OFOBS 1 (St. 11, Video station 104) started at 03:25. During the start of the descent, communications issues arose with the OFOBS system. OFOBS is stopped at 1000 m to try to troubleshoot the problem, but then the dive is aborted and OFOBS is back on deck at 03:20.

8.4 OFOBS 2 – 30/09/2019

OFOBS 2 (St. 19, Video station 106) started at 22:10, approaching the seamount from the SW. OFOBS is deployed with the "cow catcher", a rescue hook type of device designed by the NUI and NASA teams and built by the crew, which hangs below OFOBS and could, potentially, hook NUI by its float. During the descent, the system experiences electric spikes and the dive is aborted at 22:56. OFOBS is back on deck at 00:02.

8.5 OFOBS 3 – 01/10/2019

OFOBS 3 (St. 24, Video station 109) started at 21:07, approaching the seamount from the west (Figure 8.2). The sidescan sonar is not mounted as it is being repaired. This transect flies E-SE and upwards over the sedimented flank of the seamount.

Most of the time the seafloor is 80-100 % sediment. The fauna is dominated by sponges where hard substratum is available, and includes also amphipods, shrimp. Soft sediment presents many lebensspuren (life-marks), particularly burrows (Figure 8.3).

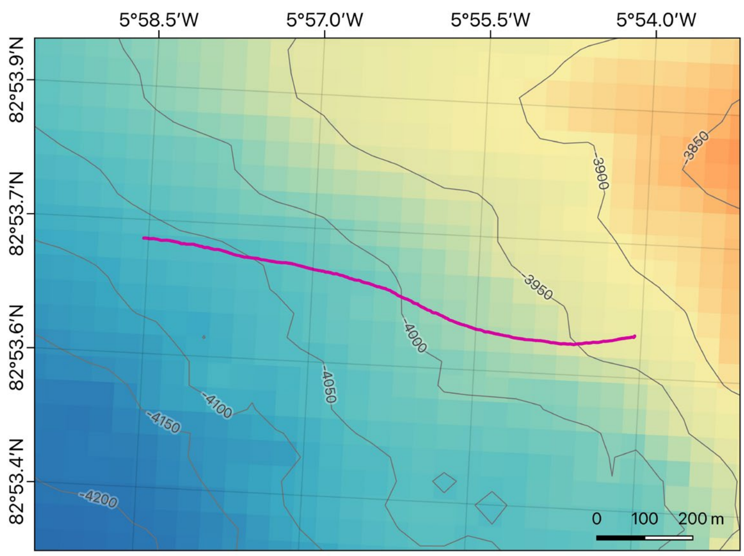


Figure 8.2. Dive track for OFOBS 3.

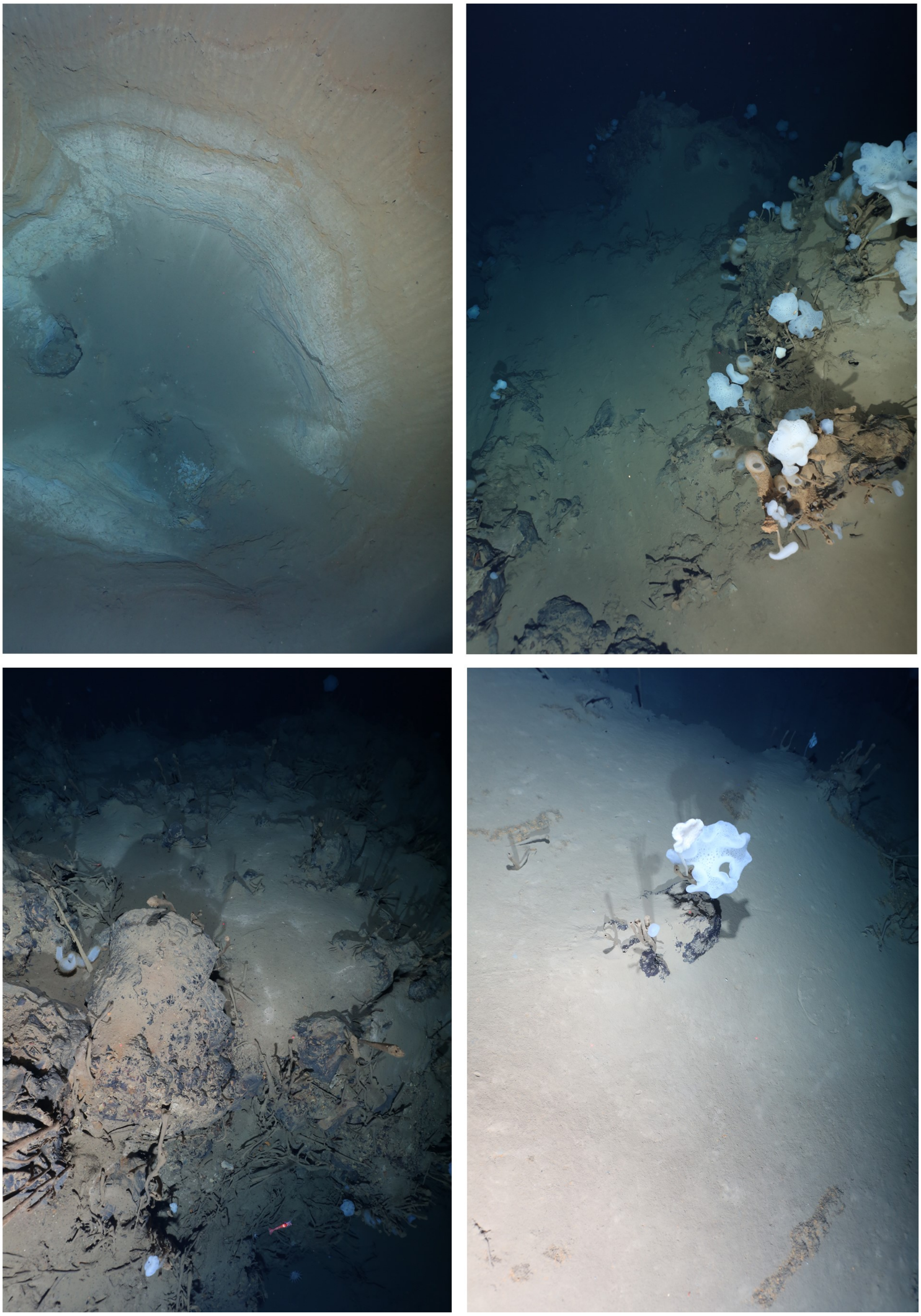


Figure 8.3. Common benthic communities observed during OFOBS dives on the Aurora seamount, showing a sink hole, live sponges and dead sponge stalks on basalt rocks.

8.6 OFOBS 4 – 03/10/2019

NOTE: On 2nd Oct, OFOBS is deployed. But when it is 20 m down, the NUI team receive signal from NUI that it is ascending! The OFOBS dive is aborted and this dive is not accounted in the logs.

OFOBS 4 (St. 29, Video station 112) started at 11:37, approaching the seamount from the north. The deployment is far from the vent site and we have a slow S-SW drift (Figure 8.4).

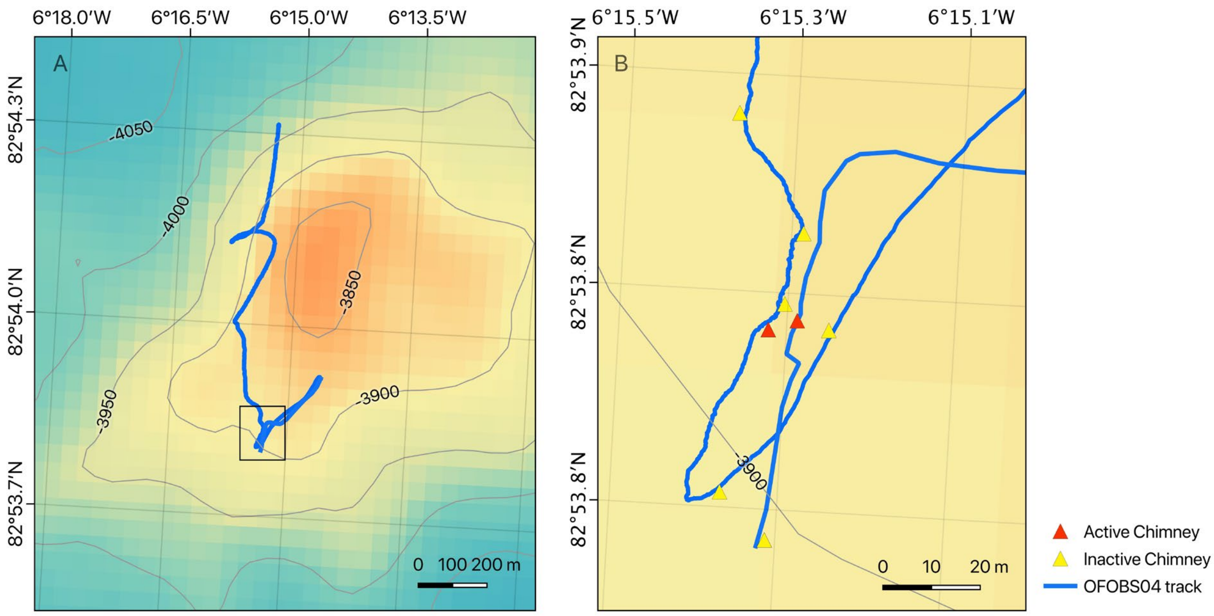


Figure 8.4. Transect of the OFOBS 4 dive over the Aurora seamount and vent field, and close up of the transect on the vent field.

For most of the dive, the seafloor is mostly composed of sediment (80-100%), with sponges, shrimp, amphipods, cerianthids, lebensuprren and many dead sponges/sponge graveyards, as well as biogenic patches of sponge's spicules. There is also basalt outcrops, often covered with sediment. Some parts are very steep, and some parts have clear ripples. This habitat lasts for ca. 8h of the dive. At 19:36, the seafloor starts changing to coarser sediment with patches of orange coloration. The first anemones appear, and at 19:48, we see inactive chimneys. OFOBS climbs up a sulphide mound, and at the top OFOBS flies straight into a black smoker (20:08)! After OFOBS comes out of the hydrothermal fluid, the cameras need to be rebooted and after a minute or so, the video is back and the dive continues (Figure 8.5). The dive continues over hydrothermal habitat, with orange colorations, inactive chimneys, basalt and coarse sediment. At 20:41, the dive is over soft sediment habitat with sponges and shrimp. The vessel slowly turns around (we are at the edge of an open lead) and go back on our course to try a second transect over the smokers. At 20:43, the sediment becomes coarser and inactive chimneys are seen as we climb a second mound. At 21:47 OFOBS is climbing the sulphide mound again, and at 21:49 the black smokers is back in view. The walls of the black smokers and sulphide mound close to the smokers are colonized by small white gastropods and amphipods. A fissure and two sink holes are observed at 22:13. Several inactive and fallen chimneys are observed. Off bottom at 23:06.

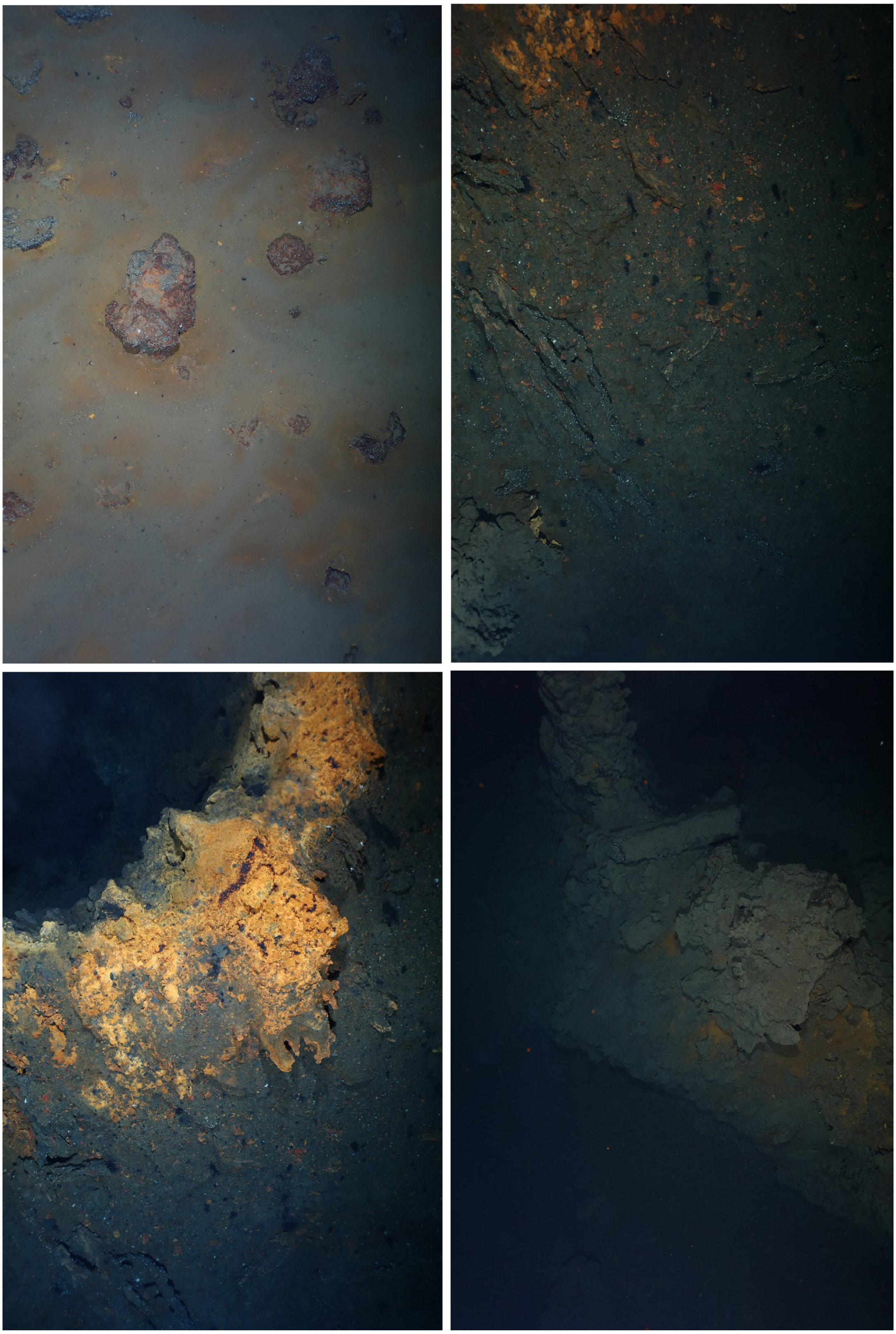


Figure 8.5. The Aurora hydrothermal vent field, showing the approach over sediments stained in orange, the wall of the sulphide mound and the BFV (Big Friendly Vent) black smoker.

8.7 OFOBS 5

OFOBS 5 (St. 33, Videostation 114) started at 10:56, approaching the seamount from the southeast (Figure 8.6). The deployment starts at 500m southeast from the vent site with a slow N-NW drift in an area with predominantly soft sediment with sparse patches of dead stalked sponges and spicules accumulations.

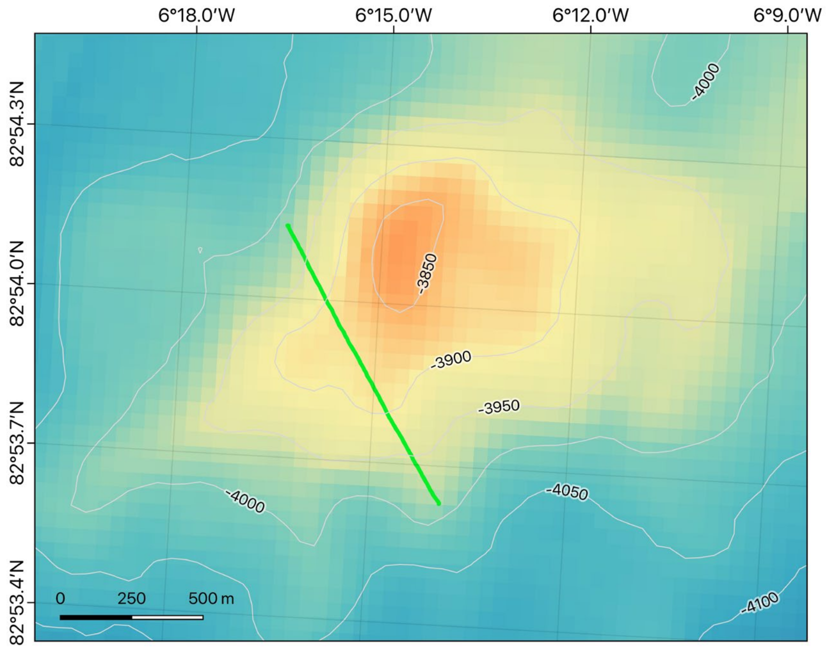


Figure 8.6. Dive track for OFOBS 5.

Small amphipods and various types of lebensspuren were frequently observed, while larger size megafauna observations were much less frequent composed of few shrimps, ophiuroids, sponges and cerianthids. Around 12:36h, changes in the seabed associated with up-wards slope and cliff areas were predominately due to an increase in basalts presence, where few attached stalked sponges and anemones were observed. As the OFOBS moves up the mound, there was an alternation between 100% soft sediment coverage similar to those at the beginning of the dive and small mounds and cliffs areas with sparse basalts with sediment (80%). Here, sponges and associated shrimps were more abundant. At 14:09h and 13:27, there were two observation of inactive broken chimneys and pillow lava spots surrounded by orange oxidized sediments and altered sediment with white coloration. Here some sparse sponges were observed together with many small gastropods. At 13:02 we crossed a sinkhole. Towards the end of the dive the seabed was predominately composed soft sediment areas but with many ripples marks oriented in various directions. Off bottom time was at 15:41.

8.8 OFOBS 6 – 05/10/2019

OFOBS 6 (St. 39, Video station 117) started at 23:23. This is a transect in background habitat about 5 km away from the seamount (Figure 8.7).

Most of the dive is over soft sediment, with shrimp, amphipods, and many small white/translucid holothurians. Some isopods, polychaetes and sponges are also observed. Feeding marks of Dumbo octopuses are also seen on the sediment, and one image catches part of a Dumbo feeding (02:11).

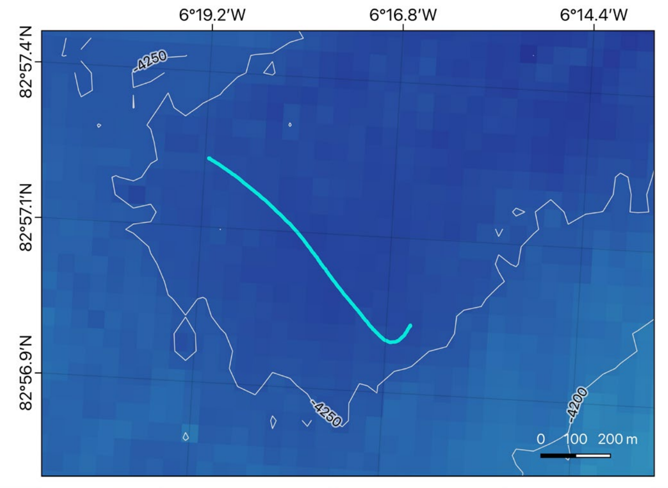


Figure 8.7. Transect of OFOBS 6 dive, N of the Aurora seamount.

8.9 OFOBS 7 – 07/10/2019

OFOBS 7 (St. 44, Video station 119) started at 07:04. We are in position with a good NE drift of 0.4 kn. The vessel is at the edge of a small lead and the dive approaches the seamount from the SW (Figure 8.8).

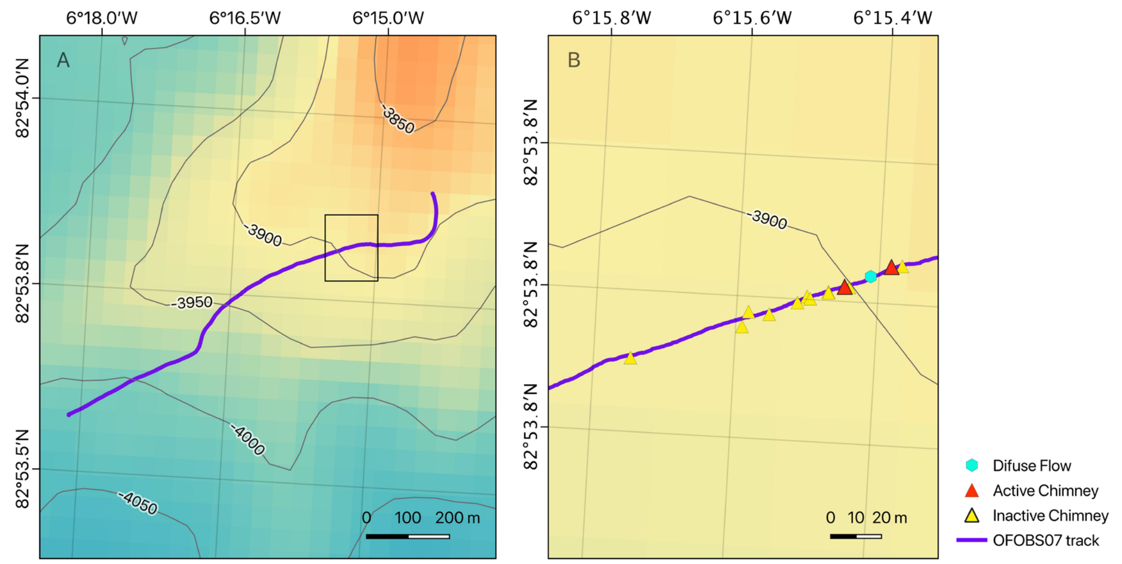


Figure 8.8. Transect of OFOBS dive 7 on the Aurora seamount and close up of the transect section over the vent field.

The start of the dive runs over soft sediment, with the usual live and dead sponges, amphipods, shrimp and lebensspuren. The dive goes over steep flanks covered with sediment and areas of marked ripples. At 09:42 the sediment is coarser and in places orange. Inactive/fallen chimneys are observed. At 09:53 the climb on the sulphide mound begins. Several inactive chimneys are seen. At

09:57, OFOBS is over a black smoker, smaller than the large one we saw in dive 4, with a more typical chimney shape. Diffuse flow is also observed (09:58). The transect moves to 80% sediment covered (10:07) as it goes downhill on the other side of the seamount. OFOBS is on deck at 11:55 for a new deployment over the same site, to profit from having an open lead over the seamount.

8.10 OFOBS 8 – 07/10/2019

OFOBS 8 (St. 45, Video station 120) started at 11:56. The vessel is re-positioned in the same open lead that we were using for OFOBS 7, for a short DP-controlled drift to the vent site (Figure 8.9). The vessel is slowly moving to follow the ice drift, but is not against the ice, giving again the possibility to adjust the positioning slightly. The dive starts on soft sediment, with amphipods, isopods, shrimp, live and dead sponges and lebesspuren. From 15:17, orange coloration of sediment, inactive chimneys and coarser sediment, as well as anemones, are observed in the approach to the black smokers. The transect descents from the sulphide mound, and then climbs another mound. Diffuse flow is observed at 15:36 and the large black smoker is seen again. The hard substrate around the black smokers is colonized by small gastropods and amphipods.The transect continues descending the mound and into background environment with soft sediment, sponges, amphipods, ceriantheds and shrimp.

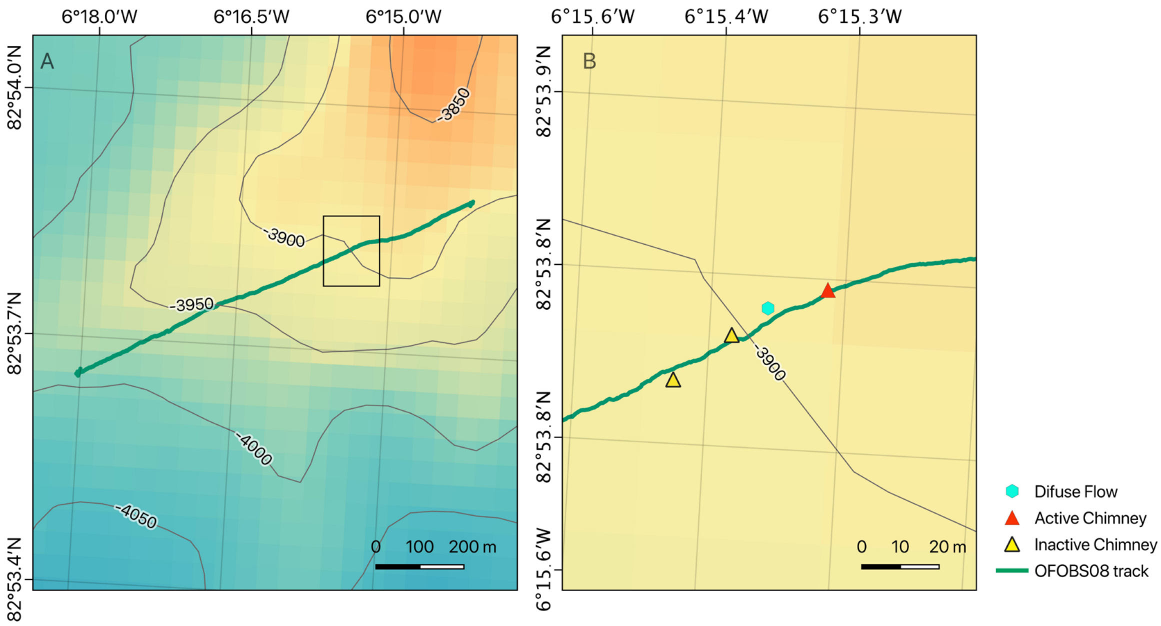


Figure 8.9. Transect of OFOBS dive 8 on the Aurora seamount and close up of the transect section over the vent field.

8.11 OFOBS 9 – 11/10/2019

OFOBS 9 (St. 63, Video station 123) started at 06:55. This is a dive about 12 km SW from the Aurora seamount, in an area where the topography indicated potential for hard substrate on the flank of the ridge (Figure 8.10). The seafloor is different from the habitat on the seamount. The sediment is coarser and there are many small rocks. The faunal community is also different, with an area with high abundance of ophiuroids and several stalked crinoids (08:10 - 08:17). Other fauna observed in previous dives is also seen here, including amphipods, shrimp, a few sponges and an anemone. During the dive, the drift decreases considerably, and it is decided to finish the dive at 09:37.

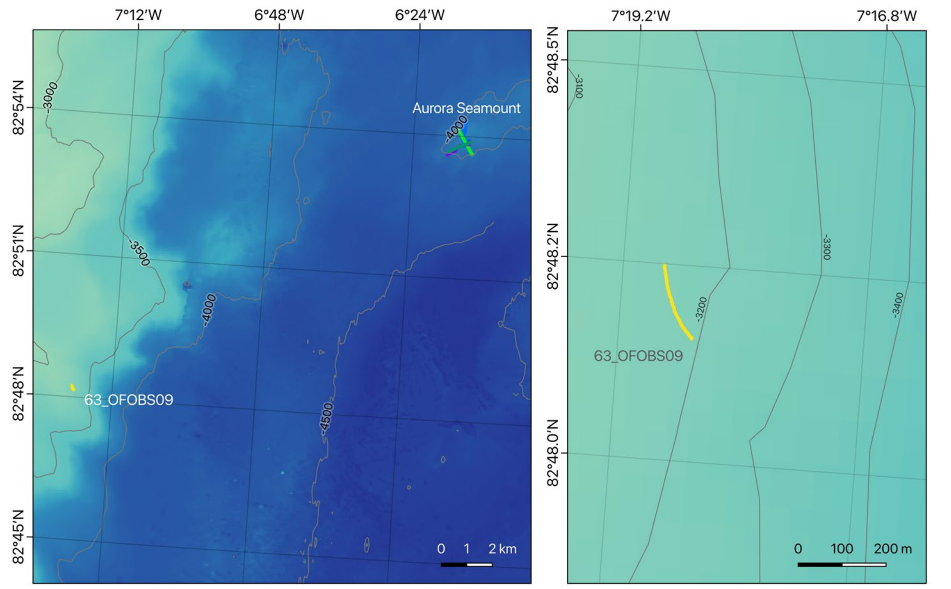


Figure 8.10. Transect of OFOBS dive 9 on the ridge flank showing the dive in relation to the Aurora seamount and close up of the dive.

9 NEREID UNDER ICE (NUI) VEHICLE

Andrew Bowen, Christopher German, Mike Jakuba, Stefano Suman, Daniel Gomez-Ibanez, Chris Judge, Molly Curran, Victor Nalicki, Sig Vågenes, Patrick Vågenes, Lu Lamar, Andy Klesh, Stefan Bünz, Eva Ramirez Llodra, Hans Tore Rapp, Pedro Ribeiro

9.1 Introduction and objectives

The Nereid Under Ice vehicle is a hybrid vehicle specifically designed for operations beneath ice covered oceans, including ice-shelves in the Antarctic, beneath the tongues of glaciers as they enter the ocean, and beneath sea-ice in the Arctic. Following two prior expeditions, diving to study ice-ocean interactions above the Aurora seamount in 2014 and at the seafloor of the Karasik seamount in 2016, NUI was brought to the HACON 2019 expedition with three primary objectives, taking advantage of both its autonomous underwater vehicle (AUV) and remotely operated vehicle (ROV) modes.

- To conduct systematic surveying (mapping, plume sensing) of the Aurora vent-field.
- To conduct detailed sampling at the Aurora vents, once they had been located.
- To conduct biological and sediment sampling at stations away from the vents.

A combination of technical issues during the first dive, compounded by ice drift issues in the second half of the cruise meant that only the third objective was attempted at sea.

9.2 Technical description

The Nereid Under Ice (NUI) Vehicle is a 5000 m depth rated robotic underwater vehicle that has been designed to provide a capability to teleoperate in the ice-covered Arctic Ocean unconstrained by the motions of the overlying ice. Designed and built at WHOI with colleagues at Johns Hopkins and the University of New Hampshire, NUI enables exploration and detailed examination of under-ice environments (Jakuba et al., 2018). The key enabling technology is a 250 µm diameter fiber-optic tether, up to 40 km in length, that allows the vehicle to achieve standoff distances of several km from its host vessel. Powered by a 24 kWh rechargeable battery, it has a range of 10 km to 40 km depending on the balance of sea floor inspection and manipulation tasks versus survey/mapping tasks. The vehicle can convert in situ between low-drag survey configuration and inspection/manipulation configuration by opening doors built into its bow (Figure 9.1). The vehicle features a high-end navigation suite (iXSea Phins, RDI DVLs, Paroscientific), a 7-function light work-class electrohydraulic manipulator (Kraft), HD and UHD video and still cameras (Kongsberg, SubC, Rayfin) and a multibeam sonar (Imagenex). It also includes a suite of water-column sensors which, for this cruise, included a SeaBird FastCat 49 CTD, a Wetlabs FLNTURTD fluorometer tuned for optical back-scatter (turbidity) measurements, and an AMT DeepORP in situ redox probe.

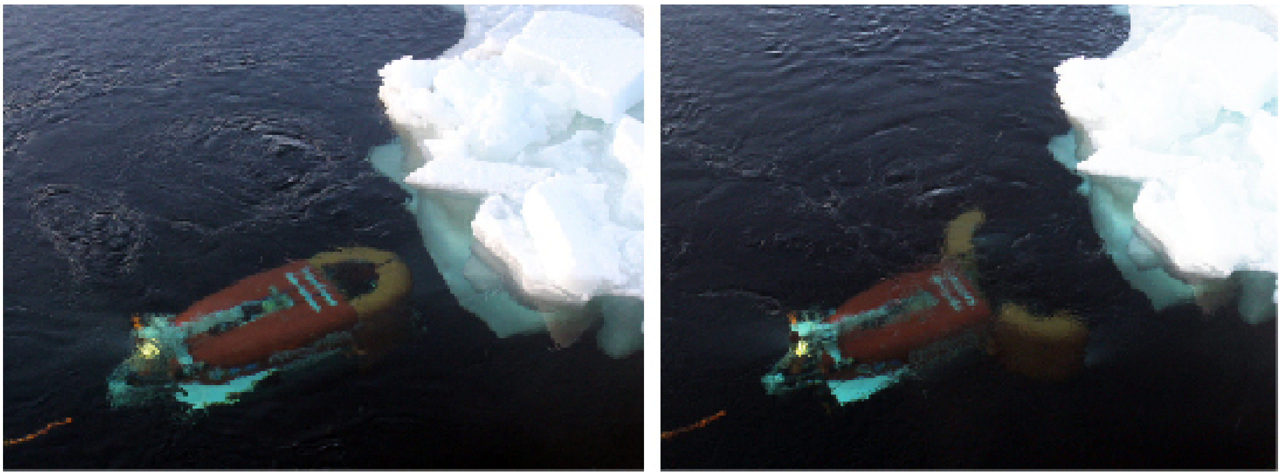


Figure 9.1. Nereid Under Ice in (NUI) on AUV configuration (left) and ROV configuration (right).

Seafloor sampling equipment included a variety of options including a 5-chamber slurp sampler, an insulated bio-box, crates for rock sampling and/or for push coring (9 push-cores per crate, up to 2 crates per dive). Lift capacity for the Aurora expedition was predicted at up to 20kg for sample acquisition per dive. A high-temperature probe was borrowed from the HOV Alvin group, National Deep Submergence Facility, WHOI for this cruise. NUI was also configured to operate with UiBergen Isobaric Gas Tight (IGT) vent-fluid samplers for Dives 17 and 18 and wih a UiBergen Blade Corer for Dive 19.

9.3 Dive 17

NUI Dive 017 was planned as primarily a mapping / reconnaissance survey dive that would complete high resolution bathymetric mapping and co-registered in situ sensing for buoyant hydrothermal plume signals over a 200 m x 200 m area centered on the known location from the PS86 (2014) cruise for active seafloor venting. The Dive Plan for NUI 017 can be found in Appendix 18.4.1. Two attempts were made to implement NUI Dive 017.

[Note: unless the tow-body separates from the depressor, a NUI Dive is not considered to have been undertaken. Hence, the dive number does not increase, even though the vehicle had entered the water].

9.3.1 NUI Dive 017a

Narrative

Dive start: 2019/09/29 7:11:18 (82.9217° N, 6.1557° W)

- Test of burn wire with wire burned via Acomms successful.
- Upper starboard horizontal fault on rotor position indicator (fault type 0x40).
- Once the vehicle had descended to 100 meters and vehicle checked completed, it was impossible to release tow-body float pack from the depressor.
- Descent weight prematurely dropped without command.

Discussion

The primary reason for NUI dive 17a termination was an inability to release the tow body once NUI reached its target separation depth of 100 meters. In normal operation, the tow body is positively latched into the depressor during launch and initial descent to 100 meters. Upon reaching this target separation depth, the latch is opened by sending a command to the depressor latch motor. This motor rotates the mechanism into a release position. Once this is accomplished, NUI continues its descent whereupon the tow body is separated from the depressor and the vehicle descent continues while paying out its fiber optic tether from dispensers on both the depressor and the NUI tow body. During dive 017a, the latch could not be actuated successfully. Upon recovery of the depressor and NUI vehicle, it was determined that the latching mechanism was obstructed from operation by ice having formed within the latch. Based on this discovery, the tow body release was revised by disabling this mechanism into its open position and retaining the tow body instead via a simple lanyard that could be removed at the surface once NUI and the depressor were launched. On subsequent dives separation still occurred at 100 m depth, with the positively-buoyant tow body remaining in the depressor passively until pulled out by NUI.

9.3.2 NUI Dive 017b

Narrative

Dive start: 2019/09/30 4:28:21 UTC (82.8928° N, 6.3118° W)

- Tow-body float pack latch actuator removed with manual release instituted.

- Descent weight mechanism reinforced to prevent un-commanded release.
- Intermittent fiber communications during final stages of descent.
- At 2019/09/30 8:26:24 UTC a series of progressive failures over approximately 10 minutes results in loss of control to NUI via both fiber and Acomms.
- Series of acoustic commands issued to drop descent weight were acknowledged but NUI remains on the seafloor. Estimated position is 82.897069°N 6.263312°W according to USBL.
- Circumstantial evidence suggests a significant failure of NUI has occurred and that the vehicle is in a negative ballast state on the seafloor at a depth of 3833 meters. Failure of both acoustic systems to release the descent weight means NUI must rely on a zinc "corrodable link" to dissolve.
- Science activities continue with periodical checks of NUI position via USBL and/or Acomms to confirm vehicle position and detect any ascent should that occur.
- At 2019/10/03 04:50:06 UTC a check of position indicated NUI was ascending and had already risen to at a depth of 2541 meters. NUI was recovered with assistance of the ship's work boat at 9:37:08 UTC (82.9009 N, 6.3011 W) and after a 1-hour period of observation to ensure no unexpected difficulties with NUI's batteries, the vehicle was lifted onboard.

Discussion

To reduce energy consumed during NUI descent, a jettisonable ballast weight is added to the vehicle prior to launch. There are 3 ways for this ballast weight to be released from the vehicle: 1) via the NUI telemetry tether using an electrically driven corrosive "burn wire", 2) via Acomms using a second burn wire arranged in series with the first and finally, 3) a passive timed-release made up of a corrodible zinc link that is set to dissolve after 24 hours at 5°C. The dive plan called for this ballast to be retained during the survey and subsequent sampling activities and then be jettisoned once NUI ascent was commanded.

Dive 17b proceeded as expected with bottom approach being completed at approximately 70 meters altitude. The dive plan called for an initial sonar survey of the Arora vent site. While NUI was preparing to begin this survey, a progressive series of failures occurred until a complete loss of contact through both the fiber tether and Acomms was experienced. The vehicle was tracked via USBL acoustic navigation which indicated NUI descending from its 70 meter altitude to the seafloor. The rate of this descent, as observed via USBL, suggested NUI was in a negative ballast condition of approximately 10 kilograms. Repeated attempts via AComms to release the ballast weight were unsuccessful thus forcing a lengthy 72 hour wait at in situ seafloor conditions (approx. -1°C) for the corrodible link to dissolve and passively release the ballast weight, thereby enabling NUI to return to the surface for recovery.

Upon physical examination of the vehicle and review of the associated dive logs, the most likely root cause of the dive failure was traced to fouling of the starboard vertical thruster with a temporary lanyard that should have been removed before the dive. This lanyard's use was specific to NUI's installation on Kronprins Haakon, to enable passage of the vehicle from the hangar to the ship's aft deck. Minimal clearances between the main deck crane pedestal and other ship's structures required removal of NUI's port and starboard vertical thrusters ahead of roll-out for each deployment and to temporarily suspend them via lanyards. Once readied for launch, the thrusters were to be reinstalled and lanyards removed. Unfortunately, the lanyard on the starboard side was left in place. Once NUI reached the "Start Survey" point at the seafloor at Aurora, this lanyard appears to have become entangled into the starboard vertical thruster, causing it to stall. While the thruster motor controller and associated protection circuitry should have been able to protect against subsequent damage to the rest of the system, the evidence suggests that a surge in current, perhaps aggravated by a high voltage typical with a sudden stoppage of the motor, caused the cable connecting the motor to its controller to short together the 3 electrical phases. As the controller failed, the fuse connected to the telemetry chassis blew for reasons that remain unclear. Surges in voltage and current appear to have caused the main batteries to trigger their own internal protection circuits resulting in them disconnecting from the vehicle itself. Once this occurred, only the battery backup to the Acomms was available. Post dive analysis indicated that the electronics required for actuation of the Acomms-commanded ballast burn wire, also independently battery-backed, had experienced a small leak of seawater causing a shorting of its battery thus forcing complete dependence on the zinc corrodible link to drop the ballast weight.

Post dive NUI 17b, the high-power switch/fuse to the motor controller was replaced, as was the starboard vertical motor controller and external interconnect cable. The ballast burn wire electronics were repaired and housing leak tested. During these post-dive activities, 2 of the 27 battery modules spontaneously reported internal problems. The modules are arranged in strings of 3, rendering 6 modules unavailable for use (22% loss in capacity). The cause or exact nature for these internal failures is unclear but suggest that some component(s) are sensitive to damage when exposed to high ambient pressures.

9.4 Dive 18

By the time NUI was repaired ready for Dive 018, the OFOBS system has successfully reconnoitered the Aurora vent-field. Consequently, given the time elapsed since arriving on station (>50% of available on-station time) it was decided to deprioritize any systematic mapping of the vent-site for Dive 018 and select first sampling for vent fluid geochemistry and associated micro- and macro-biology as the prime objectives. A detailed plan for NUI Dive 018 is presented at Appendix 18.4.2.

Narrative

Dive start: 2019/10/06 10:06:41 UTC (82.8708° N, 6.2731° W)

- Latch for tow-body released manually with nominal separation between NUI and the depressor at 100 meters
- Batteries 57 and 62 report low voltage and will not discharge early in Dive 018
- Ice drift of 0.61 knots at 007° course over ground would have NUI at only 2000 meters depth when open lead for vehicle recovery passes over Aurora vent site, leaving little or no time

on bottom before NUI must pursue ship for recovery unless drift rate and/or direction decreases dramatically.

- 2019/10/06 11:30:32 UTC at approximately 800 meters NUI depth, the vehicle experiences a failure of communications traced to a network switch. Control of the vehicle acquired over Acomms with NUI commanded to follow the ship track while fault is investigated.
- Between 11:30:32 and 12:13:17 UTC network switch trouble-shooting continues until it is decided to abort NUI Dive 018. NUI is commanded via Acomms to ascend while being commanded to follow the ship for recovery.
- Network connectivity is restored upon ascending. A decision to continue the dive is made and NUI recommences descent under piloted control.
- Network connectivity is again lost and with ice-drift remaining steady at >0.5kt the decision is made to abort the dive, using Acomms to command an ascent.
- Network connectivity is restored again upon ascending, but the decision to abort the dive stands. Network connectivity is retained for the remainder of the dive.
- At 13:29:31 UTC NUI surfaces approximately 100 meters aft of Kronprins Haakon under piloted control with the fiber intact. Control was switched to RF to permit severing the fiber and the vehicle was then manually driven to the stern of the vessel and recovered smoothly at 13:45:19 UTC (82.9038°N, 6.2009° W).

Discussion

The speed of ice drift during this dive was generally beyond advised rates for successful NUI operations. Previous planning had suggested that an ice drift speed beyond 0.5 knots would likely limit workable bottom time while ensuring acceptable opportunity for NUI recovery in an open ice lead without an unreasonable risk of entrapping the vehicle under heavy, difficult to break ice. Indeed, even if the dive had proceeded as planned and give the limited lead to work with, NUI would have only reached a depth of 2000 meters before consideration of recovery would have likely required turnaround of the vehicle as it pursued the ship for recovery. It is likely that strong winds were responsible for ice drifts at such observed speeds.

Nevertheless, NUI experienced a reset of one of its main network switches during the descent at a depth of approximately 800 meters. Connectivity was restored upon ascent, lost again upon subsequent descent, and restored again upon commencing final ascent. The resets of this switch were likely the result of marginal supply voltage to the switch resulting from externally induced variation in the resistance of a cable connecting NUI to its tow body and being powered from the same power supply feeding the network switch. This circuit was no longer in service but had not been disconnected from the supply. In tests after the dive, it was possible to simulate reset of the switch by artificially lowering the voltage as might have occurred at depth. While examination of this cable post-dive revealed that a “kink” in the external cable was present, and the insulation of the individual conductors damaged, it was not possible to fully duplicate the failure. As precautions, the cable was replaced and the disused circuit disconnected.

During NUI Dive 018 battery difficulties were again detected in several modules with at least 1 new module failure occurring. Battery modules are arranged in strings of three modules in series, with nine strings in parallel split across three tanks containing three strings each. Thus, loss of any one module reduces the capacity of that string to zero (11% of total capacity). By the end of NUI Dive 018 three of these nine strings were inoperative thus reducing NUI to only 65% of its design capacity. For this reason, NUI's batteries were removed and the failed cells were rearranged to minimize this impact. This remedial action restored NUI to approximately 89 percent of its design battery capacity in preparation for NUI Dive 019.

9.5 Dive 19

NUI was prepared and ready to dive for a repeat of the same Dive Plan as developed for NUI Dive 018 by midday on Tuesday Oct 08th. Unfortunately, ice-floe "ROLF (Really Obstinate Large Floe) which had drifted over the Aurora vent-site on the preceding afternoon came to rest and did not move again for the next 48 hours. This meant that the ship could not approach to within the safe operating environment for NUI (≤2 nautical miles from the vent and closing at ≥0.1kt) throughout the remainder of our time on station. Consequently, on the morning of Thursday Oct 10th, the decision was taken to pursue a different set of objectives that NUI could uniquely provide for the science team and conduct piloted manipulations for biological sampling of non-vent fauna at the seafloor within the Aurora rift valley. A detailed description of the Dive Plan for NUI Dive 018 is provided at Appendix 18.4.3.

Narrative

Dive Start: 2019/10/10 16:43:32 UTC (82.909° N, 6.6743° W)

- Battery 3 cells inoperative at time of launch but regrouped into 1 bad string to ensure ~89% of design capacity is available.
- During descent NUI lost 2 more battery modules, taking away 2 more strings from the available power (leaving approximately 65% of design capacity)
- Dive proceeds as planned with NUI reaching a maximum allowable depth (constrained by USBL navigation beacon and other mission-specific sensors) of 4000 meters at approximately 20:35:0 UTC.
- Conscious of limited power, sampling was conducted swiftly as soon as opportunities allowed, in two locations. First sample station = glass sponge recovered into Bio-Box; Second sample station = glass sponge recovered into Bio-Box, UiB "blade-corer" used to collect sediment ± sponge spicules at same location.
- With limited power available as a result of poor battery reliability and an operational safety requirement to retain a conservative 40% power for surface recovery, NUI was raised up off the seafloor at 21:59:25 UTC.
- At 2019/10/11, 00:52:32 UTC NUI's ascent was halted at a depth of approximately 40 meters (to protect fouling of the buoyant tow-body on the underside of the ice) at a horizontal range

of ~300 meters from the ship. The fibre tether remained intact and connected to NUI, allowing piloted operations. Tracking from both USBL and Acomms was maintained throughout the recovery.

- At 01:13:17 UTC (82.8976° N, 6.6067° W) NUI was maneuvered into an open lead located directly aft of the ship and then driven up to surface. Using the radio modem, the pilot then positioned the vehicle for recovery.

Discussion

Ice conditions prevented this dive from reaching the Aurora vent-site. The slow ice drift, lack of suitable ice lead near the site, and NUI's compromised battery capacity, meant that NUI Dive 019 could not attempt to reach Aurora. Instead, the dive was planned to undertake video surveys and limited sampling of available fauna and collection of a blade-type sediment core. Further, these activities were constrained to take place at depths of less than 4,000 meters due to limitations of the USBL beacon and the mapping/obstacle avoidance sonars mounted on NUI. In general, sampling, manipulation and use of the NUI workspace doors proceeded as expected and proved to successful given the limited experience of the pilots with NUI's new configuration.

As with previous dives, the batteries proved to be a limiting factor, with 2 more modules failing in different strings, further reducing the power capacity by 18%. It is likely that any continued operations of NUI would have been further hampered by more internal battery failures. Despite these batteries being rated by their vendor (Southwest Energy Inc.) for operations to 6,000 meters, and additional testing that the NUI team had conducted at WHOI to verify that, the operational evidence gained during HACON 2019 and the poor reliability experienced during the cruise provide strong indications that replacement or modification of NUI's batteries will need to be considered prior to any further deep diving field programs. It is plausible that the internal circuitry for the batteries was damaged by the fouled thruster event on NUI dive 017b and this will need to be investigated carefully, as a first priority, before deciding on what further action is required to address this identified weakness.

9.6 NUI Photo-shoot activity

On 2019/10/11, 14:34:09 to 15:31:44 UTC (82.8071°N, 7.2726°W), NUI was deployed for a shallow demonstration dive to enable a series of photographic opportunities conducted by Luis Lamar (free dive) supported by the Avatar Alliance Foundation.

10 MARINE GEOLOGY

Giuliana Panieri, Pierre Antoine Dessandier, Dimitri Kalenitchenko, Stefan Buenz, Ida Steen, Achim Mall, Håkon Dahle, Francesca Vulcano, Eva Maria Meckel, Eoghan Reeves.

10.1 Introduction and objectives

The sedimentary record is the result of complex processes related to the geologic setting, climate, and processes of sediment formation. It shows different chemistry as a result of changes in different combinations of minerals, and is dominated by cyclic processes that operate on a hierarchy of temporal and spatial scales on which short-lived events are superimposed to long-lived events. The sedimentary record preserves remains of organisms, like foraminiferal shells, that are used to reconstruct environmental changes occurred in the geological past.

The main objective of this team was to collect sediment samples that will define the lithostratigraphy and type of sediments and minerals in order to reconstruct the paleoenvironmental, geological evolution and the hydrothermal activity of the Aurora seamount. This will be done through the analyses of sediment geochemistry (X-Ray fluorescence scanning, magnetic susceptibility, X-ray diffraction) and imaging on defined sedimentary layer), and micropaleontological investigations. The micropaleontological investigation will focus on biostratigraphy, paleoenvironmental reconstructions of the Aurora hydrothermal field and will evaluate the effect of hydrothermal activity on foraminifera communities.
Samples for pore water analyses, head space for methane measurements, sediment organic geochemistry for biogeochemical cycling of elements (C and N), and microbiology were also taken from gravity cores, multicores and box cores.

10.2 Sampling devices and methods

The multicorer (MUC) and graviticorer (GC) were deployed in areas where suitable seafloor conditions such as soft mud and absence of larger clasts were identified in the OFOBS imagery or using previous bathymetry (Figure 10.1).

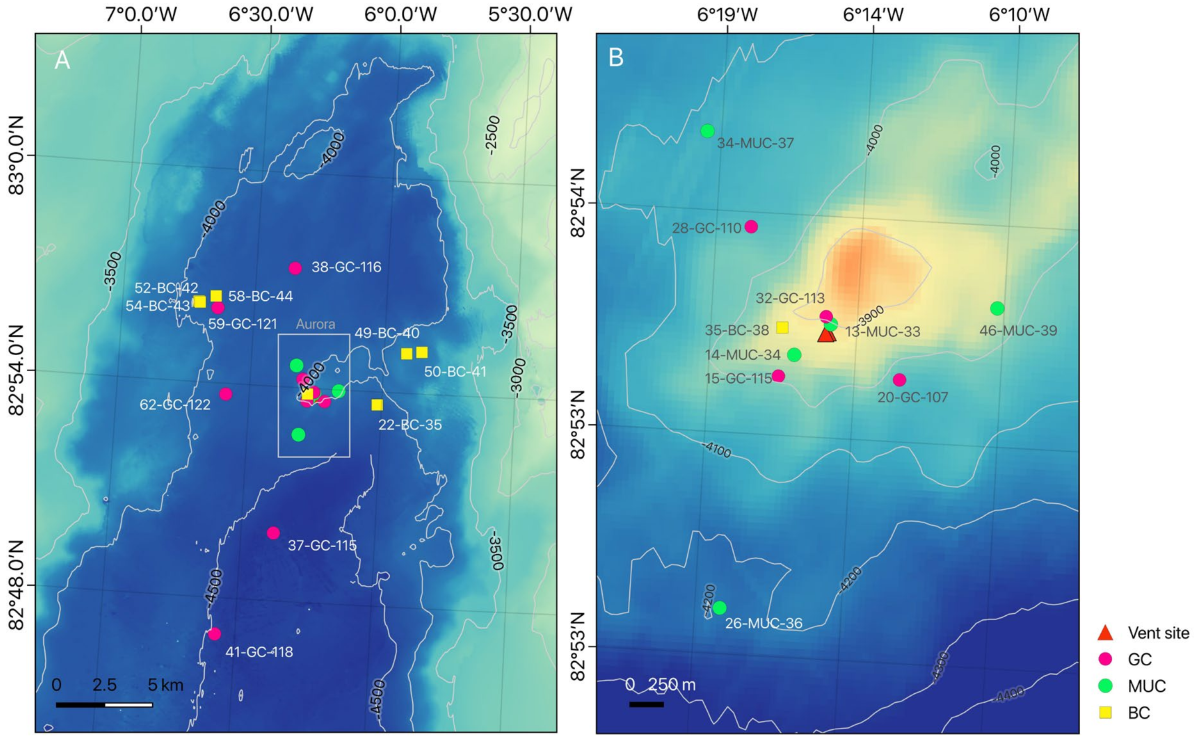


Figure 10.1. Locations for the coring samples in the study area (A) and a detail for the Aurora seamount sample stations (B). GC: gravity core; MUC: multicore; BC: boxcore.

10.2.1 Multicorer

The multicore sampling system is a KC Denmark DK8000 mounted with six parallel 70 cm long transparent tubes (liners) with a diameter of 10 cm (Figure 10.2). The core tubes are loaded with open upper and lower ends. The MUC is deployed at 1 $m.s^{-1}$, until 100 m above, then lowered to the seafloor at 0.5 $m.s^{-1}$, left on the seafloor for about 1 min seconds and recovered at 1 $m.s^{-1}$. When the multi corer lands on the seafloor, the tubes are pushed into the soft sediment by lead weights, and closed on both ends. Up to 60 cm of sediment and the immediate overlying water can be sampled. This allows the analysis of undisturbed faunal samples within their undisturbed environment. Once on board, the core tubes filled with water end sediment. The liners were carefully taken out of the sampling device, the ends were sealed, and the cores moved, in an upright position, in the wet laboratory. Once in the temperature-controlled room (2 ºC), compatible to the in-situ bottom water temperature, in racket to keep them vertical, the oxygen profiling starts. Follows contemporaneous sampling for pore water, microbiology, micropaleontology and meiofauna. Two extruders were used from the different groups that sampled contemporaneously.

Figure 10.2. Rigging the liners on the multicorer on deck.

10.2.2 Gravity corer

The gravity corer consists of a 6 m long iron barrel with iron weights attached on top of it, with a total weight of 1.3 t (Figure 10.3). The GC has an inner diameter of 11 cm. A plastic liner with outer diameter of 11cm and inner diameter of 10 cm is inserted into the steel barrel. For certain deployment, the liners were pre-drilled to facilitate pore water and microbiology sampling. During the coring operation, a core catcher and core cutter is attached to the lower end of the gravity corer. Core catcher keeps the sediments from falling out of the core, whereas core cutter helps the penetration of the core in o the sediments. The gravity corer is lifted vertically, deployed from the a-frame and lowered to the seafloor at 1 ms^{-1}, until ca. 50 m above the seafloor, and then dropped. When the gravity corer is lifted from the seabed and is brought to deck, the core catcher and core cutter are sampled first, if there are sediments present in them. Then, the plastic liner is taken out, cleaned, cut to 1-meter sections, and labeled.

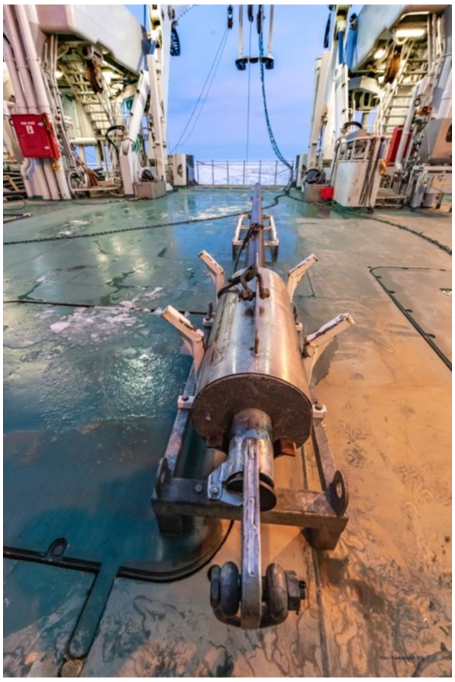


Figure 10.3. Gravity corer used during HACON19 expedition.

10.3 Sedimentology

The HACON19 expedition recovered 12 gravity cores (4465 cm in total), multicores from 5 stations, 7 box cores and 1 blade core from the area nearby the Aurora hydrothermal vent field and from the Lena trough. The sites range in water depth from 2410 to 4668 m. Most of the activities focused on the area around Aurora hydrothermal field and few gravity cores were collected from the Lena Trough during the steaming to Longyearbyen.

Several meters of sediment were recovered in the area around Aurora seamount while the attempt to collect sediment using the gravity corer from the Aurora seamount failed and the multicorer collected only two full liners characterized by layers of metalliferous sediments indicative of volcanic and/or hydrothermal events. The gravity cores were cut to 1-meter sections but not sliced on-board. However, while cutting the sections and because the very good recovery (up to 564 cm) the sediment appears to be clay. Only one core (HACON19-68-GC126) seems to have encountered a layer rich in coarse sediment, because it was 100cm in length and dark grey coarse sediment, most likely terrigenous ice-rafted debris (IRD), was found in the core catcher. Some gravity cores and multicores were chosen for pore fluid analyses, sampled for methane (headspace), and microbiology. Once sampled the gravity cores were stored in the cold room. On the contrary, from each successful multicorer cast (Appendix 18.1), the full liners were shared among groups (Appendices 18.2 & 18.3). In general, one core pipe was used for oxygen profile, pore water and sediment organic geochemistry, and the others for micropaleontology, meiofauna, and microbiology.

10.4 Micropaleontology

Samples for investigation of fossil foraminifera (benthic and planktonic) and paleoenvironmental reconstructions were taken from all sediment from gravity, multi-, and box-cores (Table 10.1). Gravity cores were not sliced on board, but we sampled all multicores and liners taken inside the box corer every cm or 2 cm for investigation of fossil foraminifera. Samples were placed in plastic bag, labelled and stored in the cold room. Details on sampling and future analyses on living foraminifera are provided in the chapter "Marine Biology".

10.5 Pore-water geochemistry

A total of 105 pore water samples were collected from 8 multicores, and 2 gravity cores using 10 cm rhizons. Fluids from gravity cores and multicores were extracted in a 2°C refrigerated room. Most samples yield >10 ml of water, with a few ranging from 1 to 5 ml. Fluids were analyzed onboard for alkalinity and pH and subsampled as shown in Table 10.1. Alkalinity was determined on board using a Metrohm 888 Titrando Tiamo autotitrator, performing a Gran-style titration using 0.1N HCl with automatic end-point detection (cross-checked with values computed using the classical Gran function approach, E. Meckel). pH (at 25°C, 1 atm) was measured potentiometrically onboard using a Ag/AgCl combination reference electrode. Selected multi-corer porewater samples were sampled for CH_4 concentration by testing the headspace gas present after Rhizon fluid extraction into plastic syringes, but analyses by gas chromatography (flame ionization detection, E. Reeves) revealed only contaminant CH_4 introduced during sampling from laboratory/ship air. The location of the cores and general working area are shown in Figure 10.1.

Table 10.1. Type of analyses on pore water samples taken during the HACON19 cruise.

Analyses	Volume (ml)	Treatment
Alkalinity	2 to 3	Titrated onboard
pH	2 to 3	Pour the samples in a Nalgene bottles and measure with pH electrode (calibrated every day with 3. Calibration)
^{13}C of DIC	1 to 1.5	1.5 ml glass vials containing 10 µl HgCl2
SO4	1.5	Frozen samples (-20°C)
ICP	6-7	3% HNO3, stored at 4°C
IC	3-4	ZnAcetate, stored at 4°C
Nuts	3	Stored at -20°C

10.6 Sediment organic geochemistry

A total of 170 samples for measurement of organic carbon, nitrogen and organic matter stable isotopes (usually known as "environmental parameters") were taken from all multi- and box-cores every cm or 2 cm interval (Table 10.2). The number of samples taken ranges from 0.2 to 0.4 g. These samples will be freeze-dried before the analysis of pigments (if any).

10.7 Microprofiling

One core from each mutlicorer deployment (see Table 10.2 for details) was transferred immediately after recovery of the sediment in a temperature-controlled room (2 ºC), compatible to the in-situ bottom water temperature to make profiles of O_2, H_2S, pH and Redox potential within the sediment. The microprobe used for the profiles are:

- A miniaturized 100 µm width Clarks type electrode for the oxygen profile.
- A miniaturized 100 µm width glass H_2S amperometric sensor with built in internal reference, sensing and guard anode. The sensor signal is generated by the re-oxidation at the sensing anode of the ferrocyanide that is formed by the oxidation of HS^- ions by ferricyanide in the probe alkaline electrolyte.
- A miniaturized 100 µm width glass PH electrode with an electrical potential relative to the reference electrode that reflects the acidity of the sample.
- A miniaturized 100 µm width platinum electrode that develop an electric potential relative to the reference electrode which reflects the tendency of the solution to release or take up electrons.

All probes where calibrated before and after each profile. For each multicore or boxcore we measured 3 oxygen profiles, 2 H_2s profiles, 1 pH profile and 1 Redox profile. We took a measurement every 200 µm down to 5 cm within the sediment and the water surface was kept in motion by a controlled air flow. For gravity core we measured one point of oxygen and H_2S every 40 cm.

Overall profiles revealed a well oxygenated sediment with a slightly basic pH (~ 7.6) with no hydrogen sulfide accumulation.

Table 10.2. Samples collected for microprofiles.

Station Id	Date (UTC)	Equipment	Core number	water depth (m)	LAT	LON	O_2 (nb)	H_2S (nb)	pH (nb)	REDOX (nb)
HACON19-13-MUC33	29.09.2019	MUC	liner 3	3912	82,90	6,25	3	2	1	
HACON19-14-MUC34	29.09.2019	MUC	liner 3	3967	82,90	6,27	3	2	1	1
HACON19-26-MUC36	02.10.2019	MUC	liner 2	4260	82,88	6,31	3	2	1	1
HACON19-34-MUC37	04.10.2019	MUC	liner 4	4102	82,91	6,33	3	2	1	1
HACON19-52-BC42	09.10.2019	BC	liner 1	4075	82,94	6,71	1	1		
HACON19-62-GC122	10.10.2019	GC	122	4201	82,90	6,59	1	1		

11 MARINE BIOLOGY

Hans Tore Rapp, Pedro Ribeiro, Sofia Ramalho, Tina Kutti, Ana Hilario, Eva Ramirez-Llodra, Håkon Dahle, Ida Helene Steen, Autun Purser, Lissette Victorero, Giuliana Panieri.

11.1 Introduction and objectives

A comprehensive baseline study of the pristine status of the Aurora seamount and, in particular, of the Aurora vent field, is essential to understand the system's biodiversity and functioning, and to provide the necessary data against which to monitor natural or anthropogenic changes. Prior to this cruise, the only ecological data available from this remote region was collected during PS86 (Boetius et al., 2015), which is currently being analysed by the research team of PS86 in collaboration with the HACON fauna/marine biology team. This work explores the organisms and deep-water ecosystems found in the Aurora area on the Gakkel Ridge, with a main focus on hydrothermal systems and other poorly known ecosystems inhabiting the enrichment zone around the vents in these areas, such as sponge grounds and sponge gardens. These hydrothermal vents and sponge dominated communities form a variety of vulnerable marine ecosystems found along the northernmost parts of AMOR, an area which potentially coincides with future deep-sea mining activity. Their biodiversity, ecological importance and biotechnological potential is assumed to be similar to, or even higher, than other deep-sea ecosystems such as the well-studied cold-water coral reefs. However, in contrast to those, hydrothermal vents and northern deep-water sponge-dominated ecosystems have so far received relatively little scientific or conservation attention.

The overarching aim for the marine biology working group during the cruise was to collect data and samples needed to conduct a systematic ecological study of the Aurora active and inactive vents and surrounding area, as well as exploring the distribution and diversity of vent-associated organisms from all size classes (microbes, meio-, macro- and megafauna) in relation to the geochemical setting.

11.2 Methods - general

The biota and ecosystems hosted at Aurora seamount were studied using a combination of underwater imagery (OFOBS and NUI), as well as box core, multicore, gravity core, and ROV-operated blade core (Figure 11.1; Table 11.1). For more detailed sampling methodology see sub-sections below and Chapter 10.

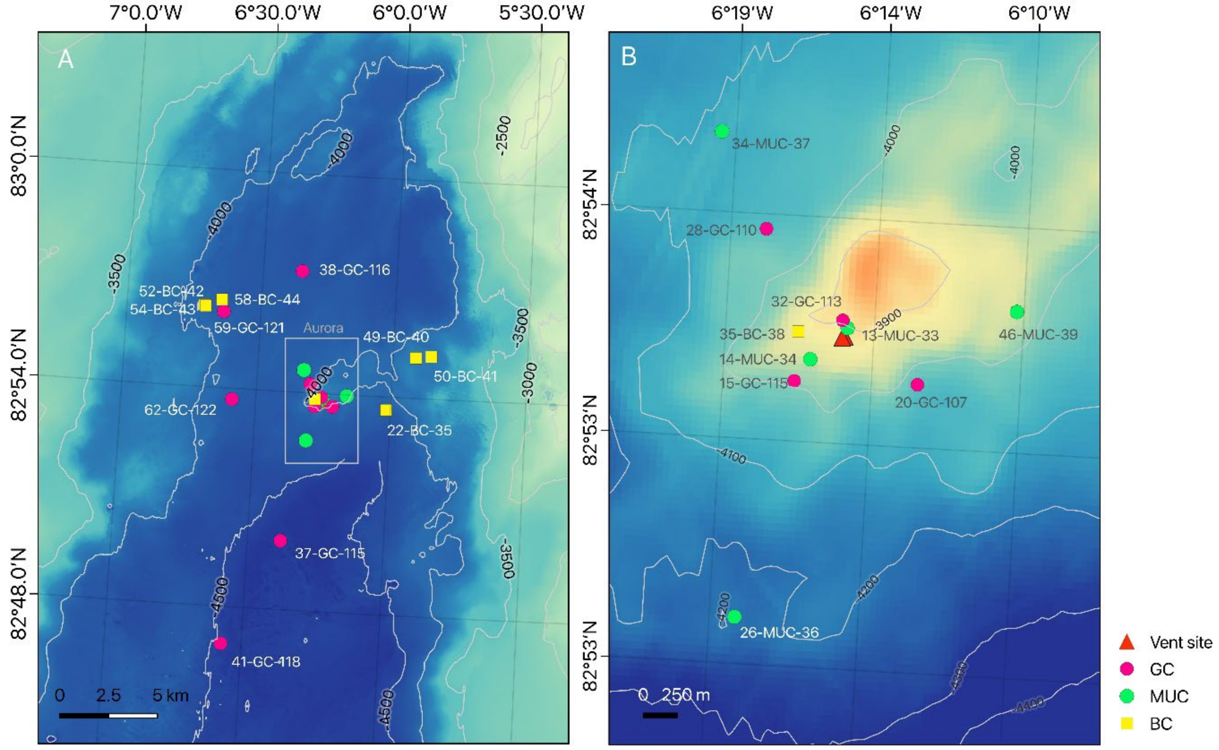


Figure 11.1. Map showing coring stations in the study area (A) and detail of the seamount (B).

11.3 Microbiology

Biological communities in hydrothermal systems are typically largely driven by chemotrophic microorganisms acquiring energy from the oxidation of reduced compounds in hydrothermal fluids (e.g. sulfide, methane, hydrogen) and oxidized compounds in seawater (e.g. sulfate, nitrate, oxygen). However, due to the geological setting and the various geochemical and biological processes occurring within a vent field, the chemical composition of hydrothermal fluids in hydrothermal chimneys, surrounding sediments, and mounds may vary considerably. In order to decipher the geobiological interactions occurring in a hydrothermal system, and to determine the overall effect hydrothermal fluid flow has on the biological communities associated with the vent field, detailed analyses of the composition of fluids alongside analyses of microbial community structure and functioning is necessary. One of our objectives was therefore to characterized chemical and microbiology community structure profiles in sediments surrounding the Aurora vent field. Second, was to establish enrichment cultures of aerobic methanotrophs.

11.3.1 Microbiology in sediments

Using sterile plastic syringes, samples for DNA extraction were taken from six gravity cores (GC105,107,110,133,122,132), four multicore stations (MUC33,34,36,37), three box cores (BC35,38,42) and one bladecore (BLC1) (Fig X-MAPSophia/see Geology section). Porewater samples, collected with rhizon samplers, were taken from all cores and pH and alkalinity was measured onboard. In addition, oxygen profiles were obtained for GC122 and all MUC stations (see details in TableX-Sophia). In order to identify the extent of chemoautotrophic carbon fixation and to identify primary producers, sediment samples from two gravity cores (GC122 and GC132) were incubated at 4°C in the presence of 13C-labelled bicarbonate for stable isotope probing. Oxygen, pH and alkalinity profiles indicate little microbial activity and little or no influence of hydrothermal fluids in any core. This, together with the general highly limited amounts of benthic life observed by OFOBS images and boxcoring, suggests that the seafloor around the Aurora vent field is considerably more energy poor then other hydrothermal systems observed along the Arctic Mid Ocean Ridge. However, further metagenomic analyses and 16S rRNA profiling from the collected sediment cores will shed further light on this.

11.3.2 Aerobic methanotroph enrichment

Samples for enrichment and isolation of methane oxidising bacteria (MOB) were taken on surface sediment (MUC 33) and bottom ice samples. Back in the ICOM (Ice cold organism laboratory, Tromsø) we will try to cultivate these microbes and compare them with our existing data of the microbial diversity of arctic methane oxidizers.

11.4 Benthic fauna

11.4.1 Living benthic foraminiferal communities

Foraminifera are eukaryotic unicellular microorganisms inhabiting all marine environments. These unicellular microorganisms are useful environmental indicators as they respond quickly to small environmental changes. They are widely distributed in marine environments, and we found them in sediment around the Aurora seamount. During the HACON19 expedition we took samples using the multicore sampler or by subsampling the boxcorer with MUC liners (Ø 10cm) for future analysis of living benthic foraminifera from seafloor hydrothermal vent environments in order to evaluate the effect of hydrothermal activity of foraminifera communities. In addition, micropaleontological observations were made on the surficial sediment (0-0.5 or 0-1 cm) of all stations sampled with multicorer or boxcorer during the cruise. Evidence of alive foraminifera were found in few stations, and when found alive the number of living foraminifera is very low. The majority of the investigated samples on board is characterized by abundant planktonic foraminifera, mostly *Neogloboquadrina pachyderma* (Figure 11.2A). The benthic foraminiferal association is dominated by agglutinated tubular text shape species (e.g. *Astrorhiza* sp.), with species with particles attached to a proteinaceous or mineralized matrix; often single-chambered or branching tubular, typical of tranquil bathyal and abyssal environment with low organic matter flux and single-chambered agglutinated (e.g *Reophax* spp.) made of a single layer of agglutinated material, often quartz. Among the calcareous species, phytodetrital fauna (e.g. *Epistominella exigua*) is very abundant, together with *Lagena* sp. and *Fissurina* sp., single chambered with an aperture with an internal tubular extension. Some living calcareous foraminifera appear to have all the chambers occupied by the cell except the last one. Also, porcelaneous, agglutinated, and allogromids foraminifera were found alive.

Table 11.1. Overview of fauna samples collected.

Super station	Gear	Station ID	Latitude	Longitude	Fixation	Description	Purpose
13	MUC	HACON19_13_MUC33	82,8977	-6,2544	Ethanol	Sediment	Spicules
22	Box corer	HACON19_22_BC35	82,8940	-6,0160	Ethanol	Polychaeta (top fraction 500uM)	Macrofauna
22	Box corer	HACON19_22_BC35	82,8940	-6,0160	Ethanol	Foraminifera (top fraction 500uM)	Macrofauna
22	Box corer	HACON19_22_BC35	82,8940	-6,0160	Ethanol	Bulk 3-10 cm 250uM	Macrofauna, spicules
22	Box corer	HACON19_22_BC35	82,8940	-6,0160	Ethanol	Bulk 3-10 cm 500uM	Macrofauna, spicules
22	Box corer	HACON19_22_BC35	82,8940	-6,0160	Ethanol	Bulk top 3 cm 250uM	Macrofauna, spicules
22	Box corer	HACON19_22_BC35	82,8940	-6,0160	Ethanol	Bulk top 3 cm 500uM	Macrofauna, spicules
35	Box corer	HACON19_35_BC38	82,8973	-6,2808	Ethanol	Top fraction, 1000 uM	Macrofauna, spicules
35	Box corer	HACON19_35_BC38	82,8973	-6,2808	Ethanol	Top fraction, 500 uM	Macrofauna, spicules
49	Box corer	HACON19_49_BC40	82,9185	-5,9148	Ethanol	Polychaeta, fragment of Bivalvia	Macrofauna
49	Box corer	HACON19_50_BC41	82,9195	-5,8575	Ethanol	Polychaeta	Macrofauna
49	Box corer	HACON19_50_BC41	82,9195	-5,8575	-20C	Surface sediment	Spicules
49	Box corer	HACON19_50_BC41	82,9195	-5,8575	-20C	5cm sediment	Spicules
49	Box corer	HACON19_50_BC41	82,9195	-5,8575	-20C	10cm sediment	Spicules
49	Box corer	HACON19_50_BC41	82,9195	-5,8575	-20C	20cm sediment	Spicules
49	Box corer	HACON19_50_BC41	82,9195	-5,8575	-20C	30cm sediment	Spicules
49	Box corer	HACON19_50_BC41	82,9195	-5,8575	-20C	40cm sediment	Spicules
51	Plankton ne	HACON19_51_H121	82,9384	-6,7246	Ethanol	Polychaeta	Macrofauna
52	Box corer	HACON19_52_BC42	82,9375	-6,7107	Ethanol	Foraminifera	Macrofauna
52	Box corer	HACON19_52_BC42	82,9375	-6,7107	Ethanol	Spicules	Macrofauna
52	Box corer	HACON19_52_BC42	82,9375	-6,7107	Ethanol	Polychaeta	Macrofauna
54	Box corer	HACON19_54_BC43	82,9371	-6,7065	Ethanol	Bivalvia	Macrofauna
54	Box corer	HACON19_54_BC43	82,9371	-6,7065	Ethanol	Polychaeta	Macrofauna
54	Box corer	HACON19_54_BC43	82,9371	-6,7065	Ethanol	Holothuroidea	Macrofauna
54	Box corer	HACON19_54_BC43	82,9371	-6,7065	Ethanol	Foraminifera	Macrofauna
54	Box corer	HACON19_54_BC43	82,9371	-6,7065	Ethanol	Frenulata	Macrofauna
58	Box corer	HACON19_58_BC44	82,9404	-6,6478	Ethanol	Frenulata	Macrofauna
58	Box corer	HACON19_58_BC44	82,9404	-6,6478	Ethanol	Bivalvia	Macrofauna
58	Box corer	HACON19_58_BC44	82,9404	-6,6478	Ethanol	Polychaeta	Macrofauna
61	ROV NUI	HACON19_61_ROV4	82,9035	-6,6955	Ethanol	*Caulophacus arcticus* 1	Reference collection, DNA, reproduction, food web
61	ROV NUI	HACON19_61_ROV4	82,8991	-6,7013	Ethanol	*Caulophacus arcticus* 2	Reference collection, DNA, reproduction, food web
61	ROV NUI	HACON19_61_ROV4	82,9035	-6,6955	Ethanol	Dead *Caulophacus* stalks	Dating, settlement studies
61	ROV NUI	HACON19_61_ROV4	82,8991	-6,7012	-20C	Sediment from blade corer	Spicules and dating

For the upcoming investigation of living benthic foraminifera, we applied two different staining methods for living foraminifera from the near- surface sediments (0-5 cm sediment depth): TEM, and Rose Bengal (RB) in order to compare the results of the different staining methods and fix living foraminifera for subsequent analyses. The rest of the core was sampled every cm or 2 cm for investigation of fossil foraminifera. In addition, we sampled water from the interstitial pore space to directly compare the carbon isotopic signature of dissolved inorganic carbon (DIC) and foraminiferal calcite.

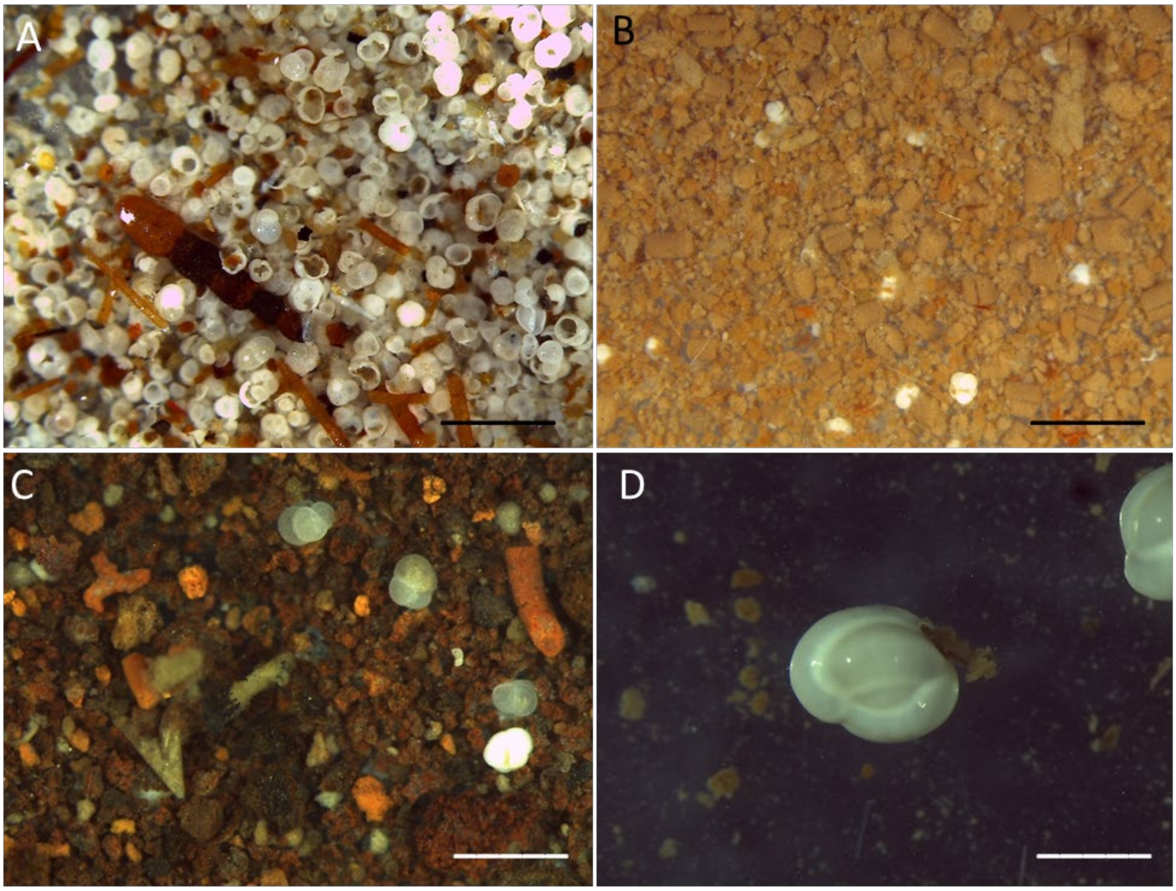


Figure 11.2. A. Foraminiferal assemblage (>63 µm) from HACON19_26_MC36_0-1 cm. The assemblage is dominated by planktonic foraminifera and agglutinated tubular benthic foraminifera (scale bar = 500 µm). B. Sediment (>63microns) from HACON19_52_BC42_0-1cm. The sediment is constituted by silty clay, fecal pellets and rare foraminiferal shells (scale bar = 800 µm). C. Sediment (>63 µm) from HACON19_13_MUC33_0-1cm. The sediment shows iron oxides and minerals with hydrothermal origin. Rare planktonic and benthic agglutinated foraminifera are present (scale bar = 200 µm). D. *Miliolinella* from HACON19_ROV4_BLC1_0-1 cm. The individual appears to be alive, with the cytoplasm protruding from the aperture, most likely feeding (scale bar = 100 µm).

11.4.2 Staining preparations for multicore and box core samples

TEM-staining (0-1 cm depth)

A TEM solution of 10 ml glutaraldehyde (defrosted), 25 ml cacodylate buffer and 15 ml distilled water was prepared 1/2 hour prior to sampling under the fume hood. During subsampling, 20 ml (1/4 core slice, 1 cm thick) of sediment from 0-1 cm depth was transferred in a 60 ml HPDE bottle. We added the TEM solution until the bottle was almost full, we shook the bottle gently, sealed it with Parafilm, and stored it in the fridge at 4°C.

Rose Bengal staining (RB) (uppermost 5 cm)

We dissolved Rose Bengal Powder 2 g L^{-1} in ethanol 96% prior to sampling, added it to the sediment sample (equal volumes of sediment and staining solution), shook gently, and stored the material in the fridge at 4°C.

SSU rRNA amplicon analyses (0-1 cm depth)

On board freshly collected sediment was sieved using 63 µm mesh with in-situ bottom water (T°C 2°C, Salinity 35). Living foraminiferal specimens with colored cytoplasm and/or encysted with sediment (occurrence of vitality) were picked using a binocular microscope, photographed, washed with filtrated seawater (2.2 µm) and stored in ethanol or RNA later buffer at – 20ºC. DNA will be extracted at UiT/UiB using standard DNA extraction kits. 16S/18S rRNA gene amplicons will be generated with selected universal primers and sequenced using the IonTorrent or Illumina sequence technology. The sequences will be filtered, clustered into operational taxonomic units, and taxonomically assigned using QIIME. This will allow us to identify the collected foraminifera to species level, and to characterize microbial communities potentially attached to the foraminifera.

FISH (0-1 cm depth)

Freshly collected sediments were directly sampled for FISH (Fluorescent In Situ Hybridisation) microscopy. 2 grams of sediment material were resuspended in saline buffer for overnight fixation in 2.5% formaldehyde at 4C°. Formaldehyde was then removed with three washing steps in saline buffer solution and samples were stored in ethanol at -20°C.

In addition, few potentially living individuals were isolated from sediments and fixated in formaldehyde solution overnight at 4°C. After three washing steps, samples were stored in ethanol at -20°C. In the lab (University of Bergen), samples will be treated for hybridisation with fluorescent probes for taxonomic identification and visualisation under the microscope.

11.4.3 Meiofauna

Sediments and the overlaying bottom water were collected within five localities of the Aurora seamount, using the multicore sampler or by subsampling the Boxcorer with MUC liners (Ø 10cm; Appendix 18.2). This sampling aimed to describe the meiofaunal density, biomass, composition and biodiversity of the Aurora site, with particular focus on both free-living nematodes and copepods. Moreover, samples were also collected for subsequent molecular analyses aiming future population connectivity studies.

In each station, three cores dedicated for meiofaunal analyses and a fourth for environmental characterization of the sediment. Each liner was sliced into 3 sediment depth layers (0-3cm, 3-5cm and 5-10cm) and fixed in a formaldehyde (4%)/seawater solution for quantitative community analyses based on morphology the sediments. The other half was preserved in DESS solution for future molecular studies. The fourth core was sliced in a similar manner and preserved at -20ºC for: total organic carbon, total nitrogen, pigment content, pore-water geochemistry, grain size.

Oxygen/redox potential profiles were also measure prior to slicing (details in section 10.7 Microprofiling).

11.4.4 Macro- and megafauna

The macro- and megafauna was studied by using a combination of visual surveys (OFOBS and ROV NUI) as well as box cores. Presence of sponge spicules in gravity cores were used as a proxy for presence of hexactinellid sponge grounds in the area back in time.

Box core sampling

Seven box corers were deployed on Aurora and the surrounding rift valley in its vicinity (Figure 11.1, Table 11.1). In three of those deployments (HACON19-22-BC-35, HACON19-22-BC-35 and HACON19-52-BC42-) the box was overfull with sediment, which did not allow the recovery of bottom water and an undisturbed seafloor surface (Figure 11.3). This issue was solved by adjusting the gear to prevent excessive penetration into the sediment.

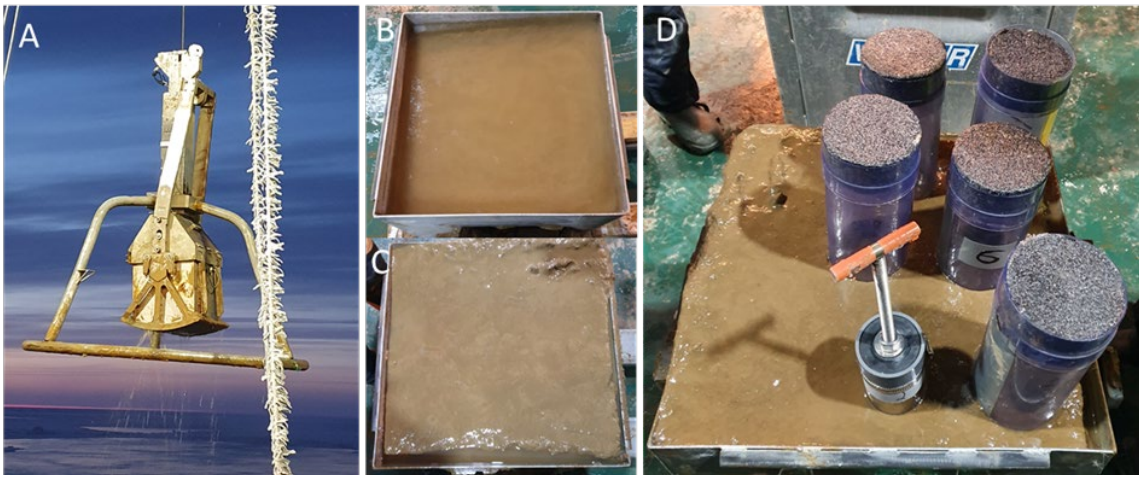


Figure 11.3. A. Boxcore used during this survey (50x50x50 cm). B and C. Box cores with the silty sediment typical for the area. D. Subcoring of boxcore for meiofauna studies and microbiology (liners = 5 and 10 cm in diameter).

The top 5-cm fraction of each box-core was slurried in sea water and filtered through 500 µm and 250 µm mesh sieves. The collected material was then examined and sorted under the microscope, and all specimens of macrofauna were preserved in 99% ethanol for taxonomy and DNA barcoding (UiB). In addition, four cores were also sub-sampled using liners and push-cores for microbiology and pore water (UiB), micropaleontology/sediment geochemistry (UiT), oxy/redox potential profiling (UiT) and meiofauna (UAveiro) (Table 11.1, Figure 11.3). Fauna and sediment from boxcores and NUI were also collected for food web studies (ref. section 7.5 in this report).

Visual observation (OFOBS and NUI)

Most parts of Aurora are covered in very fine and silty sediments, and visual surveys reveal a very low diversity and abundance of larger fauna. However, some patchiness and variation between OFOBS deployments were observed, and the crustaceans *Neohela* sp and *Bythocaris* sp were the most frequent species (Figure 11.4). In addition, there were scattered polynoid-, serpulid-polychaetes and frenulates, buccinid gastropods, ophiuroids and patches of the holothurians *Molgula* sp and *Elpidia* sp. The low diversity and abundance of soft-bottom macro- and megafauna were further confirmed by box core sampling.

In sharp contrast to the sedimentary areas, rocks, pillow lavas and basaltic crests and outcrops were densely covered by macro- and megafauna. This fauna was totally dominated by dense aggregations/grounds of the hexactinellid sponges *Caulophacus arcticus* and *Asconema megaatrialia*. Even though these species are well-known from deeper parts of the Nordic Seas (Roberts et al., 2018), such high densities of these sponges are quite unusual, and the phenomenon is here seen as a special adaptation to this particularly poor environment. The sponges act as facilitators for other fauna elements, and bythocarid shrimps, anemones and several species of isopods and amphipods seem to be more abundant in areas covered by sponges. Dead *Caulophacus* stalks also prove to be a good substrate for settlement of sponge larvae and other epifaunal species (e.g. *Corymorpha groenlandica* and *Cladorhiza gelida*) in an area where there is a lack of available hard substrates (Hestetun et al., 2017).

On soft sediments a high number of tracks and traces ("Lebensspuhr") from various organisms were observed, e.g. holothurians, gastropods, burrow-dwelling crustaceans as well as fascinating octagonal feeding tracks from octopus.

The area of active venting seems very limited and there is at present no good evidence for sedimented areas with more diffuse venting. Hence the macrofauna abundance is not very high, and the spatial distribution of vent adapted fauna is quite restricted (highly contrasting partly sedimented vents further south (Pedersen et al., 2010; Steen et al., 2016). However, the fauna bears some similarities to what has been observed along AMOR (Schander et al., 2010; Pedersen et al., 2010; Kongsrud et al., 2017; Tandberg et al., 2013, 2017, 2018), but no final conclusions can be made until infaunal taxa have been studied.

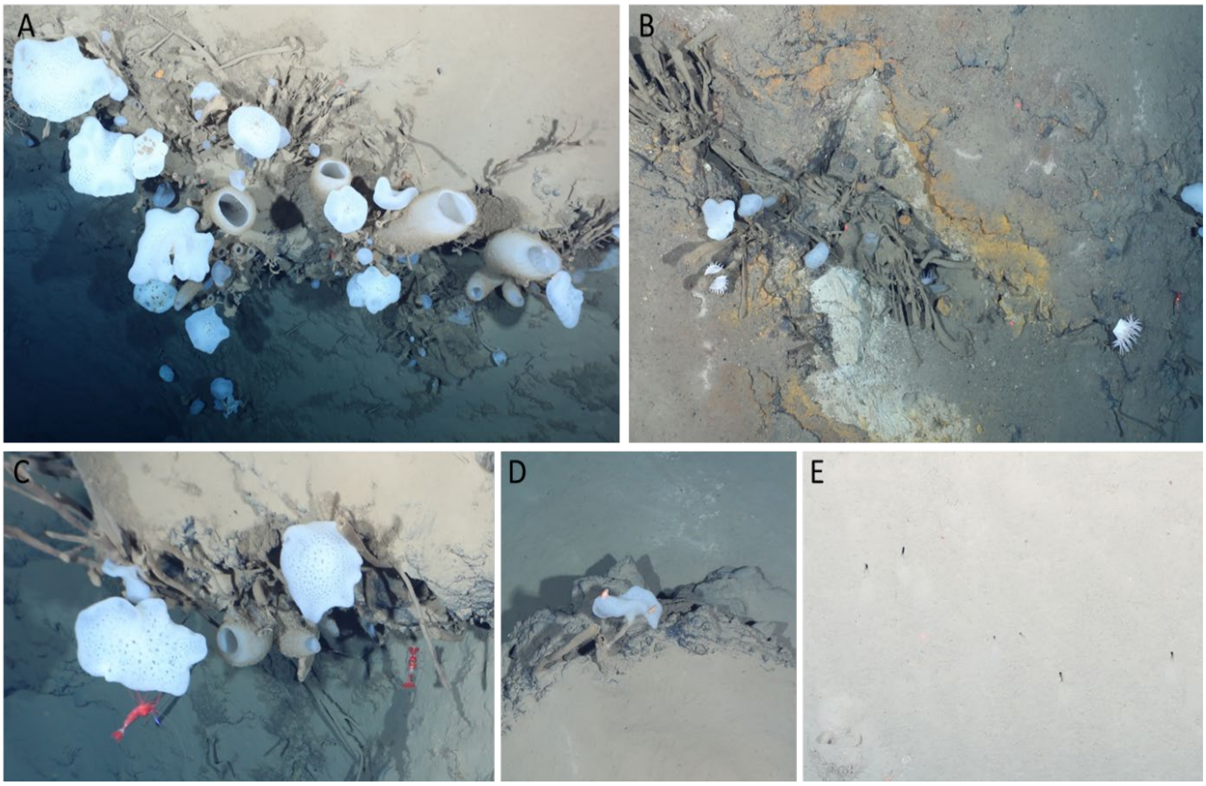


Figure 11.4. A. Typical fauna found on pillow lavas and basaltic outcrops on the Aurora mount. This fauna is highly dominated by the hexactinellid sponges *Caulophacus arcticus* (white with stalk) and *Asconema megaatrialia* (beige and vase shaped). B. When going from active venting, through an area with degrading chimney material, to the enrichment zone around the hydrothermal mound, the fauna gradually changes from vent-adapted to an assemblage of hexactinellids and anemones. C. The deep-water shrimp *Bythocaris* sp is one of the more abundant species inhabiting the clusters of sponges, as well as being frequent on the sedimentary plains. D. Some species of isopods and amphipods seem to be closely associated with the glass sponges. E. The crustacean *Neohela* sp is one of the more abundant species in sedimentary areas, making burrows in the sediments.

Both the vent fauna and the sponge grounds/background fauna have species in common with the fauna found in the Polar Basin and the northernmost Behring Sea towards north, and to the AMOR and MAR in the south. Given the high variation in distribution range of some of the Arctic vent and background fauna taxa (e.g. Cardenas and Rapp 2015; Eilertsen et al. 2018), no conclusion on the biogeographical affiliations of this area can be made until more comprehensive analyses have been done.

12 SEA-ICE OBSERVATIONS

Kevin Hand, Andy Klesh, Dimitri Kalenitchenko, Eoghan Reeves, Nadia Drake, Luis Lamar and Eva Maria Meckel

12.1 Introduction and objectives

The sea ice work consisted of three primary science objectives, each motivated by the high-level questions detailed below:

1. Ice as a window into the ocean below: How does the ice partition gases, solids, biological materials relative to their concentrations in the ocean? Can we detect a fingerprint of hydrothermal activity in the ice (e.g., methane, plume particles)?
2. Ice as an interface between the atmosphere and ocean: How is transport of gases, in particular CO_2, regulated and modulated by sea ice?
3. Life in ice: Are there any thermophiles (e.g., vent microbes) within the psychrophilic sea ice environment? How are microbes affecting the gas exchange processes (consumption/production). Lastly, what kinds of biosignatures, and at what concentrations, exist within the ice?

12.2 Observations

A total of four ice stations, and two Zodiac deployments, were used for ice and ocean water sampling. Ice cores, acquired with a Mark II Kovacs corer (ID 9.5 cm), were collected at each of the four stations and grey ice samples (<20 cm) were collected from the Zodiac. A 10-meter YSI sonde with temperature, oxygen, and conductivity sensors was used to collect profiles of ocean water beneath the sea ice. Table 12.1 provides a summary of the cores and samples collected for sea ice measurements.

12.3 Ice Core Analyses

Six ice cores were analyzed on board for carbon dioxide, methane, and $\delta^{13}CH_4$ using a Picarro cavity ringdown spectrometer (CRDS). Figure 12.1 shows an example of collecting cores on the ice. Cores were cut in one of three different ways for gas analyses: 1) 10 cm segments, 2) 20 cm segments, and 3) separated by natural breaks and fractures that could be indicative of natural differences in ice formation and history. Segments were then vacuum sealed and stored at -20 C in an onboard freezer. During gas analysis, the mass and length of each core segment was measured and then the segment melted and resulting water warmed to >35 C to exsolve as much methane and carbon dioxide as possible into the ice core bag headspace. Needle injection of the headspace gas was performed directly, sending the headspace gas into the CRDS. For small volumes of headspace gas, a 140 ml syringe was used to extract the gas from the segment bag, after which the gas was injected into the CRDS. Measurements of CO_2, CH_4, and $\delta^{13}CH_4$ were collected throughout the injection process.

Table 12.1. Sea ice cores and planned analyses.

Core #	Date collected	Station ID	Sample ID	Planned Analyses	Status	Total length (cm)
1	29-Sep-19	NA	2019708-ICE01	Gas	Analyzed on Picarro	133
2	1-Oct-19	108	2019708-ICE02	Microbiology/Electrochemistry	Treated w EtOH	148
3	1-Oct-19	"	2019708-ICE03	Gas	Analyzed on Picarro	150
4	1-Oct-19	"	2019708-ICE04	Electro chemistry/Store	Ship -20 Freezer	142
5	1-Oct-19	"	2019708-ICE05	Microbiology	Treated w EtOH	98
6	1-Oct-19	"	2019708-ICE06	Gas	Analyzed on Picarro	103
7	1-Oct-19	"	2019708-ICE07	Gas	Analyzed on Picarro	134
8	4-Oct-19	NA	2019708-ICE08	Gas/Chemistry	Ship -20 Freezer	152
9	4-Oct-19	"	2019708-ICE09	Gas, 10 cm sections	Analyzed on Picarro	162
10	4-Oct-19	"	2019708-ICE10	Microbiology	Treated w EtOH	172
11	4-Oct-19	"	2019708-ICE11	Gas/Chemistry	Ship -20 Freezer	181
12	4-Oct-19	"	2019708-ICE12	Microbiology	Treated w EtOH	154
13	4-Oct-19	"	2019708-ICE13	Gas, 20 cm sections	Analyzed on Picarro	92
Grey Ice	8-Oct-19	NA	2019708-GI01	Gas	Analyzed on Picarro	8
14	8-Oct-19	NA	2019708-ICE14	Microbiology	Treated w EtOH	152
15	8-Oct-19	"	2019708-ICE15	Microbiology/Chemistry	Ship -20 Freezer	160
16	8-Oct-19	"	2019708-ICE16	Gas/Chemistry	Ship -20 Freezer	167
17	8-Oct-19	"	2019708-ICE17	Gas/Chemistry	Ship -20 Freezer	127
18	8-Oct-19	"	2019708-ICE18	Algae/Forams/COS/Microscopy	Ship -20 Freezer	154
Grey Ice	11-Oct-19	NA	2019708-GI02	Gas	Analyzed on Picarro	15
Grey Ice	11-Oct-19	NA	2019708-GI03	Gas	Analyzed on Picarro	11

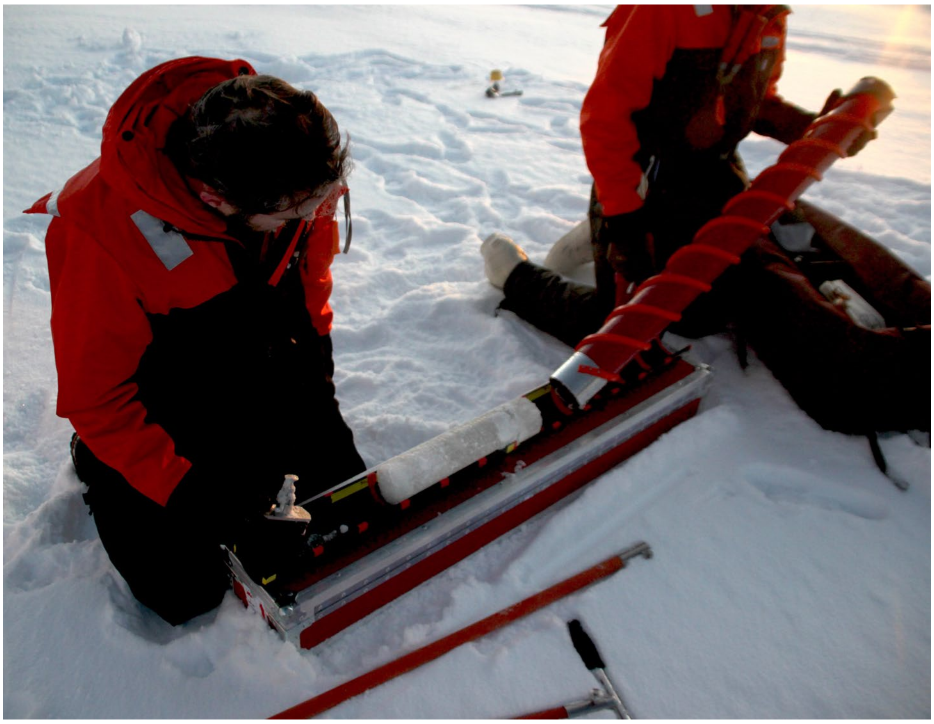


Figure 12.1. Collecting ice cores during the HACON cruise.

Once gas analysis of the full headspace was complete, the pH, conductivity, and total dissolved solids of the melted segment was measured. Subsequent to those measurements, 100 ml of core water was injected into a 300 ml evacuated serum vial. The headspace of this vial was then also analyzed with the CRDS to measure any carbon dioxide and methane that had not fully exsolved from the water.

In addition to the above analyses of each segment for each core, the chemistry of the ice-ocean interface was investigated on Core 2 with micro-probes for pH, oxygen, and redox. Several new and novel methods were developed for these analyses, much of which will continue on shore.

Throughout the cruise air samples were collected from the bow of the ship to provide an atmospheric baseline for carbon dioxide concentrations above the ocean and sea ice. Similarly, seawater was collected from Kovacs core holes in the sea ice for analysis. The carbon dioxide, methane, and methane isotopic values above the Aurora vent field site were measured to be 336 ppm, 1.596 ppm, and -49.93 per mil, respectively. A latitudinal transect was conducted throughout the cruise to examine carbon dioxide and methane concentrations from 76N to 82.9N.

12.4 Microbiology

12.4.1 Experiment to isolate thermophiles

This experiment tests the hypothesis that thermophilic microbes living in vents might be transported by plume activity and ocean currents and get incorporated in the seawater ice. Fifteen centimeters of ice from top and bottom of core 15 (Table 12.1) were melted in a 4ºC incubator over

36 h after decontamination, the rest of the core was melted for gas measurements (eee ice gas section). 50 ml of the melted water was transferred into two groups of nine 120 mL vials, one group for the top section and one group for the bottom section. The 120 mL vials were filled with 50 mL of filtered seawater mixed with NMS medium and then autoclaved prior to sample inoculation (Figure 12.2). After inoculation the headspace (20 mL) was filled with a 15% methane atmosphere.

For each group one triplicate was incubated at 4 °C for 6 days as control, another at 60 °C for an hour and then 50 °C for 6 days and the last one at 80 °C for an hour and then 50 °C for 6 days.

Figure 12.2. Vials in the 50ºC incubator.

Samples for nutrient, pH and microbial DNA sequencing (See water column section) were taken on October 10, 2019 (T0) and October 15, 2019 (T6). Every day at 1700 UTC a sample for flow cytometry was taken to quantify the cell growth in all vials (See water column section).

12.4.2 Microbial community

Five ice cores were selected for microbiology analyses (Table 12.1). For each core, 20 cm section were cut and dipped into cold ethanol and transfer to a sterile bag. After 2 hours at 4ºC ~5mm of the ice surface has been melted. The remaining solid ice was cleaned with MilliQ water and transferred in a new sterile bag. After ~ 36 hours at 4ºC, a sample for microbial cultivation was taken on each core bottom by filtering 50 mL on a Sterivex cartridge that will be used as an inoculum for methanogenesis microbe enrichment at the ICOM lab (Tromsø, Norway) (Figure 12.3). For all core sections including the bottom, flow cytometry triplicates were taken, and the remaining volume was measured, filtered through a Sterivex cartridge (See water column section) and stored at -80ºC until further analyses in CAGE (Tromsø, Norway).

Figure 12.3. Sterivex filter from a bottom section.

12.5 Drone mapping of the sea ice

A Mavic 2 pro DJI drone (RO1 License) equipped with a Sentera near infrared sensor (Red band: 625nm CWL x 100 nm width; NIR band: 850 nm CWL x 40 nm width band) was used to map sea ice. One goal of this effort is to examine whether the Red and NIR band can prove useful for mapping variations in ocean cover, from open water, to grease and grey ice to first and multi-year ice. Such measurements are useful for assessing changes in sea ice cover, over time, at very high resolution. The band placements of the commercially available NDVI Sentera system are not ideal for these analyses (Figure 12.4 shows several high-resolution contact spectra of sea ice), but when coupled with the simultaneously acquired visible imagery, relative band ratios may prove useful and inexpensive to acquire.

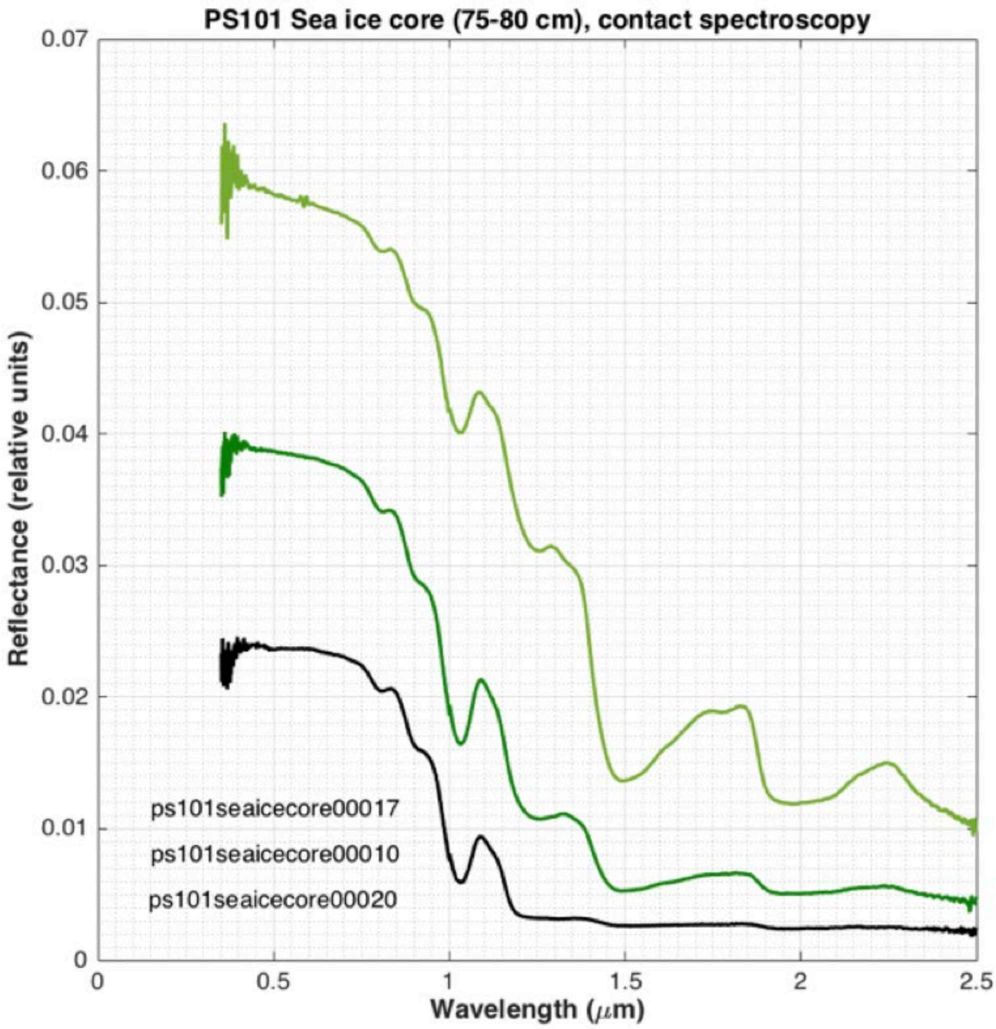


Figure 12.4. Visible to Near-Infrared (NIR) spectra of sea ice showing variations in grainsize within an ice core. Features at ~1.7 and 2.2 microns indicate small ice grains (green) and large ice grains (black). At shorter wavelengths, e.g., 625 nm and 850 nm relative band ratios might enable rapid mapping of grain size and ice types.

In addition to the above analyses, the drone imagery will also be used for simulations and testing of hazard avoidance landing systems that may be used on future robotic missions to ice-covered ocean worlds, such as Jupiter’s moon Europa).

In total 1306 near infrared images and 273 visible light images were taken within 2 grids and 4 transects over uneven ice-covered water. Figure 12.5 shows a NIR and visible light image for comparison.

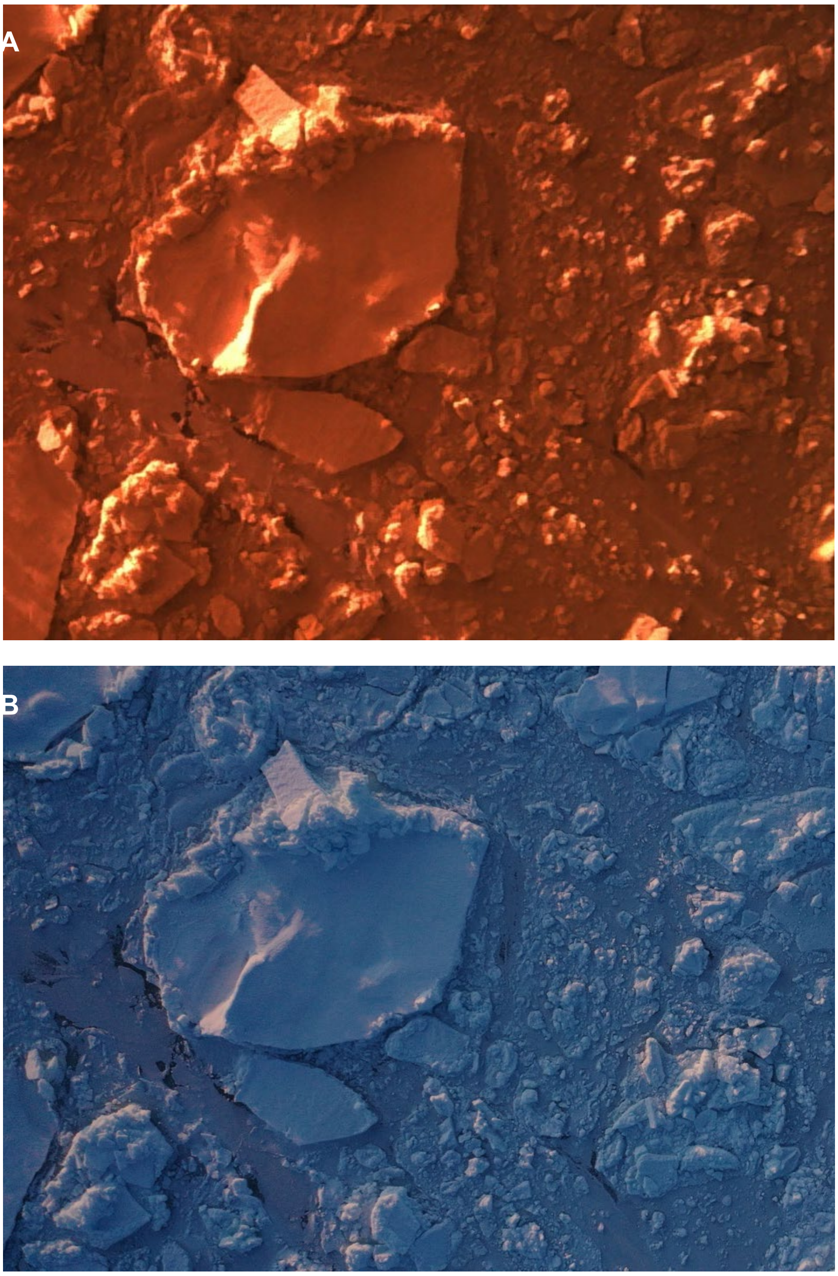


Figure 12.5. Near infrared (A) and Visible light (B) pictures taken 70 m above sea level.

13 Data management

Autun Purser and Eva Ramirez-Llodra

All cruise sample metadata will be made publicly available via the PANGAEA data repository within 6 months of cruise completion. All image and video data collected during the cruise will be made fully available via request from PANGAEA within 6 months of cruise completion, with the full datasets being made fully open access within 2 years of cruise completion. All raw sidescan data from the OFOBS deployments will be available from PANGAEA within 6 months of cruise completion, with derived map products also made publicly available within 2 years of cruise completion or following publication of scientific papers outlining the work.

Biological data will be made available via the appropriate publicly accessible data archives at time of scientific publication, or two years after data analysis.

14 DISSEMINATION AND COMMUNICATION

Nadia Drake, Luis Lamar and Eva Ramirez-Llodra

Hydrothermal vents under permanent ice cover are a last frontier for exploration and research, that easily raise the curiosity of children and adults alike. The cruise provided a unique opportunity to engage society's interest and increase awareness in marine and Arctic research of a region on Earth that is not accessible for most. Increasing awareness based on robust science is essential, not only to advance knowledge and educate the next generation, but also when developing management and conservation measures. HACON has invested considerable effort, in collaboration with WHOI, NOAA-OE and National Geographic, to ensure the highest level possible of scientific communication from the cruise.

14.1 National Geographic print and digital stories

National Geographic will publish at least two stories related to the HACON cruise. The first will be a digital news story about the Aurora vent and ecosystem, ideally to be published within a few weeks of returning home, and at the same time as institutional press releases. Later, the print magazine will publish a feature that weaves the cruise into a broader narrative about ocean exploration – the challenges, rewards, technologies and treasures that await – both on Earth and beneath alien seas, particularly those on the moons Titan, Enceladus and Europa. As well, several additional stories about the cruise and onboard teams could be published at National Geographic within the next years; and maintaining contact with science and engineering teams will undoubtedly lead to future publications.

14.2 Photography and filming

As a contract filmmaker and photographer for the Avatar Alliance Foundation, my primary objective has been to document the HACON expedition in editorially compelling and cinematic ways.

Contracted by AAF to provide best in class cinematography services, I have been honing in on specific sequences, attempting to cover themes associated with the broader OCEAN WORLDS initiative at WHOI and NASA. One of the primary story lines includes coverage of the WHOI NUI hybrid remotely operated vehicle, its assembly, launch, and its attempt to reach previously unexplored hydrothermal vents at the Aurora Field, in the Arctic ocean. Another primary story line includes following Kevin Hand, from NASA-JPL, while he investigates the chemistry associated with multi-year arctic ice cores, which he sampled throughout the course of the HACON expedition. In parallel, I have been covering these same themes and characters, using still photography, for a feature print story in National Geographic Magazine, currently titled "Alien Oceans", of which coverage of the HACON expedition is expected to be a primary component.

14.3 HACON web blog and school activities

A cruise blog was written during the cruise, with 8 stories posted in the HACON website during the cruise (https://haconfrinatek.com/blog/). The posts where shared via Twitter.

In addition, two activities with schools have taken place. Before the cruise, a seminar was given by Ine De Mol (4th grade) and Nia De Mol (3rd grade) in Billingstad school (Asker, Norway) about deep sea and hydrothermal vents. The children of the 2 classes wrote their names on polysterene cups which we took down to 4000 m, to show the effects of high pressure in the deep sea. A web blog and follow up seminar in the school with finalise this project.

The second project was designed by Carolina Sarti (15 years old), who is in her last year at the International School TRINT in Tromsø (Norway). Carolina is writing a book for her personal school project. One chapter of the book will discuss climate change and ocean sustainability. To gather information, Carolina asked her mother (Dr Giuliana Panieri) to interview her colleagues and the RV Kronprins Haakon crew during the cruise with 6 questions on the relevant topics. The book will be presented in March 2020 to the school committee.

15 Engineering repair and technological development

Andrew T. Klesh and the NASA, WHOI, OFOBS, Ægir and National Geographic Teams

15.1 Introduction & Objectives

While engineering repair and technological development and were not objectives planned for the cruise, circumstances demanded significant efforts for virtually all submersible vehicles onboard. The NASA and NUI teams had some level of spare parts and repair capability, along with significant stock and expertise from the ship's crew. Original objectives were to:

- To test the under-ice survey capabilities of NASA's BlueROV, especially in rafted or grey ice terrain
- To develop an under-ice sampler for NASA's BlueROV
- To support operational scientific objectives with the various submersible systems

- Test and operate the NUI vehicle as a new benthic Polar sampling and survey tool to 4,000 meters

Several campaigns were completed with the BlueROV, however a sampler was not completed. Technical problems with other submersible vehicles led to significant efforts to support the third objective.

15.2 IGT Sampler

An important sampling device for vent research included in this cruise was the IGT sampler (Chapter 9). The sensor relies on a low frequency inductive coupling for communications between the ROV and sampler, however previous testing at WHOI and within the Longyearbyen harbor showed that this connection was unreliable when multiple sensors were used together. To increase reliability, the electronics for the sensor head were reverse-engineered and replaced to provide an external 12V power supply and RS-232 communications for sampler valve operations, compatible with the NUI vehicle (Figure 15.1). This allowed for tethered operations of the sampler without the need to rely on the inductive coupling. The unit was tested at 350 m with operational communications, and maintained valve integrity during the 72-hour NUI Dive 017. An additional IGT with ICL communications, wrapped with aluminum foil, also communicated at this depth.

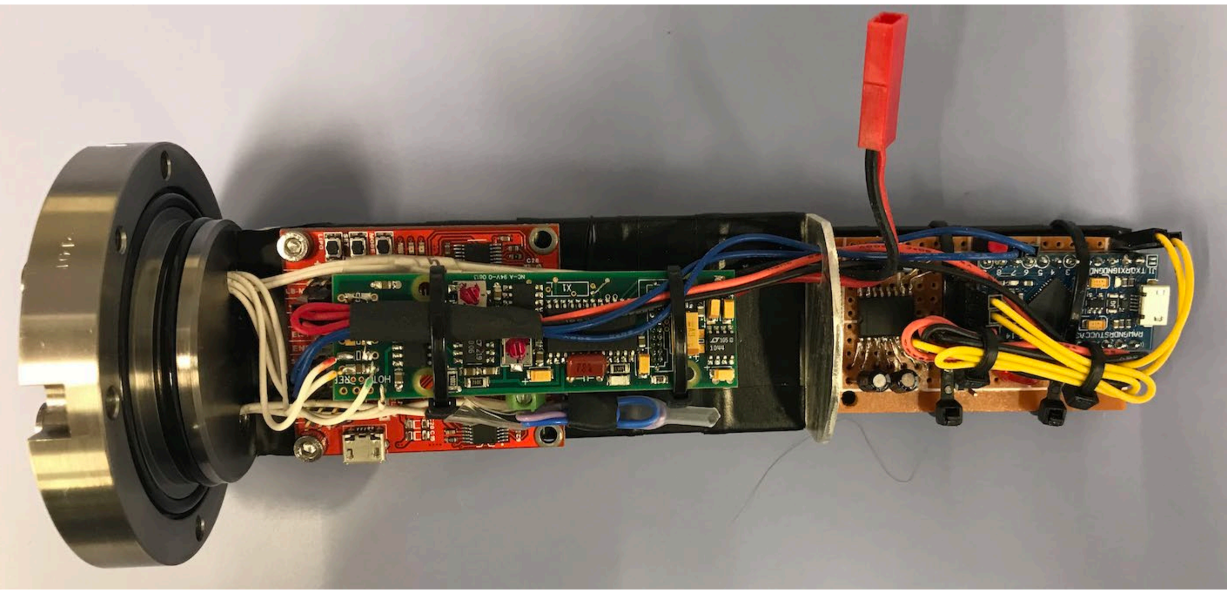


Figure 15.1. Modified IGT electronics to allow tethered ROV operations of the IGT sampler.

15.3 NUI Under-Ice Retrieval

The significant ice coverage over the Aurora vent site led to a fear that 1) NUI might attempt to surface underneath the ice and be unable to achieve radio communications to return to the ship; or 2) be in a location where the Kronprins Haakon was unable to break ice and get close enough for recovery of NUI. While this never occurred, the NASA and NUI teams prepared modifications to NASA's BlueROV for under-ice retrieval in the case where NUI was trapped but close enough to the vessel to attempt recovery. A carabiner with hook was placed within the BlueROV's grasping claw to hook onto the NUI vehicle (Figure 15.2). This carabiner was connected to a spool towed by the BlueROV, which would allow a mechanical line to be returned to the KPH. Weights added to this line would decrease NUI's buoyancy, allowing it to be towed out from under the ice. The BlueROV would be used to provide a 3rd person perspective during these operations. Luckily, this system never needed to be operated, though testing took place within the ship's moon pool.

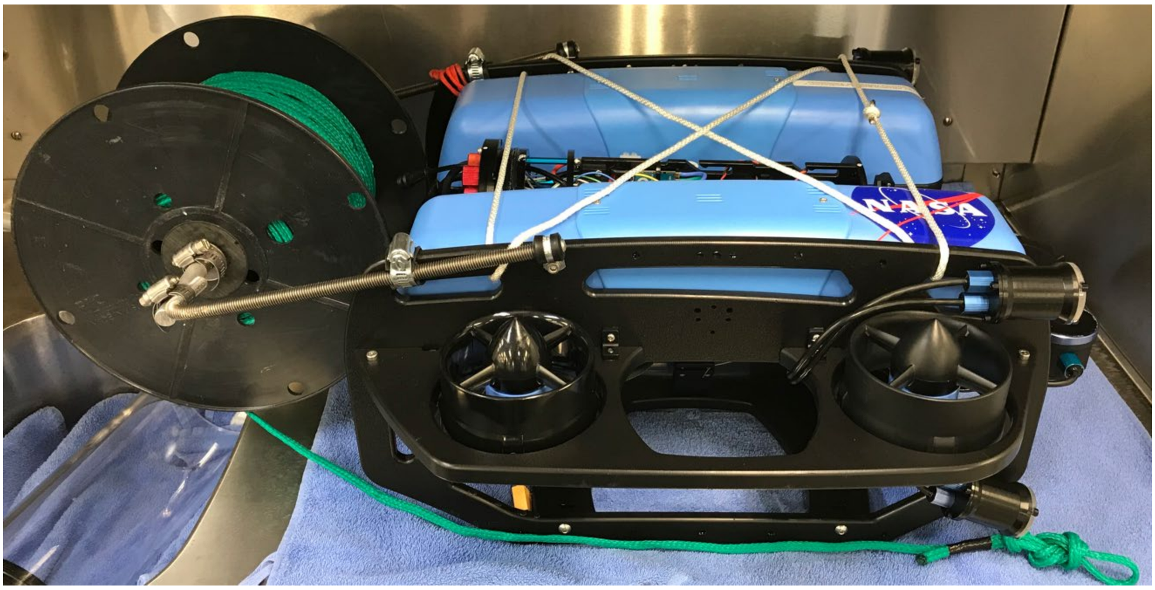


Figure 15.2. Modified BlueROV for NUI under ice recovery.

15.4 OFOBS Forward Looking and Side Scan Sonar

OFOBS dive 2 was aborted early due to current spikes and unresponsive sonar, leading to a vehicle brown-out. Investigation into the sonar enclosure showed water damage & corrosion to the network switch via a flooded cable (between the forward looking and side-scan sonar enclosures) which had undergone previous repair (Figure 15.3). The switch was replaced with a spare from the NASA team. Further investigation showed a salt trace down the backboard leading to corrosion of the capacitor bank. Each capacitor was desoldered, cleaned, tested, and replaced, bringing the side-scan sonar back online. Unfortunately, the forward-looking sonar was significantly flooded and unrepairable.

Figure 15.3. Capacitor damage within the side-scan sonar unit prior to repair.

15.5 NUI Retrieval

During NUI Dive 17, the vehicle remained on the sea floor for approximately 72 hours. As no burn-wire commands were successful at releasing the descent weights, and with a fear that the vehicle may have been trapped at the bottom, several retrieval efforts were developed:

- An under-OFOBS grapple and fin stabilizer to attempt to capture the NUI tow-body.
- A 4000 m ROV to be deployed below OFOBS to "clothes-line" and grapple NUI or the tow-body.

A stand-up design session was held between the WHOI, NASA, OFOBS, National Geographic and cruise leadership teams to understand potential retrieval options following NUI loss-of-communications. With limited ship maneuverability due to the ice, a maneuverable grapple was the preferred option to dredging, which would have limited success. Previous testing by WHOI showed that the thrusters from NASA's BlueROV might be more capable than rated (~100m depth) and upcoming OFOBS dives might provide both testing and observational opportunities to assist NUI. In addition, any close flyby of NUI by OFOBS might provide a grappling opportunity.

A basic grapple was designed to hang beneath OFOBS and quickly constructed by the ship's crew (Figure 15.4A). In addition, a fin was added to OFOBS to help with alignment during any potential flyover (Figure 15.4B).

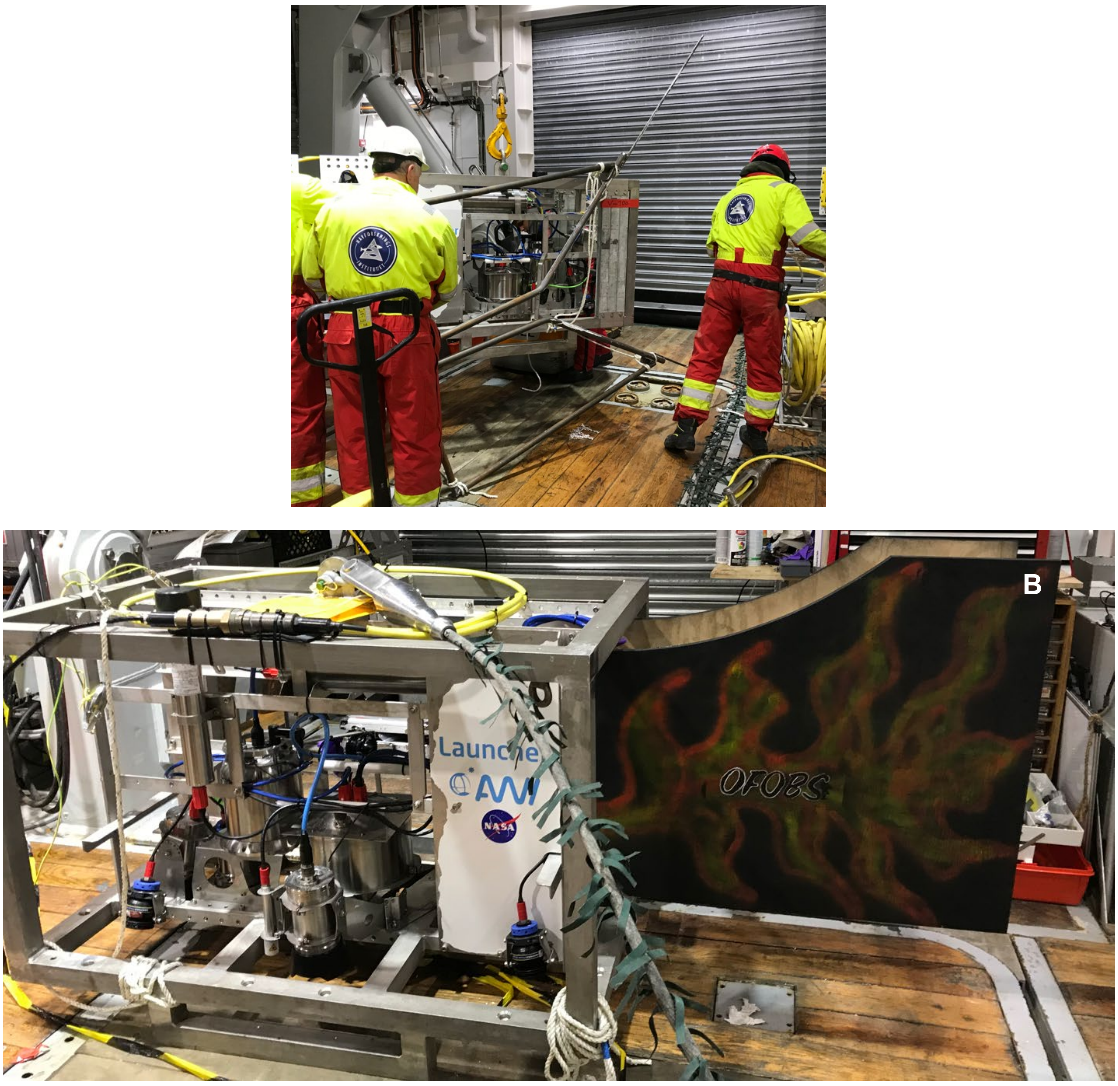


Figure 15.4. OFOBS prior to deployment, with the NUI grapple, the so-called "Stinger" (A) and with the alignment fin (B).

The NASA and NUI teams worked closely to disassemble the existing BlueROV and rebuild it with spare deep-water housings, foam, and connectors to try and better survey and capture NUI. A BlueROV thruster, generally used on vehicles rated to 100m, was sent with OFOBS to 4000 m for several hours with no apparent ill-effects. Ideally, the vehicle would hang from OFOBS on a 100m tether, carry a camera and light, and quickly survey the area, using its tether and grapple to attach to NUI for retrieval.

This vehicle, known as HÅPE (Norwegian for "Hope"), was not completed as NUI returned to the surface after 72 hours on the sea bottom. Enough design and construction had been completed, however, to consider completing a smaller 4000 m capable vehicle, operationally demonstrating both the thrusters and potential sampling benefits of a small "daughter" vessel to OFOBS.

The BlueROV was reassembled in a 6-thruster configuration to support under-ice survey activities and potential NUI retrieval. Two spare thrusters, along with pressure housings and 6000 m NUI foam were assembled into a small vehicle that could hang 2 meters underneath OFOBS and collect sponges if found. The vehicle was names Sponge Bob Spare Parts (Figure 15.5).

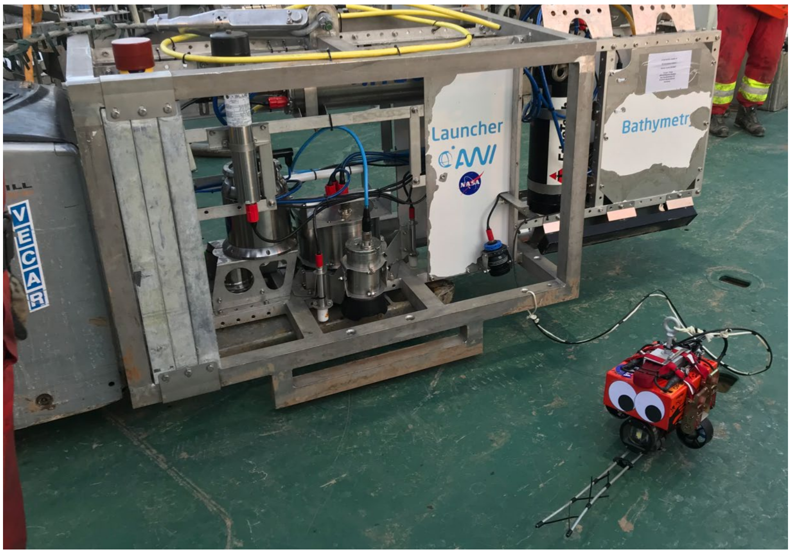


Figure 15.5. OFOBS with "Sponge Bob Spare Parts" prior to its first dive.

Test Dive: The vehicle was lowered by the CTD winch over the side for checkout operations. Both engineering and scientific personnel drove the vehicle via a simple keyboard interface, demonstrating both ease of operations and significant interest by the science party in personalized ROVs.

Dive 1: The little ROV descended below OFOBS to a depth of 4000 m. Tether communications was lost at 800 m, later found to be caused by a flooded cable. Both thrusters and electronics performed well in post-dive checkout

Dive 2: OFOBS dove to 2420 m with the smaller vehicle dangling 2 meters below. While the ocean bottom was fairly barren, personnel were able to drive the vehicle to investigate fish and sponges (though no samples were captured). Thrusters performed well during and after the dive.

The small vehicle demonstrated the use of smaller thrusters at depth and significantly increased the collaboration between the NASA, NUI and OFOBS engineering teams.

15.6 OFOBS CTD and Niskin Bottle

While NUI was under repair, a CTD and Niskin bottle were located for attachment to OFOBS. Though the CTD unit was missing its primary interface cable, the engineering team was able to connect to it, program it, and verify readiness for autonomous recording during the dive. Unfortunately, depth limitations precluded its eventual dive.

16 ACKNOWLEDGEMENTS

We would like to thank the Officers and Crew of the RV Kronprins Haakon for the valuable assistance at sea, particularly with finding the best drift positions to sample. The HACON project is funded by the Norwegian Research Council through a FRINATEK grant (274330), providing 2 weeks of shiptime. The remaining shiptime was provided by UiT. From the US, participation of the NUI team was supported by NOAA's Office of Ocean Exploration and Research through grant number NA19OAR0110406. Additional support to both the WHOI and NASA-JPL research teams was provided through the NASA Astrobiology PSTAR program through grant number NNX16AL04G. Nadia Drake was funded by National Geographic Partners. Luis Lamar was funded by the Avatar Alliance Foundation and WHOI. Safety equipment for the Ice work were provided by UNIS through the CLIMAGAS project (294764/E10).

The scientific party of the HACON 2019 cruise. Photo by Alexander Eeg.

17 REFERENCES

Boetius, A. et al. (2014a) PS86 Cruise Report.

Boetius, A., W Bach, C Borowski, A Diehl, C German, N Kaul, J Köhler, Y Marcon, C Mertens, M Molari, V Schlindwein, A Türke, G Wegener and Science Party of RV POLARSTERN Expedition Aurora PS86 (2014b). Exploring the Habitability of Ice-covered Waterworlds: The Deep-Sea Hydrothermal System of the Aurora Mount at Gakkel Ridge, Arctic Ocean (82°54' N, 6°15W, 4000 m). AGU Fall Meeting. B24A-02.

Cardenas P, Rapp HT. 2015. Demosponges from the northern Mid-Atlantic Ridge shed more light on the diversity and biogeography of North Atlantic deep-sea sponges. *Journal of the Marine Biological Association of the UK*. 95(7): 1475-1517. doi:10.1017/S0025315415000983.

Edmonds, H.N., Michael, P.J., Baker, E.T., Connelly D.P., Snow J.E., Langmuir, C.H., Dick, H.J.B., German, C.R. & Graham, D.W. (2003). Discovery of abundant hydrothermal venting on the ultraslow-spreading Gakkel Ridge in the Arctic Ocean. Nature 421: 252-256.

Eilertsen MH, Georgieva MN, Kongsrud JA, Wiklund H, Glover AG, Rapp HT. 2018. Genetic connectivity from the Arctic to the Antarctic: *Sclerolinum contortum* and *Nicomache lokii* (Annelida) are both widespread in reducing environments. *Scientific Reports* 8:4810 DOI:10.1038/s41598-018-23076-0.

German et al. (2010) Diverse styles of submarine venting on the ultraslow spreading Mid-Cayman Rise. PNAS, 102(32) pp14020-14025.

German, C.R., Boetius A. and the Scientific Teams of PS86 and PS101 (2017). Keynote: Hydrothermal exploration of the Gakkel Ridge, 2014 and 2016. Goldschmidt Conference, Paris.

Hestetun JT, Tompkins-MacDonald G, Rapp HT. 2017. A review of carnivorous sponges from the boreal North Atlantic and Arctic Oceans. *Zoological Journal of the Linnean Society*. 181(1): 1–69. https://doi.org/10.1093/zoolinnean/zlw022

Kongsrud JA, Eilertsen MH, Alvestad T, Rapp HT. 2017. Two new species of Ampharetidae (Polychaeta) from the Loki Castle vent field. *Deep-Sea Research Part II* 137: 232-245. http://dx.doi.org/10.1016/j.dsr2.2016.08.015.

Michael, P.J., Langmuir, C.H., Dick, H.J.B., Snow, J.E., Goldstein, S.L., Graham, D.W., Lehnert, K., Kurras, G., Jokat, W., Mühe R., and Edmonds, H.N. (2003). Magmatic and amagmatic seafloor generation at the ultra-slow spreading Gakkel ridge, Arctic Ocean. Nature 423: 956-962.

Pedersen RB, Rapp HT, Thorseth IH, Lilley M, Barriga F, Baumberger T, Flesland K, Fonseca R, Früh-Green GL, Jørgensen SL. 2010. Discovery of a black smoker field and a novel vent fauna at the ultraslow spreading Arctic Mid-Ocean Ridges. *Nature Communications* DOI:10.1038/ncomms1124.

Roberts EM, Mienis F, Rapp HT, Hanz U, Meyer HK, Davies AJ. 2018. Oceanographic setting and short-timescale environmental variability at an Arctic seamount sponge ground. *Deep-Sea Research* I 138: 98-113. doi.org/10.1016/j.dsr.2018.06.007

Schander C, Rapp HT, Kongsrud JA, Bakken T, Berge J, Cochrane S, Oug E, Byrkjedal I, Cedhagen T, Fosshagen A, Gebruk A, Larsen K, Nygren A, Obst M, Plejel F, Stöhr S, Todt C, Warén A, Handler-Jacobsen S, Kuening R, Levin L, Mikkelsen NT, Petersen KK, Thorseth I, Pedersen RB. 2010. The fauna of the hydrothermal vents on the Mohn Ridge (North Atlantic). *Marine Biology Research* 6(2): 155-171.

Steen IH, Dahle H, Stokke R, Roalkvam I, Daae FL, Rapp HT, Pedersen RB, Thorseth IH. 2016. Novel barite chimneys at the Loki's Castle Vent Field shed light on key factors shaping microbial communities and functions in hydrothermal systems. *Frontiers in Microbiology* Vol 6, article 1510. DOI: 10.3389./fmicb.2015.01510.

Tandberg AHS, Vader W, Olsen BR, Rapp HT. 2018. *Monoculodes bousfieldi* n. sp. from the Arctic hydrothermal vent Loki's Castle. *Marine Biodiversity* 48(2): 927-937. https://doi.org/10.1007/s12526-018-0869-6

Tandberg AHS, Olsen BR, Rapp HT. 2017. Amphipods from the arctic hydrothermal vent field «Loki's Castle», Norwegian Sea. *Biodiversity Journal* 8(2): 553-554.

Tandberg AHS, Rapp HT, Schander C, Vader W. 2013. A new species of *Exitomelita* (Amphipoda: Melitidae) from a deep water woodfall in the northern Norwegian Sea. *Journal of Natural History.* 47(25-28): 1875-1889.

18 APPENDICES

18.1 Complete log of operations

Site/Area	Ship SS	Ship LS	Equip.	Station Id	Date (UTC)	In water Time (UTC)	At bottom Time (UTC)	LAT	North/ South	LON	East/ West	Water Depth (m)	Recovery/ Bottle nº	Penetr	Comments
North Svalbard continental margin	3	254	CTD	HACON19-3-CTD-254	21.09.2019	4:41	NA	81,1827	N	18,473	E	265	7	NA	W1 mooring
North Svalbard continental margin	3	98	Mooring	HACON19-3-Mooring-1	21.09.2019	6:36	NA	81,1793	N	18,49	E	NA		NA	Mooring recovery
North Svalbard continental margin	4	255	CTD	HACON19-4-CTD-255	21.09.2019	8:09	NA	81,3794	N	18,397	E	650	1	NA	W2 mooring
North Svalbard continental margin	4	99	Mooring	HACON19-4-Mooring-2	21.09.2019	10:02	NA	81,374	N	18,435	E	NA		NA	Mooring recovery
North Svalbard continental margin	5	256	CTD	HACON19-5-CTD-256	21.09.2019	11:45	NA	81,4591	N	18,453	E	1998	1	NA	W3 mooring, LADCP

North Svalbard continental margin	5	100	Mooring	HACON19-5-Mooring-3	21.09.2019	14:32	NA	81,4473		18,39	E	NA		NA	Mooring recovery
North Svalbard continental margin	6	257	CTD	HACON19-6-CTD-257	21.09.2019	19:52	NA	81,4851	N	21,923	E	851	4	NA	INTAROS mooring, LADCP
Yermak Plateau	7	258	CTD	HACON19-7-CTD-258	22.09.2019	12:18	NA	80,5993	N	7,2369	W	737	11	NA	L'Ocean mooring, LADCP
Aurora Seamount	10	259	CTD	HACON19-10-CTD-259	28.09.2019	7:36	NA	82,916	N	6,255	W	4070	12	NA	11h cast, interrupted
Aurora Seamount	10	260	CTD	HACON19-10-CTD-260	28.09.2019	18:03	NA	82,852	N	6,228	W	4070	12	NA	wrong cnv format
Aurora Seamount	11	104	OFOBS	HACON19-11-OFOBS-01	29.09.2019	1:22	NA	82,9113	N	6,3551	W	NA		NA	
Rift valley, NorthEast of Aurora	12	1	NUI	HACON19-12-NUI-17	29.09.2019	7:41	NA	82,9204	N	6,1554	W	4050		NA	
Aurora Seamount	13	33	MUC	HACON19-13-MUC-33	29.09.2019	11:17	12:33	82,8977	N	6,2544	W	3912	2 cores	NA	

Aurora Seamount	14	34	MUC	HACON19-14-MUC-34	29.09.2019	15:16	16:45	82,8955	N	6,2735	W	3967	4 cores	NA	
Aurora Seamount	15	105	GC	HACON19-15-GC-105	29.09.2019	19:48	22:30	82,8940	N	6,2815	W	3895		core catcher	
Aurora Seamount	16	2	NUI	HACON19-16-NUI-18	30.09.2019	4:27	NA	82,8927	N	6,3119	W	4020		NA	
Aurora Seamount	17	261	CTD	HACON19-17-CTD-261	30.09.2019	12:02	NA	82,89149	N	6,324	W	3982	12	NA	HiPAP conflict with NUI. No USBL
Rift valley, North of Aurora	18	262	CTD	HACON19-18-CTD-262	30.09.2019	14:10	NA	82,89917	N	6,3301	W	4026	12	NA	in a plume; focus on LADCP data
Aurora Seamount	19	106	OFOBS	HACON19-19-OFOBS-02	30.09.2019	22:16	23:21	82,8812	N	6,3405	W	NA		NA	
Aurora Seamount	20	107	GC	HACON19-20-GC-107	30.09.2019	23:30	1:37	82,8942	N	6,2152	W	4165		300 cm	
South of Aurora	21	263	CTD	HACON19-21-CTD-263	01.10.2019	8:53	NA	82,89233	N	6,243	W	3903	12	NA	focus on LADCP data

Rift valley, East of Aurora	22	35	BC	HACON19-22-BC-35	01.10.2019	17:27	18:48	82,8940	N	6,0160	W	4165	full core	NA	Full box with no overlying water; brown fine sediment
Rift valley, East of Aurora	24	109	OFOBS	HACON19-24-OFOBS-03	01.10.2019	21:07	22:30	82,8995	N	6,0015	W	3930-4070		NA	
South of Aurora	25	264	CTD	HACON19-25-CTD-264	02.10.2019	9:14	NA	82,878	N	6,3728	W	4175	12	NA	focus on LADCP data, GPS used for coordinates, can't trust USBL
Rift valley, South of Aurora	26	36	MUC	HACON19-26-MUC-36	02.10.2019	12:52	14:11	82,8781	N	6,3063	W	4260	5 cores	NA	
Rift valley, North of Aurora	27	118	Håv	HACON19-27-Håv-118	02.10.2019	19:46	21:36	82,9128	N	6,3115	W	3300			
Aurora Seamount	28	110	GC	HACON19-28-GC-110	02.10.2019	0:30	1:26	82,9040	N	6,3010	W	3983		531 cm	
Aurora Seamount	29	112	OFOBS	HACON19-29-OFOBS-04	03.10.2019	11:37	13:12	82,9085	N	6,2557	W	3870-3970		NA	

South East of Aurora	30	265	CTD	HACON19-30-CTD-265	04.10.2019	0:39	NA	82,89374	N	6,2646	W	3894	12	NA	dirty C-star; only one set of sensor operational, USBL corrected for EK80 interference
North of Aurora	31	266	CTD	HACON19-31-CTD-266	04.10.2019	4:35	NA	82,90004	N	6,2472	W	3817	12	NA	No HiPAP
Aurora Seamount	32	113	GC	HACON19-32-GC-113	04.10.2019	7:25	9:44	82,8982	N	6,2572	W	3892		218cm	NO USBL
Aurora Seamount	33	114	OFOBS	HACON19-33-OFOBS-05	04.10.2019	10:56	12:20	82,8938	N	6,2318	W	3880-3990		NA	
Rift valley, North of Aurora	34	37	MUC	HACON19-34-MUC-37	04.10.2019	17:30	18:50	82,9103	N	6,3279	W	4102		NA	NO USBL
Aurora Seamount	35	38	BC	HACON19-35-BC-38	05.10.2019	6:05	7:25	82,8973	N	6,2808	W	3940	too full	NA	sediment overflow, no samples for macrofauna
South of Aurora	36	267	CTD	HACON19-36-CTD-267	04.10.2019	4:35	NA	82,8932	N	6,2605	W	3897	12	NA	CTD for Hacon and Tina

Rift valley, South of Aurora	37	115	GC	HACON19-37-GC-115	05.10.2019	18:25	19:20	82,8316	N	6,3785	W	4272	Core catcher hit a rock	93cm	
Rift valley, North of Aurora	38	116	GC	HACON19-38-GC-116	05.10.2019	20:59	21:50	82,9555	N	6,3543	W	4283		459cm	
Rift valley, North of Aurora	39	117	OFOBS	HACON19-39-OFOBS-06	05.10.2019	23:23	0:51	82,9538	N	6,3191	W	4250-4290		NA	
Aurora Seamount	40	3	NUI	HACON19-40-NUI-19	06.10.2019	10:16	20:36	82,8724	N	6,2721	W	4270		NA	
Rift valley, SouthWest of Aurora	41	118	GC	HACON19-41-GC-118	06.10.2019	19:19	20:20	82,7829	N	6,5745	W	4667		477cm	
South of Aurora	42	268	CTD	HACON19-42-CTD-268	07.10.2019	21:24	NA	82,78998	N	6,545	W	4520	12	NA	
South of Aurora	43	269	CTD	HACON19-43-CTD-269	07.10.2019	1:36	NA	82,95633	N	5,9563	W	4070	0	NA	CTD Kapout - no bottle
Aurora Seamount	44	119	OFOBS	HACON19-44-OFOBS-07	07.10.2019	7:04	8:14	82,8932	N	6,3021	W	3870-4030		NA	

Aurora Seamount	45	120	OFOBS	HACON19-45-OFOBS-08	07.10.2019	11:56	13:25	82,8941	N	6,3007	W	3890-4000		NA	
Aurora Seamount	46	39	MUC	HACON19-46-MUC-39	07.10.2019	17:44	19:11	82,8994	N	6,1639	W	3963	5 Cores	NA	
Rift valley, East of Aurora	47	119	Håv	HACON19-47-Håv-119	08.10.2019	1:34	3:24	82,8954	N	5,9754	W	3300		NA	
Rift valley, NorthEast of Aurora	48	120	Håv	HACON19-48-Håv-120	08.10.2019	18:42	20:32	82,9169	N	6,0772	W	3300		NA	
Rift valley, East of Aurora	49	40	BC	HACON19-49-BC-40	08.10.2019	23:38	0:34	82,9185	N	5,9148	W	3878		NA	Clear water, surface sediment smooth and undisturbed
Rift valley, East of Aurora	50	41	BC	HACON19-50-BC-41	09.10.2019	1:48	2:45	82,9195	N	5,8575	W	3946		NA	Clear water, surface sediment smooth and undisturbed
Rift valley, NorthWest of Aurora	51	121	Håv	HACON19-51-Håv-121	09.10.2019	15:09	15:13	82,9384	N	6,7246	W	100		NA	

Rift valley, NorthWest of Aurora	52	42	BC	HACON19-52-BC-42	09.10.2019	15:29	16:37	82,9375	N	6,7107	W	4075	6 cores (sub-sampling)	NA	No overlaying water; surface relativelly undisturbed, but box to full
Rift valley, NorthWest of Aurora	53	122	Håv	HACON19-53-Håv-122	09.10.2019	18:05	18:08	82,9368	N	6,7058	W	100		NA	
Rift valley, NorthWest of Aurora	54	43	BC	HACON19-54-BC-43	09.10.2019	18:44	19:43	82,9371	N	6,7065	W	4075		NA	Clear water, surface sediment smooth and undisturbed
Rift valley, NorthWest of Aurora	55	123	Håv	HACON19-55-Håv-123	09.10.2019	20:48	20:51	82,9376	N	6,7079	W	100		NA	
South of Aurora	56	270	CTD	HACON19-56-CTD-270	09.10.2019	21:10	NA	82,93783	N	6,7082	W	4014	6	NA	background of background for Hacon
Rift valley, NorthWest of Aurora	57	124	Håv	HACON19-57-Håv-124	10.10.2019	0:00	1:07	82,9412	N	6,6995	W	2000		NA	
Rift valley, NorthWest of Aurora	58	44	BC	HACON19-58-BC-44	10.10.2019	4:07	5:27	82,9404	N	6,6478	W	4153		NA	Clear water, surface sediment smooth and undisturbed

Rift valley, NorthWest of Aurora	59	121	GC	HACON19-59-GC-121	10.10.2019	7:38	8:50	82,9350	N	6,6383	W	4119		543cm	
Rift valley, West of Aurora	60	125	Håv	HACON19-60-Håv-125	10.10.2019	13:03	16:23	82,9134	N	6,7227	W	2000		NA	
Rift valley, West of Aurora	62	122	GC	HACON19-62-GC-122	11.10.2019	2:18	3:15	82,895	N	6,5883	W	4201		564 cm	
Rift valley, SouthWest of Aurora	63	123	OFOBS	HACON19-63-OFOBS-09	11.10.2019	6:55	8:00	82,80397	N	7,3134	W	3165-3180		NA	
Rift valley, South of Aurora	64	271	CTD	HACON19-64-CTD-271	11.10.2019	11:45	NA	82,80236	N	7,2988	W	3180	0	NA	Station Giuliana/Bene
Lena trough	65	124	GC	HACON19-65-GC-124	12.10.2019	3:07	3:44	81,71076	N	6,1915	W	3397		425cm	
Lena trough	66	125	GC	HACON19-66-GC-125	12.10.2019	12:23	13:03	81,085	N	1,9517	W	3000		empty, didn't hit the seaflor	

Lena Trough	67	272	CTD	HACON19-67-CTD-272	13.10.2019	22:38	NA	80,68098	N	0,9828	W	2374	12	NA	Station Giuliana/Bene
Lena trough	68	126	GC	HACON19-68-GC-126	13.10.2019	0:33	1:00	80,685	N	0,9853	W	2410		100cm	
Lena trough	70	128	OFOBS	HACON19-70-OFOBS-10	13.10.2019	11:13	12:42	80,47284	N	1,2334	W	2665-2725		NA	
Lena trough	71	129	OFOBS	HACON19-71-OFOBS-11	13.10.2019	21:59	23:27	80,41326	N	1,0108	W	2435-2445		NA	
Lena Trough	72	273	CTD	HACON19-72-CTD-273	14.10.2019	6:11	NA	80,5007	N	0,2506	E	2992		NA	
NorthEast Svalbard continental margin	73	131	GC	HACON19-73-GC-131	15.10.2019	0:04	0:19	79,9164	N	5,6537	E	1048		409cm	
NorthEast Svalbard continental margin	74	132	GC	HACON19-74-GC-132	15.10.2019	1:15	1:35	79,90983	N	5,6517	E	1040		346cm	
East Svalbard continental margin	75	274	CTD	HACON19-75-CTD-274	15.10.2019	14:03	NA	78,6277	N	10,586	E	82		NA	

East Svalbard continental margin	76	275	CTD	HACON19-76-CTD-275	15.10.2019	15:35	NA	78,4965	N	10,415	E	95		NA	
East Svalbard continental margin	77	132	OFOBS	HACON19-77-OFOBS-12	10/15/2019	16:36	16:52	78,564	N	10,134	E	90		NA	
East Svalbard continental margin	78	276	CTD	HACON19-78-CTD-276	15.10.2019	18:07	NA	78,5634	N	10,135	E	100		NA	

18.2 Description of subsampling for all deployments

Site/Area	Ship SS	Ship LS	Activity	Station Id	Notes	Sub Samples
North Svalbard continental margin	3	254	CTD	HACON19-3-CTD-254	W1 mooring	UiT
North Svalbard continental margin	3	98	Mooring	HACON19-3-Mooring-1	Mooring recovery	
North Svalbard continental margin	4	255	CTD	HACON19-4-CTD-255	W2 mooring	UiB
North Svalbard continental margin	4	99	Mooring	HACON19-4-Mooring-2	Mooring recovery	
North Svalbard continental margin	5	256	CTD	HACON19-5-CTD-256	W3 mooring, LADCP	UiB
North Svalbard continental margin	5	100	Mooring	HACON19-5-Mooring-3	Mooring recovery	
North Svalbard continental margin	6	257	CTD	HACON19-6-CTD-257	INTAROS mooring, LADCP	UiT/UiB
Yermak Plateau	7	258	CTD	HACON19-7-CTD-258	L'Ocean mooring, LADCP	UiT/UiB
Aurora Seamount	10	259	CTD	HACON19-10-CTD-259	11h cast, interrupted	UiB/UiT/NASA/IMR

Aurora Seamount	10	260	CTD	HACON19-10-CTD-260	Wrong cnv format	UiB/UiT/NASA/IMR
Aurora Seamount	11	104	OFOBS	HACON19-11-OFOBS-01		AWI/NIVA
Rift valley, NorthEast of Aurora	12	1	NUI	HACON19-12-NUI-17		NA
Aurora Seamount	13	33	MUC	HACON19-13-MUC-33		Core3 (78cm): Oxi profile/Pore-water/Micropaleontology/Sediment Geochemistry(Utromso); Core 4 (39.5cm): Porewater (Methane conc. Eoghan; Methane isotope Kevin); Microbiology and porewater(UIB); Porewater/Micropaleontology/Sediment Geochemistry(Utromso)
Aurora Seamount	14	34	MUC	HACON19-14-MUC-34		Core3 (53cm): Oxi profile/redox potential/Micropaleontology/Sediment Geochemistry(Utromso); Microbiology and porewater (UiB) and Grain size(U.Aveiro), Porewater (Methane conc. Eoghan; Methane isotope Kevin); Core 2 (55cm; Meiofauna in both 4% formol and 20%DESS); Core 4 (53cm; Meiofauna in both 4% formol and 20%DESS); Core 5 (59cm; Meiofauna in both 4% formol and 20%DESS)
Aurora Seamount	15	105	GC	HACON19-15-GC-105		Headspace(Methane); porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic suseptibility (U. Tromso); Microbiology (UIB)
Aurora Seamount	16	2	NUI	HACON19-16-NUI-18		NA
Aurora Seamount	17	261	CTD	HACON19-17-CTD-261	HiPAP conflict with NUI. No USBL	UiB

Rift valley, North of Aurora	18	262	CTD	HACON19-18-CTD-262	In a plume; focus on LADCP data	UiB/UiT/NASA/IMR
Aurora Seamount	19	106	OFOBS	HACON19-19-OFOBS-02		AWI/NIVA
Aurora Seamount	20	107	GC	HACON19-20-GC-107		Headspace(Methane); porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic suseptibility (U. Tromso); Microbiology (UIB)
South of Aurora	21	263	CTD	HACON19-21-CTD-263	Focus on LADCP data	UiB/UiT/NASA/IMR
Rift valley, East of Aurora	22	35	BC	HACON19-22-BC-35	Full box with no overlying water; brown fine sediment	Microbiology and porewater (UiB); Micropaleontology/Sediment Geochemistry(Utromso); Macrofauna (UiB): 0-3 cm, 3-10 cm, 500micron, 250micron
Rift valley, East of Aurora	24	109	OFOBS	HACON19-24-OFOBS-03		AWI/NIVA
South of Aurora	25	264	CTD	HACON19-25-CTD-264	Focus on LADCP data, GPS used for coordinates, can't trust USBL	NIVA/IMR/UiB
Rift valley, South of Aurora	26	36	MUC	HACON19-26-MUC-36		Core 2 (54cm): Oxi profile/redox potential/Micropaleontology/Sediment Geochemistry (UTromso); Microbiology (UiB) and Grain size (U.Aveiro); Core 5 (56cm; Meiofauna in both 4% formol and 20%DESS); Core 3 (64cm; Meiofauna in both 4% formol and 20%DESS); Core 1 (41cm; Meiofauna in both 4% formol and 20%DESS); Core 6 (totally full - UTromso - frozen for classes)

Rift valley, North of Aurora	27	118	Håv	HACON19-27-Håv-118		
Aurora Seamount	28	110	GC	HACON19-28-GC-110		Headspace(Methane); porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic suseptibility (U. Tromso); Microbiology and porewater (UIB)
Aurora Seamount	29	112	OFOBS	HACON19-29-OFOBS-04		AWI/NIVA
South East of Aurora	30	265	CTD	HACON19-30-CTD-265	Dirty C-star; only one set of sensor operational, USBL corrected for EK80 interference	UiB/UiT/NASA/IMR
North of Aurora	31	266	CTD	HACON19-31-CTD-266	No HiPAP	UiB/UiT/NASA/IMR
Aurora Seamount	32	113	GC	HACON19-32-GC-113	NO USBL	Headspace(Methane); porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic suseptibility (U. Tromso); Microbiology (UIB)
Aurora Seamount	33	114	OFOBS	HACON19-33-OFOBS-05		AWI/NIVA

Rift valley, North of Aurora	34	37	MUC	HACON19-34-MUC-37	NO USBL	Core1 (71cm): Meiofauna in both 4% formol and 20%DESS; Core2 (72cm): Microbiology and porewater (UIB)/Foodweb (IMR); Core3 (74cm): Meiofauna in both 4% formol and 20%DESS; Core4 (??cm): Oxi profile/redox potential/Micropaleontology/Sediment Geochemistry(Utromso); Core5 (68cm): Micropaleontology/Sediment Geochemistry(Utromso) and Grain size (U.Aveiro); Core6(60cm): Meiofauna in both 4% formol and 20%DESS; Oxi profile/redox potential/Micropaleontology/Sediment Geochemistry(Utromso)
Aurora Seamount	35	38	BC	HACON19-35-BC-38	Sediment overflow, no samples for macrofauna	2 MUC liners for microbiology and porewater (UiB), pore water and micropaleontology (UiT)
South of Aurora	36	267	CTD	HACON19-36-CTD-267	CTD for Håkon Dahle and Tina Kutti	
Rift valley, South of Aurora	37	115	GC	HACON19-37-GC-115		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic suseptibility (U. Tromso)
Rift valley, North of Aurora	38	116	GC	HACON19-38-GC-116		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic suseptibility (U. Tromso)
Rift valley, North of Aurora	39	117	OFOBS	HACON19-39-OFOBS-06		AWI/NIVA
Aurora Seamount	40	3	NUI	HACON19-40-NUI-19		UiB (Sponges and Blade corer)
Rift valley, SouthWest of Aurora	41	118	GC	HACON19-41-GC-118		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic suseptibility (U. Tromso)
South of Aurora	42	268	CTD	HACON19-42-CTD-268		

South of Aurora	43	269	CTD	HACON19-43-CTD-269	CTD Kapout - no bottle	
Aurora Seamount	44	119	OFOBS	HACON19-44-OFOBS-07		AWI/NIVA
Aurora Seamount	45	120	OFOBS	HACON19-45-OFOBS-08		AWI/NIVA
Aurora Seamount	46	39	MUC	HACON19-46-MUC-39		Core 1 (cm):Porewater and Microbiology (UIB) ; Core 2 (cm):Meiofauna in both 4% formol and 20%DESS; Core 3 (cm): Meiofauna in both 4% formol and 20%DESS; Core 5 (cm):Micropaleontology/Sediment Geochemistry (UTromso),Microbiology (UIB) and Grain size (U.Aveiro); ; Core 6 (cm):Meiofauna in both 4% formol and 20%DESS;
Rift valley, East of Aurora	47	119	Håv	HACON19-47-Håv-119		Food web analysis (IMR)
Rift valley, NorthEast of Aurora	48	120	Håv	HACON19-48-Håv-120		Food web analysis (IMR)
Rift valley, East of Aurora	49	40	BC	HACON19-49-BC-40	Clear water, surface sediment smooth and undisturbed	Macrofauna (UIB)
Rift valley, East of Aurora	50	41	BC	HACON19-50-BC-41	Clear water, surface sediment smooth and undisturbed	Top 5 cm for Macrofauna; 10, 20 30 and 40 cm fractions for sponge spicules (UIB)
Rift valley, NorthWest of Aurora	51	121	Håv	HACON19-51-Håv-121		Food web analysis (IMR)

Rift valley, NorthWest of Aurora	52	42	BC	HACON19-52-BC-42	No overlaying water; surface relatively undisturbed, but box to full	Sub-sample for macrofauna (UIB); Push-core for Oxy/redox potential profiling and pore waters (UTromso); MUC liners: Core 2 (59cm): Porewater and Microbiology (UIB) ; Core 6 (59cm): Meiofauna in both 4% formol and 20 %DESS; Core 1 (58cm): Meiofauna in both 4% formol and 20 %DESS; Core3 (58 cm): Micropaleontology/Sediment Geochemistry (UiT), Microbiology (UiB) and Grain size (Uni. Aveiro); Core 4 (58cm): Meiofauna in both 4% formol and 20 %DESS
Rift valley, NorthWest of Aurora	53	122	Håv	HACON19-53-Håv-122		Food web analysis (IMR)
Rift valley, NorthWest of Aurora	54	43	BC	HACON19-54-BC-43	Clear water, surface sediment smooth and undisturbed	Macrofauna (UIB)
Rift valley, NorthWest of Aurora	55	123	Håv	HACON19-55-Håv-123		Food web analysis (IMR)
South of Aurora	56	270	CTD	HACON19-56-CTD-270	Background of background for Håkon Dahle	
Rift valley, NorthWest of Aurora	57	124	Håv	HACON19-57-Håv-124		Food web analysis (IMR)

Rift valley, NorthWest of Aurora	58	44	BC	HACON19-58-BC-44	Clear water, surface sediment smooth and undisturbed	Macrofauna (UIB), Micoplaleontology (UiT)
Rift valley, NorthWest of Aurora	59	121	GC	HACON19-59-GC-121		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic susceptibility (UiT); Microbiology and porewater (UiB)
Rift valley, West of Aurora	60	125	Håv	HACON19-60-Håv-125		Food web analysis (IMR)
Rift valley, West of Aurora	62	122	GC	HACON19-62-GC-122		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic susceptibility (UiT); Microbiology and porewater (UiB)
Rift valley, SouthWest of Aurora	63	123	OFOBS	HACON19-63-OFOBS-09		AWI/NIVA
Rift valley, South of Aurora	64	271	CTD	HACON19-64-CTD-271	Station Giuliana Panieri/Benedicte Ferre	UiT
Lena trough	65	124	GC	HACON19-65-GC-124		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic susceptibility (UiT)
Lena trough	66	125	GC	HACON19-66-GC-125		NA
Lena Trough	67	272	CTD	HACON19-67-CTD-272	Station Giuliana Panieri/Benedicte Ferre	UiT
Lena trough	68	126	GC	HACON19-68-GC-126		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic susceptibility (UiT)
Lena trough	70	128	OFOBS	HACON19-70-OFOBS-10		AWI/NIVA

Lena trough	71	129	OFOBS	HACON19-71-OFOBS-11		AWI/NIVA
Lena Trough	72	273	CTD	HACON19-72-CTD-273		
NorthEast Svalbard continental margin	73	131	GC	HACON19-73-GC-131		Porewater; micropaleontology; sedimentology; sediment geochemistry; magnetic susceptibility (UiT)
NorthEast Svalbard continental margin	74	132	GC	HACON19-74-GC-132		Microbiology (UIB)
East Svalbard continental margin	75	274	CTD	HACON19-75-CTD-274		
East Svalbard continental margin	76	275	CTD	HACON19-76-CTD-275		
East Svalbard continental margin	77	132	OFOBS	HACON19-77-OFOBS-12		AWI/NIVA
East Svalbard continental margin	78	276	CTD	HACON19-78-CTD-276		

18.3 Description of sample sharing for core samples

Station Id	Date (UTC) dd.mm.yyyy	Equipment	Core number	water depth (m)	latitude	longitude	Rose Bengal (cm)	TEM (cm)	Sediment Geochemistry (cm)	Pore water (cm)	Head space (# samples)	Microprofiles	Microbiology	Core Length (cm)
HACON19-13-MUC33	29.09.2019	MUC	liner 4	3912	82,90	6,25	2-5	0-2		0-34				
HACON19-13-MUC33	29.09.2019	MUC	liner 3	3912	82,90	6,25	0-5		0-70			X		
HACON19-14-MUC34	29.09.2019	MUC	liner 3	3967	82,90	6,27	0-1	0-2	0-10	0-44		X		
HACON19-15-GC105	29.09.2019	GC	105	3895	82,89	6,28							X	
HACON19-20-GC107	30.09.2019	GC	107	4165	82,89	6,22							X	300
HACON19-28-GC110	02.10.2019	GC	110	3983	83,51	6,50				52-254			X	531
HACON19-26-MUC36	02.10.2019	MUC	liner 2	4260	82,88	6,31	0-5			0-17		X		
HACON19-34-MUC37	04.10.2019	MUC	liner 5	4102	82,91	6,33			0-65	0-61				
HACON19-34-MUC37	04.10.2019	MUC	liner 4	4102	82,91	6,33	0-10					X		
HACON19-32-GC113	04.10.2019	GC	113	3892	82,90	6,26					3		X	218
HACON19-35_BC38	05.10.2019	BC	liner 1	3940	82,90	6,28	0-10	0-1	0-33	0-33	1			
HACON19-37-C115	05.10.2019	GC	115	4272	82,83	6,38								93

HACON19-38-GC116	05.10.2019	GC	116	4283	82,96	6,35								459
HACON19-41-GC117	06.10.2019	GC	118	4667	83,28	6,57								477
HACON19-46-MUC39	07.10.2019	MUC	liner 5/1	3963	82,90	6,16	0-5		0-70	0-51				
HACON19-52-BC42	09.10.2019	BC	liner 1	4075	82,94	6,71	0-5	0-1	0-52	0-53		X		
HACON19-54-BC43	09.10.2019	BC	surface	4075	82,94	6,71	0-1							
HACON19-59-GC121	10.10.2019	GC	121	4153	82,94	6,64								543
HACON19-62-GC122	10.10.2019	GC	122	4201	82,90	6,59					8		X	564
HACON19-65-GC124	12.10.2019	GC	124											
HACON19-ROV4-BLC1		BLC					0-1	0-1		0-12				
HACON19-68-GC126	13.10.2019	GC	126	2411	80,41	0,60								100

18.4 NUI dive plans

18.4.1 NUI17_DivePlan_v1

Objectives: Seafloor mapping ± video reconnaissance at Aurora vents

Science Leads: Stefan, Eva, Chris

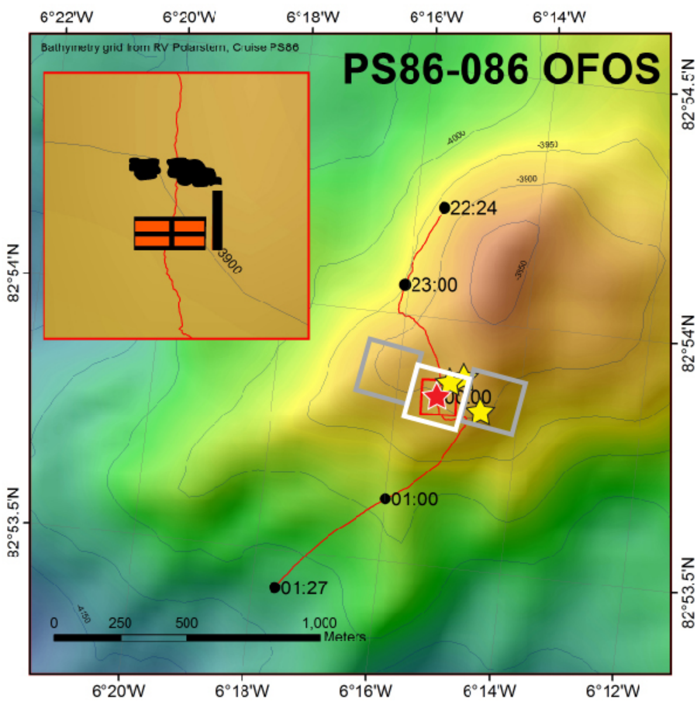
Dive Plan:

-02h Select Launch Target, NUI team begins pre-dive
[Launch point = 8h up-drift from Aurora vent target at 82°53.83'N, 006°15.32'W

±00h Launch vehicle but not depressor, conduct drop-weight test, recover and re-set.
[Opportunity to confirm that drift of ship is as predicted when launch site was chosen]
[Nominally, dive prediction should pass within ±1km of Aurora (slower drift = wider)

+04h Arrive at seafloor, offset to E or W from target
Determine which way current is blowing so we can orient mapping survey
Drive in to begin survey at 50m altitude

+05h Execute mapping survey at 50m altitude
If fiber is intact, use real-time sensor data to reveal buoyant plume interception



Option A

+06h If fiber is intact, select a target at seafloor and dive to locate, open doors, conduct:

- Video reconnaissance/imaging of pristine site

- Measure temperature of vent with NUI T-probe
- Test 2 x IGT fluids

Option B

+06h If fiber is NOT intact

- Expand the dimensions of the mapping survey in AUV mode

[can be informed by T data from NUI for buoyant plume interceptions]

+08h Leave seafloor
+12h At surface
+14h Secure on deck

18.4.2 NUI Dive 018

Approximate duration: 12h in water (4h on seafloor)

Dive lead scientist: Eva Ramirez Llodra

Dive aims:

1. Land approx. 100m south (downhill) from Aurora (Chris)
2. Drive uphill to Aurora noting any diffuse flow and locate active vents at summit (Chris)
3. Measure temperature of high-temperature vent-fluids to select fluid sampling site (Chris/Eoghan)
4. Sample 2 x IGT vent-fluid samples (Eoghan)
5. Collect complementary sulphide sample for microbiology (Eoghan & Ida)
6. Collect mobile fauna with slurp sampler into a single chamber (Eva)
7. Collect sessile fauna attached to a rock (Eva)

Optional Tasks:

1. Dedicated RayFin imaging at the vent site (Lu) – 30 minutes
2. Mapping survey if energy & time allows (Chris & Stefan) – 60 minutes

Equipment:

1. High-T probe
2. 2 x IGT
3. Slurp sampler
4. Milk crate for sulphides/rocks
5. Scoop for biology
6. 2 x Alvin dive weights (Mkr 1, Mkr 2)

18.4.3 NUI Dive 019

Approximate duration: 12h in water (4h on seafloor)

Dive lead scientist: Eva Ramirez Llodra

Dive aims:

01. Land approx. 100m south (downhill) from Aurora (Chris)
02. Drive uphill to Aurora noting any mobile fauna that are readily accessible (Chris)
03. Collect mobile fauna with slurp sampler into a single chamber (Eva)
04. Locate active vents and break off a sample of sulphide (Ida)
05. Sample 2 x IGT vent-fluid samples (Eoghan)
06. Measure temperature of high-temperature vent-fluids to select fluid sampling site (Eoghan)
07. Collect further mobile fauna with slurp sampler (Eva)
08. Collect sessile fauna attached to a rock (Eva)
09. Dedicated imaging at the vent site (Lu)
10. Mapping survey (Chris & Stefan)

Operations in priority order, 01-10
If fiber breaks, proceed directly to #10.

Equipment:

1. High-T probe
2. 2 x IGT
3. Slurp sampler
4. Milk crate for sulphides/rocks
5. Scoop for biology
6. 2 x Alvin dive weights (Mkr 1, Mkr 2)