CAGE - Centre for Arctic Gas Hydrate Environment and Climate Report Series, Volume 10 (2022)

To be cited as: Ferré, B. et al. (2022). CAGE22-3 Cruise Report: EMAN7 cruise. *CAGE - Centre for Arctic Gas Hydrate Environment and Climate Report Series, Volume 10*. https://doi.org/10.7557/cage.6760
Additional info at: https://septentrio.uit.no/index.php/cage/database

ISSN: 2703-9625
Publisher: Septentrio Academic Publishing Tromsø Norway

Cruise report

EMAN7 cruise

CAGE 22-3

Myre – Tromsø 08-16/06/2022

Participants: Bénédicte Ferré (chief scientist), Giuliana Panieri, Claudio Argentino, Fatih Sert, Marie Stetzler, Luca Fallati, Michael Dills, Sebastian Petters, Rohan Thomas, Thibaut Barreyre, Marie Eide Lien, Tina Kutti, Jorge Corrales Guerrero, Michael Kjær, Rhoda Luo Na Ting, Mikkel Dahlin Bojesen, Axel Walta, Stormer Jensen and the ROV team: Bjørn Løfquist, Frode Evensen, Andreas Storebø, Marco Micheel

Centre for Arctic Gas Hydrate, Environment and Climate (CAGE)
Department of Geology
UiT – The Arctic University of Norway
N-9037 Tromsø, Norway

Contents

1 PARTICIPANTS LIST

Name	Expertise	Affiliation
Benedicte Ferré	Chief scientist – Physical oceanographer	UiT
Fatih Sert	WC geochemistry /sampling	UiT
Marie Stetzler	EK80 / multibeam / WC sampling	UiT
Giuliana Panieri	Micropaleontologist	UiT
Luca Fallati	Photomosaik	UNI MIB
Claudio Argentino	Sedimentology, geochemistry	UiT
Stormer Jensen	Engineer	UiT
Michael Dills	Microbiology	UiT
Sebastian Petters	Microbiology	UiT
Rohan Thomas	Filmmaker - outreach	Beyond Index LTD
Thibaut Barreyre	Marine Geophysicist	UiB
Marie Eide Lien	Marine Geophysicist	UiB
Tina Kutti	Ecology/trophic	IMR
Jorge Corrales Guerrero	Ecology/trophic	IMR
Michael Kjær	Art historian	University of Copenhagen
Rhoda Luo Na Ting	Artist	StudioThinkingHand
Mikkel Dahlin Bojesen	Artist	StudioThinkingHand
Bjørn Løfquist	Ægir	IMR
Frode Evensen	Ægir	IMR
Andreas Storebø	Ægir	IMR
Marco Micheel	Ægir - multibeam	IMR
Axel Walta	Piezometer installation	NGI

2 EMAN7

The cruise was performed in the frame of the NFR-funded project EMAN7 (Environmental impact of Methane seepage and sub-seabed characterization at LoVe – Node 7). The project is funded by the Norwegian council and industry (equinor, Total and Conoco Phillips), and consists in a consortium between UiT – The Arctic University of Norway, UiB and IMR. Although much focus has been placed on reducing anthropogenic inputs of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4, a more potent greenhouse gas compared to CO_2) associated with underwater reservoirs of hydrocarbons, can erupt as climate driven changes to the physical environment reduce its stability. In addition, increased anthropogenic activities in hydrocarbon rich areas (i.e., oil and gas exploration) may cause additional release of greenhouse gases (CH_4 and CO_2) altering several biogeochemical processes and threatening health of the local ecosystem. EMAN7 uses the observatory facility located in the resource rich area of Lofoten-Vesterålen (LoVe) for monitoring a wide range of physical, biological and chemical parameters associated with cold-water coral reefs and CH_4 seepage. These parameters will provide cross-disciplinary research with a complete picture of the ecosystem response to CH_4 seepage, as well as temporal and spatial variation of the seepage system itself. Furthermore, as this region serves as a conduit of warm Atlantic water transport to the Arctic, data collected at the LoVe nodes will provide needed insight to predict potential impacts of climate change in Arctic regions. Annual research surveys in the Hola Trough will complement the long-term data with spatial variability in CH_4 seepage and greenhouse gases exchange across air-sea interface. This project aims also at improving the understanding of sub-seafloor fluid flow over a wide range of systems that are involved in the transfer of carbon from the sub-seafloor to the ocean. These results will thus provide constraints

to estimate fluxes both at the studied sites and globally, while gaining particular insight into the properties, dynamics and fluxes of sediment-hosted systems.

3 CRUISE OBJECTIVES

The cruise mainly focused on the area around nodes 1 and 7 of the LoVe ocean observatories in the Hola Trough (Figure 1). We aimed at characterizing i) the seafloor and local biology via photomosaicing and microbathymetry, ii) the bubbles via visual observation, iii) the gas origin via bubble catcher, iv) the water column chemistry via water sampling, and v) methane dynamic, fluxes, chemistry within the sediment via push cores and gravity cores. In addition, we planned to collect corals and transplant them in other locations to study adaptation. The installation of Piezometers and temperature probes were also planned for future fluid flow calculation.

4 HOLA TROUGH

Hola is a trough between the banks Vesterålsgrunnen and Eggagrunnen, on a seafloor formed by the action of ice and later partly covered by fine-grained glaciomarine sediments. The area is mainly covered with sand, but can also be covered with gravely sand, sandy gravel and coarser sediment. Giant Barchan-type sandwaves up to 3 km long, 7 m high, and up to 300 m apart are formed by strong current. The Hola trough is also known for a large amount of cold-water coral reefs (Lophelia pertusa) immediately east of sandwaves (Bøe et al, 2009).

Two main currents flow through the area, the Norwegian coastal current and the Norwegian Atlantic current along the 500 m isobath. Both currents are strong (> 1m/s, typical 0.2-0.4m/s), and a complex pattern of currents and tide influence the circulation in the narrow trough (Bøe et al., 200).

The seeps, mainly located near node 7 but also in other locations of the trough, have been active for 7 and 10 000 years old (Crémière et al., 2015), with current methane concentrations 10 times higher than the normal background concentrations (Ferré et al., 2018). The source of methane is dominated by a thermogenic origin (Crémière et al., 2015) and the area is charcterised by carbonate crusts (Chand et al., 2008).

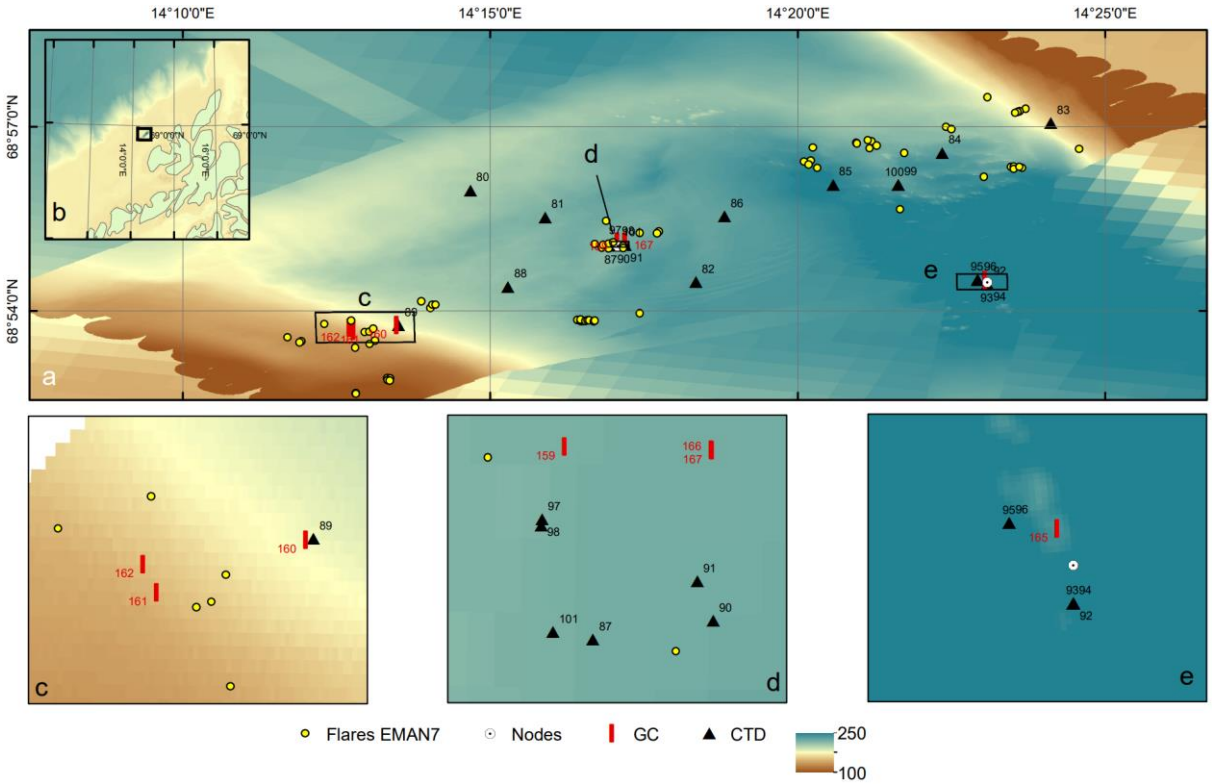

Figure 1. Map of the working area. a) bathymetry from multibeam survey, overlapping the GEBCO bathymetry. CTD casts are represented with black triangles, flares with yellow dots and gravity cores with red segments. Areas in insets c, d and e are shown. b) location of Hola Trough offshore Vesterålen.

5 SCIENTIFIC EQUIPMENT AND METHODS

5.1 Hydroacoustic systems

Multibeam echosounders use a swath of beams giving off-track depth. Basic components of a multibeam system are two linear transducer arrays in a Mills cross configuration with separate units for transmitting and receiving. Echosounders measure the two-way travel time that a sound wave initiated by the transmitter needs to reach the seafloor and be reflected back to the receiver. The time-depth conversion can be done using the sound velocity through seawater calculated from the closest CTD measurements.

R/V Kronprins Haakon is equipped with the flush mount Kongsberg EM302 multibeam echosounder system and the Kongsberg EM710 multibeam echosounder system mounted on the drop keel. For better data quality, we only used the EM302 Its nominal sonar frequency of the sound waves is 70 kHz with an angular coverage sector of up to 140° and 400 beams per ping. The system was used with a 45°/45° opening angle. The ping rate depends on the water depth and opening angle and switched frequently between 0.5 and 2 Hz. The EM302 provides high-resolution bathymetric data up to a water depth of 7000 m. The achievable swath width on the seafloor depends on the bathymetry and the selected opening angle.

During the cruise, the EM302 provided continuous bathymetric data to give an overview of the seafloor morphology in the study area, but it was not logging during ROV surveys to avoid interferences with the ROV.

Another application of the EM302 is to monitor the water column. The acquired data were analyzed using the QPS FMMidwater software. Before any analysis could be done, the provided sonar source files (*.all, *.wcd) had to be converted to the generic water column file format (*.gwc). The analysis of

water column data allows the detection of acoustic flares indicating gas seepage from the seafloor to the water column and the spatial mapping on top of the bathymetry.

A third option of the EM302 is to use in parallel the SBP300, a bub-bottom profiler measuring with a low frequency transmit transducer and very narrow beam width. We performed 8 lines during the cruise (Figure 2), with a chirp pulse of 50 ms and frequency bandwidth of 2.5 – 6.5 kHz.

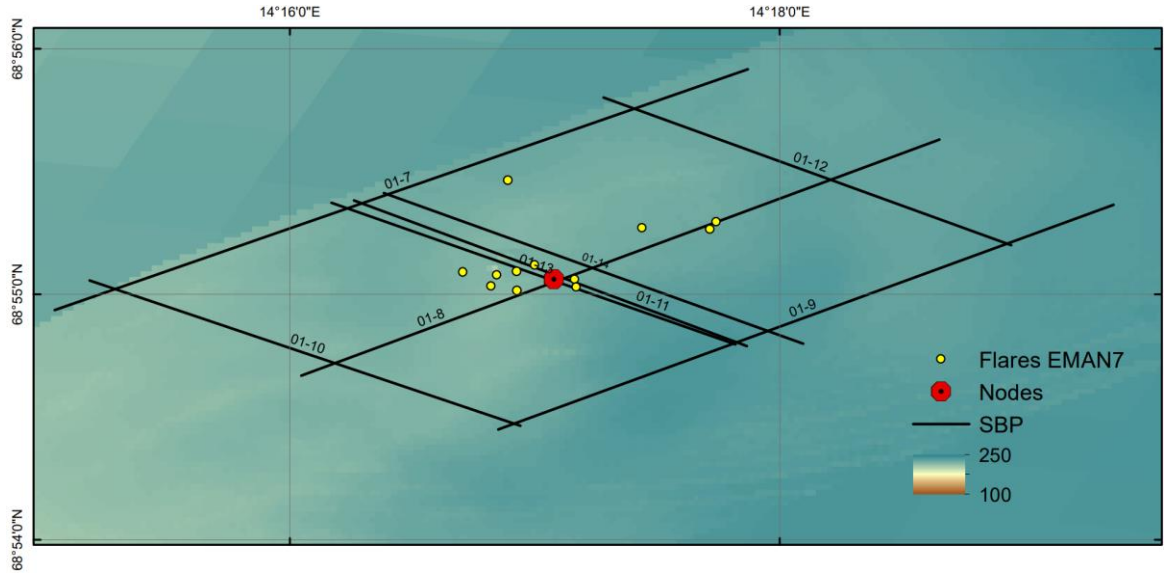

Figure 2. SBP lines (black) with the numbers as indicated in Appendix 1. Yellow dots are the flares detected in the multibeam (not clustered) and node 7 is the red dot. The line across node 7 was redone due to the strong reflection from the coral that hindered the sub-bottom signal.

R/V Kronprins Haakon is equipped with two Kongsberg Simrad EK80 singlebeam echosounder systems (flush mount and drop keel), both having six frequency channels: 18, 38, 70, 120, 200 and 333 kHz. All channels operate in narrowband using a continuous wave (CW) pulse type, but the four latter channels can also acquire broadband data using a linear frequency modulated (LFM) pulse type. The high frequency EK80 echosounder system is very sensitive to gas bubbles in the water column, and the rising bubbles appear as high amplitude anomalies (acoustic flares) in the water column. We performed two EK80 lines along with the MB in order to compare both signal for further analysis (Figure 3).

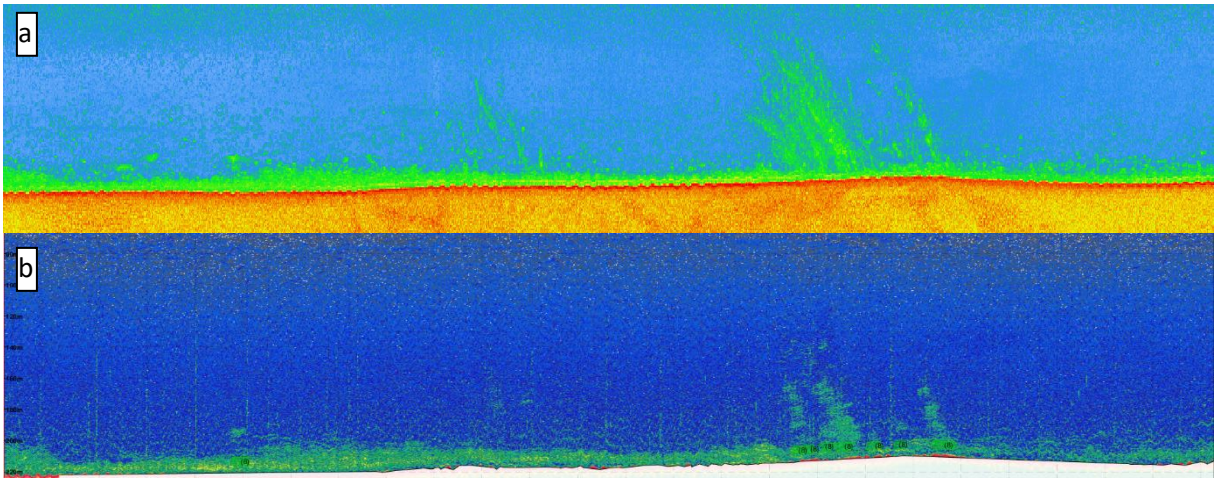

Figure 3. a) MB line performed along with b) EK80 line (38 kHz) across node 7.

5.2 CTD and sampling for geochemistry

The CTD (Conductivity, Temperature, Depth) sensors measure the physical properties of seawater. In addition to measuring the conductivity, temperature and pressure (from which depth is calculated), the CTD sensors can measure or calculate salinity of seawater, density, P-wave velocity, turbidity, fluorescence/chlorophyll, and oxygen content. R/V Kronprins Haakon uses the SBE 911plus CTD to produce vertical profiles of seawater properties. A winch lowers the CTD system into the water at 1 m/s. The CTD sensors record data at a rate of 24 samples per second. A total of 12 × 10-liters Niskin bottles are attached to the CTD instrument set up to collect water samples from chosen depth. A single conductor cable supplies power to the system and transmits data from and to the CTD system in real time.

5.2.1 Water sampling for methane concentration

To prepare water samples for measurements of methane concentrations we applied the conventional headspace gas extraction technique. Water samples were collected bubble free into 120 mL crimp seal bottles, and poisoned with 1 mL NaOH solution. In exchange with sampled water 5 ml of nitrogen gas was added and the bottles were vigorously shaken to facilitate equilibration of dissolved and headspace gas. 442 Bottles were kept in the fridge (5 °C) until analysis back in Tromsø with the Gas Chromatographer – FID at CAGE.

5.2.2 Sampling for biochemical parameters

The major portion of the primary production is happening in the euphotic ocean where sunlight penetrates enough for photosynthesis to produce organic matter from carbon dioxide. In cold seeps and surrounding environments, reduced carbon (such as methane) is also used as the main carbon source for some organisms called methane-oxidizing bacteria (MOB). MOB utilize methane and modifies the composition of DOM in the water column. The extent of these modifications is unknown in many cold-seep environments and our objective is to reveal compositional changes of DOM under the influence of methane input in the cold seeps. Collected DOM composition data will be also compared with the other methane-receiving water (cold-methane seepages) areas around the Svalbard archipelago.

With this study, we focussed on DOM composition and nutrient profiles along with the other biological measurements in the LoVe -Node 7. Composition of DOM was sampled with solid-phase extraction from 1 L seawater samples for high-resolution mass spectrometry (FT-ICR-MS). Additionally, dissolved methane, dissolved organic carbon (DOC), coloured-DOM, stable oxygen isotope (δ18O), dissolved inorganic nutrients (nitrate, phosphate, silicate, ammonia), dissolved inorganic carbon (DIC) and 13C-DIC and carbon isotopes 13C-DOC were sampled for the characterisation of water column around the cold seeps.

Water samples were taken from Niskin bottles mounted on CTD rosette system. Firstly, samples for methane concentration were collected. Then seawater was taken into 1 L glass bottles for filtration and subsampling. Samples were kept in +4 C cooling room if immediate filtration is not possible. Before filtration nutrients, δ18O, DIC and C13-DIC were directly sub-sampled from unfiltered water samples. Filtration was carried out by glass filtration towers on GF/F filters, and then DOC and colored dissolved organic matter (CDOM) are sampled from the filtrate water. One liter of filtrate water were 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). Shortly, styrene divinyl 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. Then, acidified seawater samples were 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 -20C freezer until analysis date.

5.3 ROV (Remoted operated vehicle) Ægir6000

The ROV Ægir6000 is a work-class ROV 150 Hp equipped with samplers and sensors. It is sufficiently powered to operate seafloor drilling systems and to install and maintain seafloor observatories. It is deployed together with a 750 m+ tether management system (TMS) and is equipped with 7 cameras. Its manipulators consist of pincers able to grab targeted samples once on the seafloor, but also collect sediment samples and perform other operations. Samples are stored in the bio drawer (bio-box), until the ROV is back on the ship. ROV Ægir 6000 is equipped with coring devices, gas and water samplers, oceanographic and geochemical sensors as well as a multibeam system, in order to image the seafloor on a more precise scale (Figure 4).

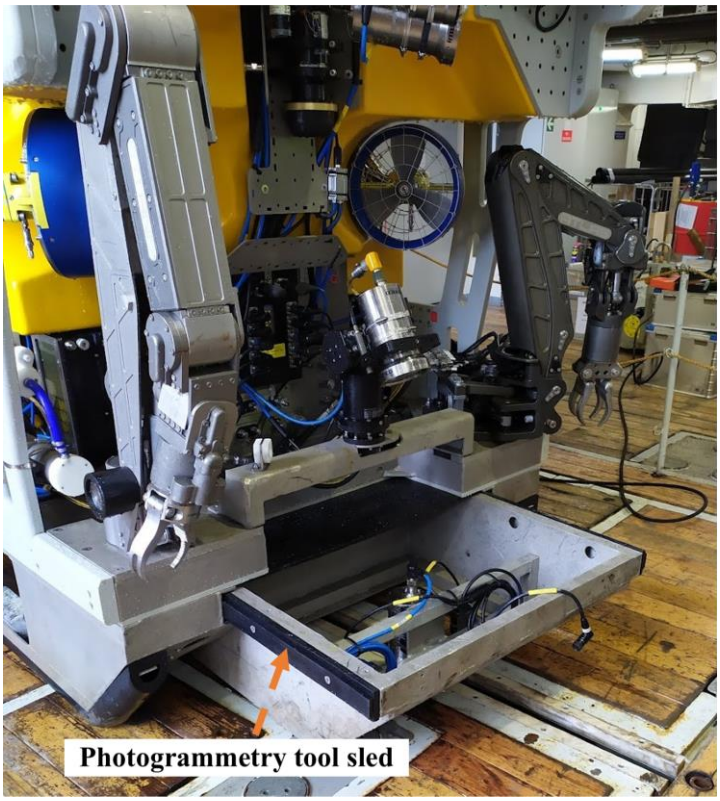

Figure 4. ÆGIR6000 photogrammetry settings

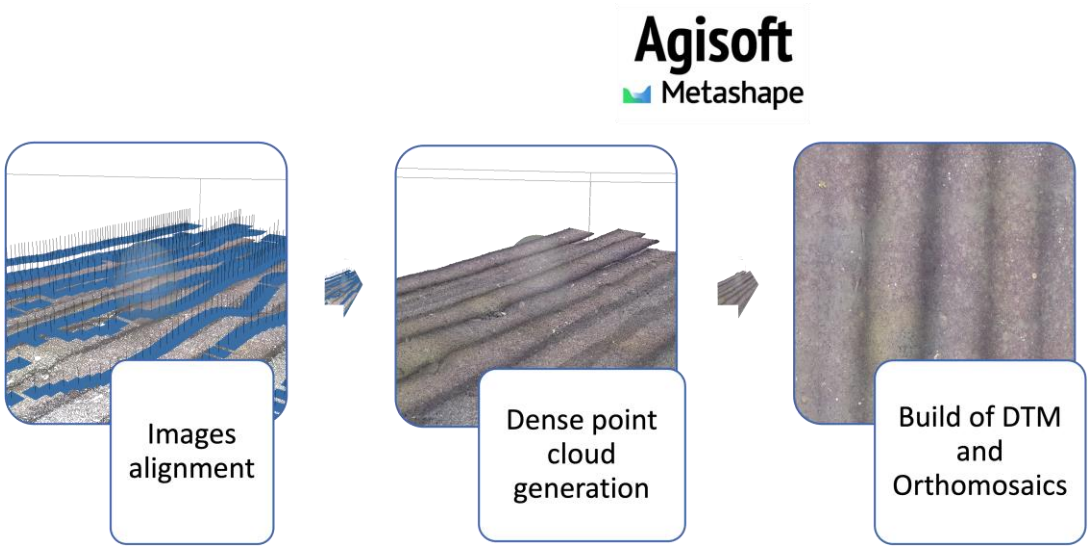

Figure 5. Structure from Motions (SfMs) processing workflow

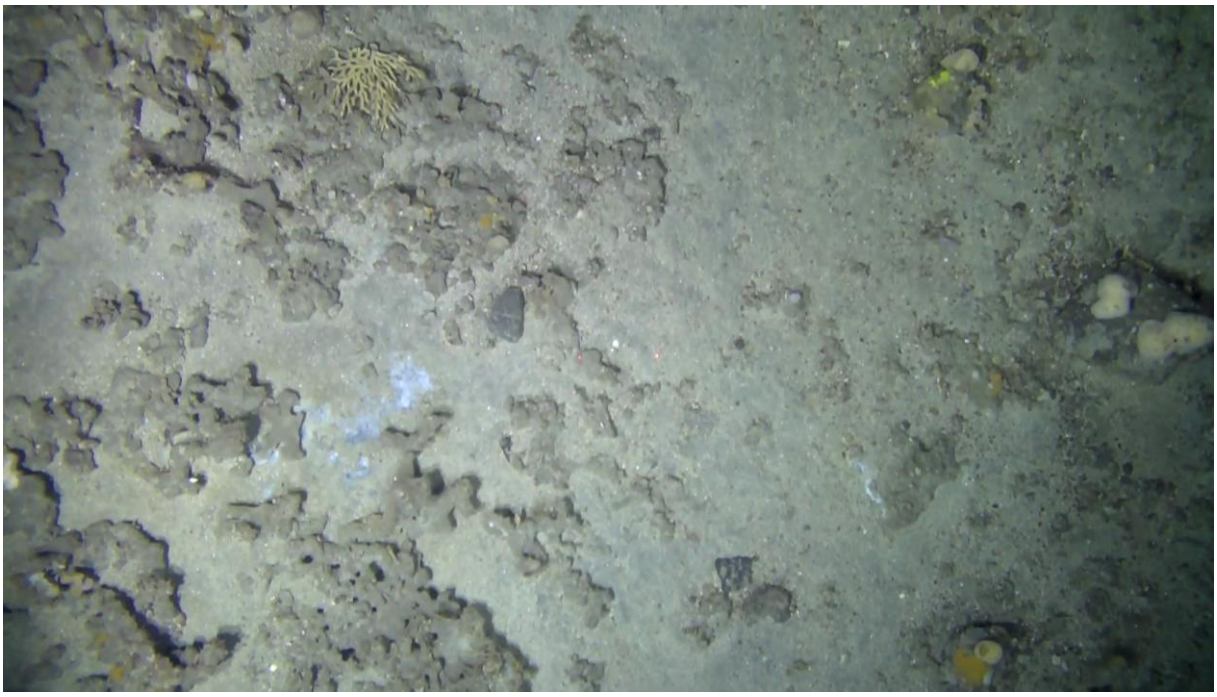

Figure 6. Video frame from ROV HD video. The two laser points are 15cm in the distance from each other.

The photomosaic was performed during the following dives:

DIVE02
During Dive02 3 subareas (Area01, Area02 and Area03) closed to Node 7 were mapped. The seafloor was surveyed through a downward looking camera to obtain suitable images to implement photomosaic and Structure from Motion (SfM) techniques. Videos were acquired at a constant speed of 0.3 kn and altitude of 2.5 meters, along parallel transects, 2 m spaced in order to obtain a field of view slightly larger than 2.
Survey on Area01 was performed along 5 parallel lines, 60 meters long, covering an area of 600m^2
Survey on Area02 was performed along 6 parallel lines, 40 meters long, covering an area of 400m^2.
Survey on Area03 was performed along 4 parallel lines, 40 meters long, covering an area of 320m^2.

DIVE07
During Dive07 a portion of a corals mount was mapped (Area04). The mount was surveyed through a downward looking camera to obtain suitable images to implement photomosaic and Structure from Motion (SfM) techniques. Videos were acquired at a constant speed of 0.3 kn and altitude of 3.5m meters, along parallel transects, 2 m spaced in order to obtain a field of view slightly larger than 2. The complexity of the mount, covered with big coral colonies, has made straight line acquisition difficult. The survey on this Area04 was perform along 11 parallel lines, 3 of those 60 meters long while others 8 35 meters long, covering a total area of 540m^2

DIVE14
During Dive 14 an area (Area05) with carbonatic crust and bacterial mats was mapped. The seafloor was surveyed through a downward looking camera to obtain suitable images to implement photomosaic and Structure from Motion (SfM) techniques. Videos were acquired at a constant speed of 0.3 kn and altitude of 2.5 meters, along parallel transects, 2 m spaced in order to obtain a field of view slightly larger than 2. Survey on Area05 was performed along 7 parallel lines, 30 meters long, covering an area of 300m^2.

5.4 ROV coral collections, onboard incubations and transplantations

Coral collections. Three ROV dives were allocated to coral collections (5, 9 and 13). The three dives were performed in three different areas; the coral mound area at node 7, the coral mound north west of node 1 and at a coral mound north of node 7 and node 1. All collection sites were separated by an equal distance from each other.

From all sites 7 different coral colonies were collected for onboard incubations, biochemical analysis and for transplantation experiments. In addition, 5 separate coral colonies were collected for microbial analysis. Corals were collected using the ROV manipulator arm by carefully gripping small coral colonies (40-10 cm in maximum diameter) at the basis of the colony and gently transferring them to the bio-box of the ROV (for the 7 larger colonies) or to separate sealable cores (for the 5 colonies uses for microbial analysis).

Onboard incubations. Once on deck coral colonies were transferred from the bio-box of the ROV to smaller holding tanks, kept in an 8 ^{o}C climate room, for fragmentation. Incubations were performed in the lab, in another 300 liters holding tank filled with deep water collected from 2 m above the seabed at each of the collection site using the Niskin bottles of the CTD and kept at constant temperature using a water cooler (AquaMedic Titan 1500). For the onboard incubations one fragment of approximately 7-10 cm in length and with >25 polyps were prepared from all the 7 different coral individuals collected. Each coral fragment was put in 1000 ml cylindrical polycarbonate respiration chamber fitted with a submersible micropump operating at 100 ml/min to ensure non-static conditions. The chambers were kept submerged in the holding tanks to achieve constant temperature and were set to flushing mode until the majority of the polyps had their tentacles extended. This acclimation period lasted 5 to 12 hours. After this, the chambers were sealed and the experiment commenced by shifting the pump from flushing to recirculation mode.

In all, the experimental tank contained eight chambers: one for each of the 7 coral fragments and an empty one, used as a sea-water control. In all 8 chambers oxygen concentration in the sea-water was measured and monitored continuously using optical probes (PreSense OXY-4 ST). Each incubation lasted until 80-70% oxygen saturation had been reached, roughly 4 to 8 hours depending on coral size and level of activity. Before and after each incubation water samples were collected from each chamber and for analysis of ammonium and nutrients. Furthermore, pH was measured using a pH and

salinity probes (Hach-Lange Ltd). Thereafter the volume of water in each chamber was measured and the coral fragments were put in a drying oven. Corals were kept at dark during the incubation period except for the short time required for water sampling, sealing the chambers for starting the incubations.

Dry weight will be determined later in the laboratory on land after coral fragments have been dried at 65^{o}C for 14 days (in total) to measured dry weight. Thereafter corals will be combusted at 480 ^{o}C for 5 h to measure the ash free dry weight. These values will be used to standardize oxygen consumption rates and nitrogen metabolism.

Sample collections. From all 21 (7 x 3) large coral fragments coral polyps were collected to fill up a 50 ml falcon tube. These samples were transferred immediately to the -80 ^{o}C freezer onboard. Later in the laboratory these samples will be analysed to determine Cellular Energy Allocation (CEA) as well as the content of lipids, carbohydrates and proteins in the fragments. The 15 (5 x 3) coral samples for microbiological analysis were collected as quickly as possible from the individual collection tubes, transferred to 50 ml falcon tubes and stored at -80 ^{o}C until extraction and further analysis in the laboratory. To prevent cross contamination a new set of fragmentation tools were used for each coral individual.

Transplantation experiment. The transplantation work included moving coral fragments from Node 7 to Node 1 and coral from Node 1 to Node 7 to examine the capacity of the coral to acclimate to different environmental conditions. In all 12 transplantation units were prepared. At Node 7, six transplantation units were deployed. Three of the units had coral fragments originating from Node 1 and three on the units had coral fragments originating from Node 7 (serving as transplant controls). At Node 1 six transplantation units were deployed. Three of the units had coral fragments originating from Node 7 and three on the units had coral fragments originating from Node 1 (serving as transplant controls). Fragments for 12 transplantation units were prepared by cutting fragment of suitable sizes (20-30 polyps) from the 7 *L. pertusa* colonies collected from each site. For each site the transplantation units were prepared just before deployment by attaching 15 coral fragments to three different granite tiles with a metal rod in the centre for the ROV manipulator arm to grip. On each of the site a separate transplantation unit, holding a pH and temperature sensor (AquapHOx Logger Gen 1, Pyro Sience GmbH), was deployed in the immediate vicinity of the coral transplantation units (Figure 7). Transplantation units will be left on the sea-bed for one year after which they will be recollected to run on-board incubations, examine linear growth, biochemistry and microbiology in a similar manner as what will be done for the samples collected on this cruise. A third pH sensor was deployed at the third coral collection site, preliminarily named node X.

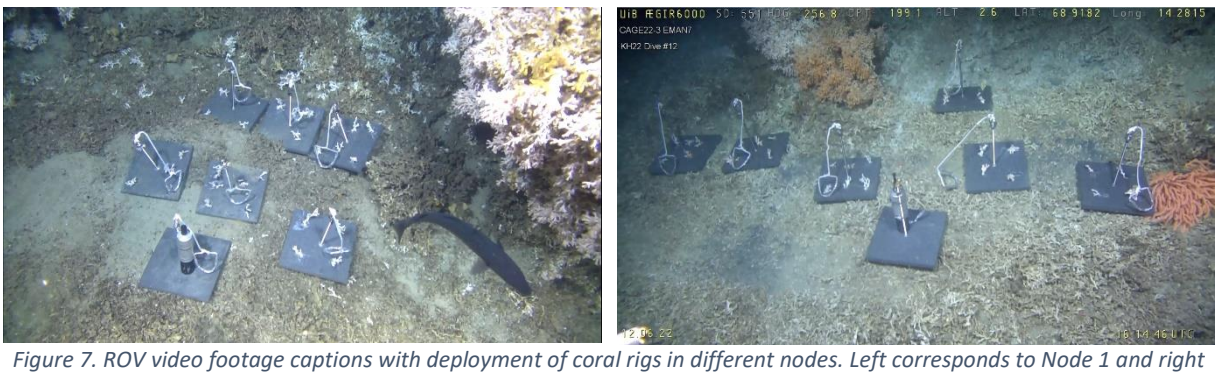

Figure 7. ROV video footage captions with deployment of coral rigs in different nodes. Left corresponds to Node 1 and right image corresponse to Node 7.

5.5 Sediment and pore fluid sampling

5.5.1 Micropaleontology

Sediments for micropaleontological investigations were collected from Node 7 and Node X using either the ROV-guided push cores (Ø 8 cm) or the blade cores (32 x 25 x 10 cm) deployed with the ROV Ægir6000 (see Appendix 4). The coring targeted micro-habitats were bacterial mats, sediments in the vicinity of the seep, and background area unaffected by methane flaring or without visible bacterial mats. The sampling of the seafloor appeared to be very difficult due to the very coarse sediment in the area, often covered by coral rubbles. This sampling aimed to investigate the infauna biodiversity of the studied micro-habitats in this area namely from the >32 µm fraction of the sediments. Additionally, surface sediment samples were also collected for subsequent molecular analyses of foraminifera (ID-Gene, Switzerland). The protocol for sampling sediment eDNA for benthic monitoring according to ID-Gene ecodiagnostics, Campus Biotech, 15, av de Sécheron, 1202 Geneva, Switzerland was used to determine the biodiversity of foraminifera. Surface sediment was sampled using a sterilized spoon kept in a sterilized plastic bag, fixed with Life Guard TM (QIAGEN, ref. 12868-1000) solution for preserving eDNA, and stored at 5°C.

Once on-bard, push cores and blade cores were first dedicated to pore-water extraction. When this was completed, each liner or blade was sliced into 5 sediment depth layers (0-1cm, 1-2cm, 2-3cm, 3-4cm, 4-5cm) and fixed in an ethanol/Rose Bengal solution for the staining of living foraminifera and following morphological analyses. The blade and push cores where then sliced every cm to the bottom and the samples will be dedicated to micropaleontological investigation, stable isotope geochemistry of foraminifera shells, and various parameters for sediment geochemistry.

Blade Coring

The Blade corer is a sediment sampler operated by the ROV, consisting of a 32 cm-long frame with a rectangular base of 25 x 10 cm (Figure 8, left). The Blade corer has a locking system to avoid sample loss upon retrieval. The system consists of two lateral springs acting on two blades at the bottom of the frame and activated by the ROV during samplings. The blade corers are pre-drilled every 2 cm to facilitate the pore water extraction after samplings.

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

Push Coring

The push core is a 60 cm-long cylindrical tube (8 cm inner diameter) made of fiber glass (Figure 8, right) which is pushed into the sediment by the ROV during samplings. Push cores are pre-drilled for pore water sampling with a resolution 2 cm. The push cores are placed in the hull of the ROV during the entire dive, while the blade core container is held by one of the ROV arm during descent and ascent.

5.5.2 Gravity Coring

The gravity corer consists of a 6 m long iron barrel with iron weights attached on top of it (Figure 9). The whole apparatus weighs ~ 2 tons. The gravity corer has an inner diameter of 11 cm. Prior to the coring operation, a plastic liner is inserted into the steel barrel and a core catcher and a core cutter are attached to the lower end of the gravity corer. Core catcher keeps the sediments from falling out of the core, whereas core cutter helps the penetration of the core into the sediments. Back on deck, the core liner is extracted from the barrel and cut into 1 m sections and taken to the wet lab for pore water sampling.

Figure 9. Gravity corer deployment from RV Kronprins Haakon.

5.5.3 Pore water and gas in the sediment

We extracted pore water samples from push cores, blade cores and gravity cores upon retrieval using 5 cm long pre-wetted rhizons (0.15 µm mesh) and 12 mL syringes (Figure 10, left). The pore water samples were split in two aliquots: 1) 1.5 mL subsamples were transferred into screw cap glass vials for dissolved inorganic carbon (DIC) analysis. We added 10 µL of mercuric chloride ($HgCl_2$) and stored DIC samples at 4 °C. 2) >1 mL was transferred into Eppendorf tubes and stored at -20 °C for sulfate analysis and pH. The pore water sampling was conducted in cold storage (4 °C). Bulk sediment samples (5 mL) were extracted from the bottom of push cores, and at 5-10 cm in blade cores using a cut-off syringe. The samples were transferred into glass vials prepared with 5 mL of NaOH (1 M) to stop microbial activity, plugged with a rubber septum (Figure 10, right), sealed with aluminum crimp caps and shaken, then stored upside-down at 4 °C.

Figure 10. Pore water and gas samplings.

5.6 Microbiology

DNA sequencing is a molecular tool to investigate the living organisms in a habitat or environment. It serves as a proxy for organismic abundance and genetic potential of the (micro)biota in situ. A specific region of the small ribosomal subunit gene (the SSU rRNA gene) is highly conserved in all living organisms. For the prokaryotic fraction (bacteria and archaea) of the tree of life it is the so called 16S region, which is conserved enough that an amplification of the gene with specific primers and subsequent sequencing of that fragment provides precise information on the taxonomic origin, potentially all the way down to species level. With this method, specific organisms can be detected and a microbial community profile can be created, using relative abundances to compare the presence of different taxa in relation to the whole microbiome. In addition, fragments of all genomes of all sampled organisms (the metagenome) in a habitat can be sequenced, i.e. the so called metagenomic shotgun sequencing. The resulting information can be used to detect specific genes in a given habitat in order to estimate the genetic potential and capacities of the microbiome.

5.6.1 Sample Collection

We collected seawater at 5 depths from two locations – one methane seep and one control site. The samples recovered from the CTD rosette are placed in presterilized carboys by attaching sterilized tubing with 200 µm mesh filter to the Niskin outlet port. Before connecting tubing, we flushed approximately 0.5 liters of seawater through the outlet port. The collected seawater samples are then stored at 4° C until filtering.

5.6.2 Filtration

The filtration technique goes as follows: we remove the cotton barrier from 25 ml serological pipette with sterile forceps and attach sterile 25 gauge peristaltic tubing. Then we insert a pipette into the sample carboy and lower the lid to limit the airflow. We start the pump and fill 3 x 50ml tubes, preloaded with 5 ml 37% formaldehyde, for a total of 50 ml. Further we attach a 0.2 µm Sterivex filter to the tubing and begin filtering seawater, then collect filtrate in sterilized container with volume graduations. The fixed samples are stored at 4° C for enumeration. Finally, we pass 2 liters of seawater through each filter, or as much as possible before the filter clogs and make a note of the volume filtered for each sample. The excess seawater is expelled from the filter using a 60 ml syringe with syringe filter, and the labeled filter is frozen at -80° C.

5.6.3 Sediment Samples

Sediment samples were taken from push core layers in 1 cm intervals to a depth of 10 cm. Three replicates per layer were scooped into sterile falcon tubes. Remainders of each layer were transferred into plastic bags. Additional samples were taken from bacterial mats from two additional push cores and a blade core. Samples were stored at -20 °C.

5.7 Sediment temperature

A temperature logger probe was placed to monitor variability of the temperature in the sediments. During ROV dive #3 a low-temperature probe (loT024, sn:2319683, WHOI MISO low-temperature) was deployed. The probe consists of an 11.4 cm long cylindrical body, with an inner diameter of 2.5 cm, and a 12.7 cm long rod. It was deployed in the sediments close to a methane seep, at 68.9181°N,14.2847°E, 09.06.22, 19:26 local time (Figure 11). The sediment temperature was sampled every 20 seconds. The probe was deployed for 4.5 days (109 hours) and recovered at 8:31 local time on 14.06.22. The probe was in good condition. After some cleaning and drying of the probe, the data was retrieved. Time-correction and other processing will be performed on land. However, the data presented a drift and some tests were needed prior a new deployment could be considered.

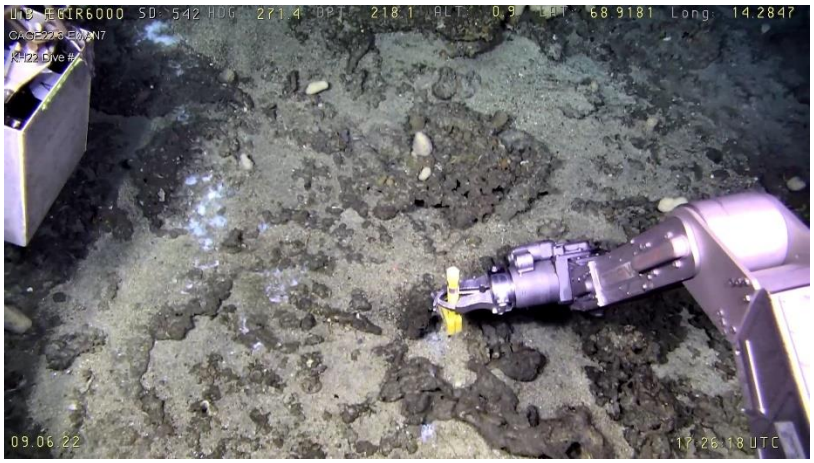

Figure 11. The temperature logger is deployed in sediments close to methane seeping from the sediments.

5.8 Sub-seafloor pore pressure

The objective was to deploy two piezometers in order to monitor the pore pressure within the sediment near the seeps. Ultimately, the data will be analyzed and used to constrain the subseafloor permeability and associated fluxes. The proposed piezometer concept has been developed and improved by NGI and tested and operated by UiB and UiT; provided technical information to be used only in conjunction with this experiment for the LoVe/EMAN7 projects.

Standpipe installation rig **-** The piezometer installation rig was used for installing the piezometer's standpipes. The rig allows for guided penetration of OD 45mm pipes using a 2.2T deadweight. ROV support is needed to unlock the deadweight after the rig has landed on the seabed and to re-lock the deadweight after completed standpipe penetration. The lifting/crane wire is connected to the dead weight during operations and used to lift the complete rig. Rig dimensions: overall height ~6.3m, triangular footprint with 4 m sides, lifting weight 4T (dry) and 3.5T (wet), the legs can be disabled for transports. The rig is outfitted with a subsea bullseye for inclination checks after landing on the seabed.

Piezometer standpipe **-** The 3m long piezometer standpipe consists in a filter tip (50 micron sintered), 45mm OD steel pipe and hydraulic receptacle on top. During handling and installation, the hydraulic receptacle is protected by a dummy plug. The top part of the steel pipe is outfitted with anodes to minimize corrosion on vital parts.

Sensor/logger head **-** The sensor/logger head contains two total pressure sensors, data logger and battery for standalone operation of the piezometer. It is docked by ROV to the hydraulic receptacle on the installed standpipe after recovery of the installation rig. The receptacle is protected by a dummy plug with vents and deployment of the sensor/ logger head can be done in a later campaign after installation of the standpipes. The dimensions of the sensor/logger head are ~L: 700 mm and OD: 150mm, the weight in water is <15 kg.

Locations for deployed piezometers (standpipes and loggers), fixe points from ROV:

Piezometer	Latitude	Longitude
L01	68° 55' 04.29734'' N	14° 17' 09.6209'' E
L02	68° 55' 04.82745' N	14° 17' 07.75718'' E

L01 – Standpipe deployment

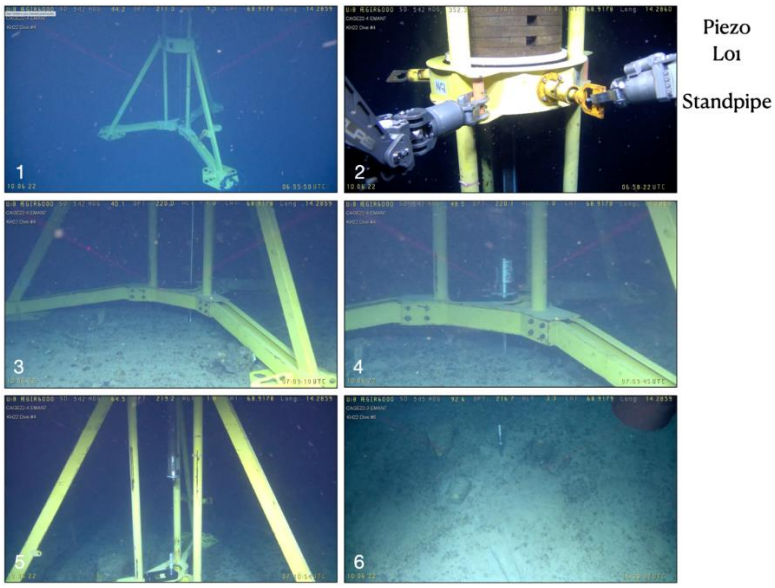

Figure 12. Deployment of the piezometer L01 standpipe using a rig. Dive #4, 10/06/22, 07am. 1: rig is being lowered down from the boat; 2: weight is being released by the ROV; 3: standpipe starts penetrating the seabed; 4: standpipe is fully in the seabed; 5: the standpipe is released from the rig; 6: standpipe is deployed.

L01 – Logger 1st deployment (Failed)

Long-term deployment (511 days)
Time set to UTC
Sampling interval = 30 min

Note: Failed as the logger couldn't be deployed on the standpipe (too much friction), we also broke the handle, hence we aborted and recovered the logger for refurbishing and reconditioning.

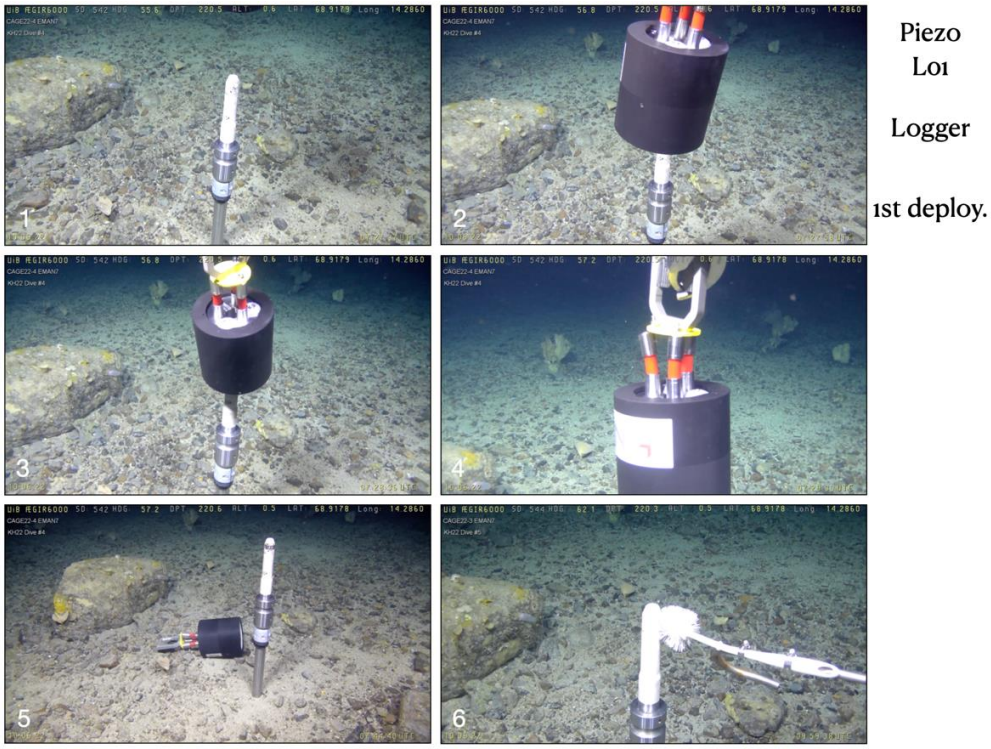

Figure 13. Deployment of the piezometer L01 Logger using the ROV (1st deployment). Dive #4, 10/06/22, 0730am. 1: view on the deployed standpipe; 2: logger positioned on the standpipe; 3: we try to deploy and push the logger on the standpipe but there is resistance/friction; 4: the handle starts to break; 5: logger falls, and deployment fails; 6: the standpipe is being cleaned to remove particles responsible for the friction.

L01 – Logger 2nd deployment

Short-term deployment (3.5 days)
Time set to UTC
Sampling interval = 20 sec

Note: all went well, logger was deployed for a short-term period.

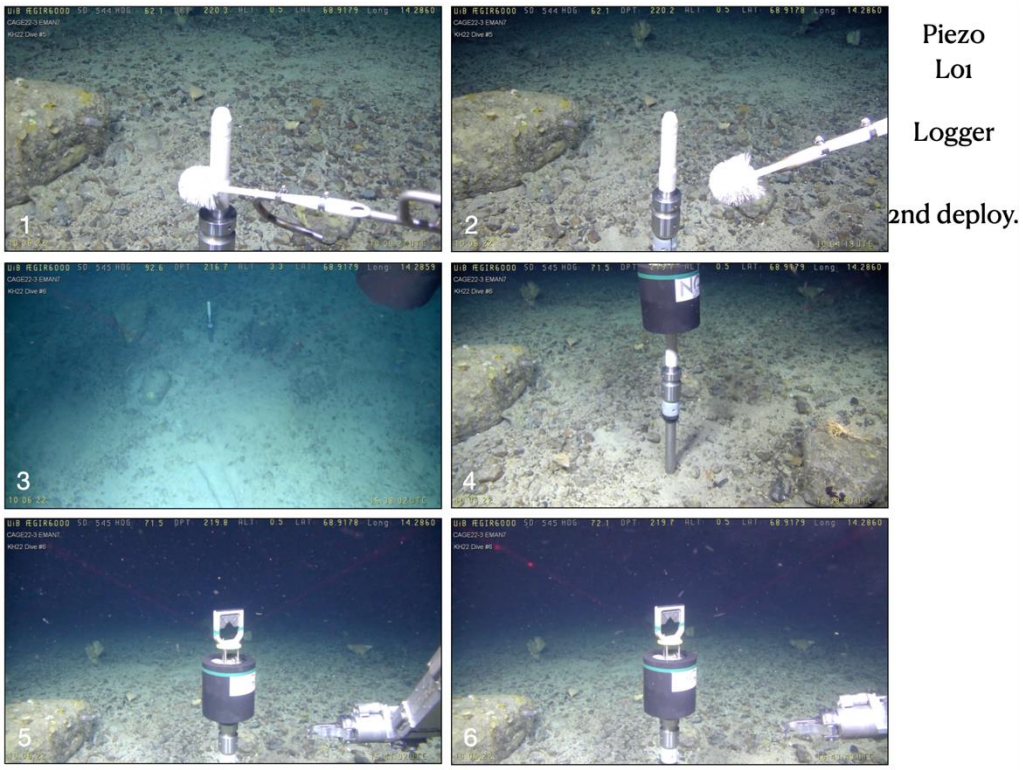

Figure 14. Deployment of the piezometer L01 Logger using the ROV (2nd deployment). Dive #6, 10/06/22, 1630am. 1: standpipe is being cleaned to avoid friction with the logger; 2: cleaned standpipe; 3: view on the deployed standpipe; 4: logger positioned on the standpipe; 5: logger is deployed, and piezometer is complete; 6: logger is deployed, and piezometer is complete.

The logger was recovered on Dive #16, 14/06/22 @ 06:37am UTC.

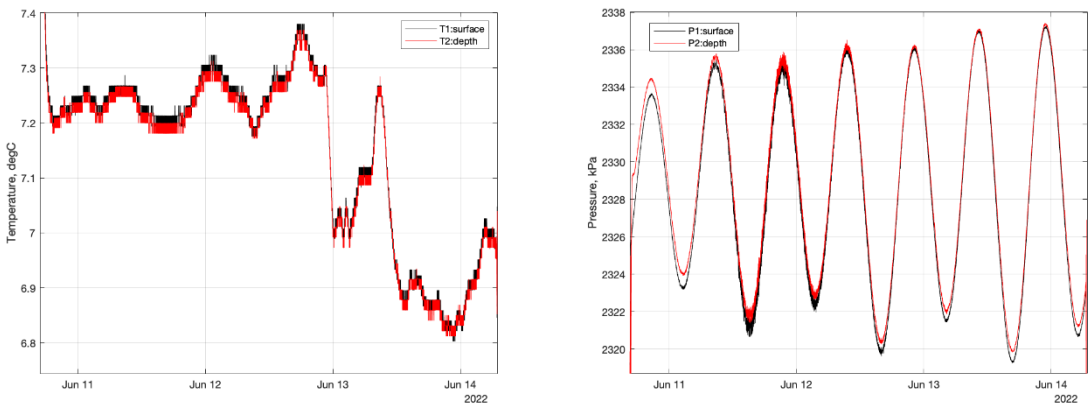

Figure 15. Preliminary L01 (2nd deploy.) piezometer data: temperature (left) and pressure (right).

L01 – Logger 3rd deployment

Long-term deployment (340 days)
Time set to UTC
Sampling interval = 20 min

Note: all went well, logger was deployed for a Long-term period.

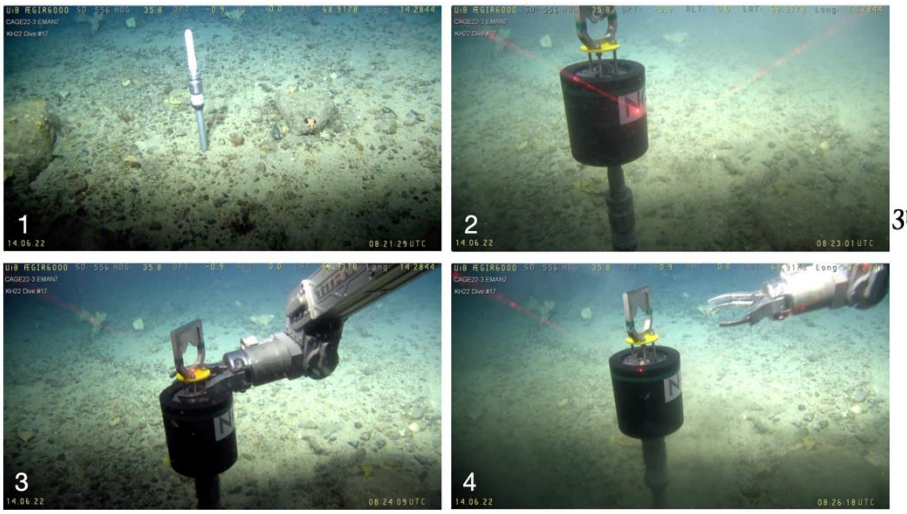

Figure 16. Deployment of the piezometer L01 Logger using the ROV (3rd deployment). Dive #17, 14/06/22, 0826am. 1: standpipe; 2: logger positioned on the standpipe; 3: pushing on the logger; 4: logger is deployed, and piezometer is complete.

L02 – Standpipe deployment

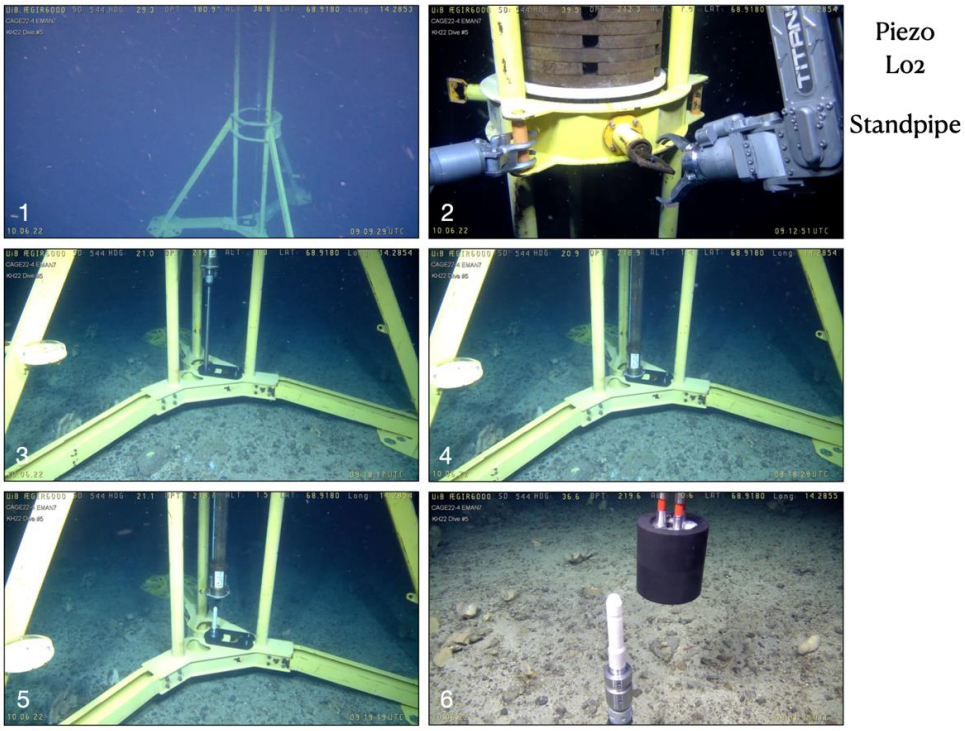

Figure 17.Deployment of the piezometer L02 standpipe using a rig. Dive #5, 10/06/22, 09am. 1: rig is being lowered down from the boat; 2: weight is being released by the ROV; 3: standpipe starts penetrating the seabed; 4: standpipe is fully in the seabed; 5: the standpipe is released from the rig; 6: standpipe is deployed.

L02 – Logger 1st deployment

Long-term deployment (511 days)
Time set to UTC
Sampling interval = 30 min

Note: all went well, both standpipe and logger were deployed for a long-term period.

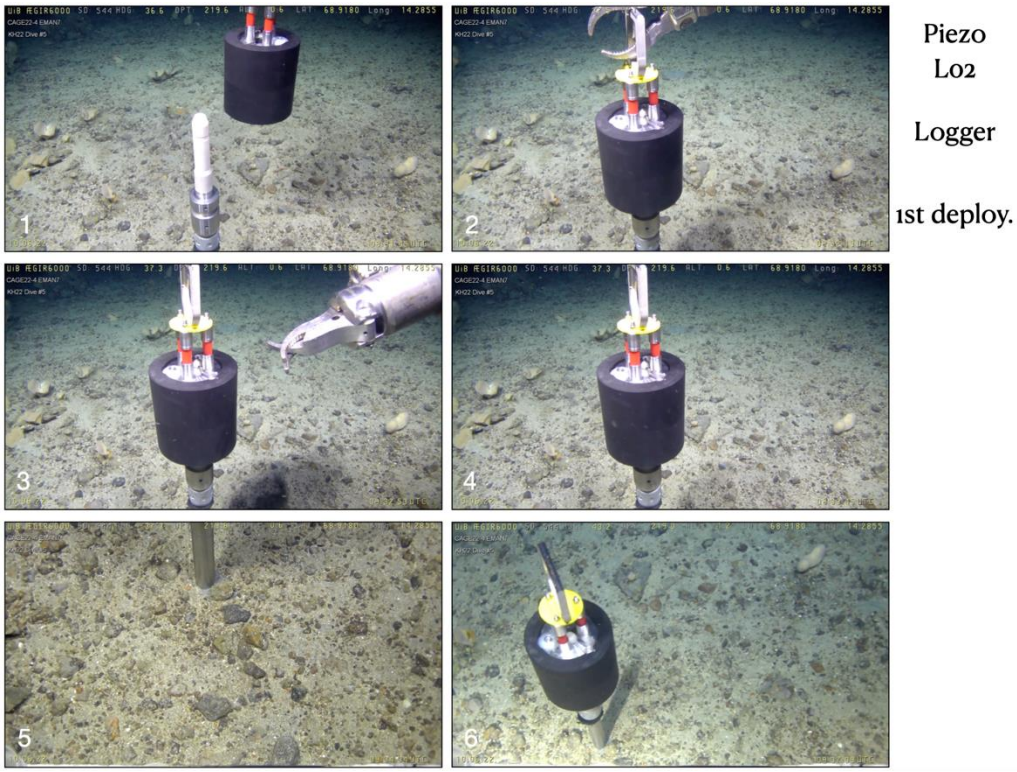

Figure 18. Deployment of the piezometer L02 Logger using the ROV. Dive #5, 10/06/22, 0930am. 1: standpipe and logger in the ROV arm; 2: logger positioned on the standpipe; 3: logger pushed all the way down on the standpipe; 4: logger pushed all the way down on the standpipe; 5: base of the piezometer where bubbles were spotted; 6: logger is deployed, and piezometer is complete.

5.9 Checkerboard experiment

Knowing bubble size distributions and rising speeds at seep sites is necessary for flow rate quantification. To estimate these sizes and rising speeds, a checkerboard with 3 x 3 cm squares was placed behind several bubble streams as a size reference, and distances between the bubble release source and checkerboard position were measured along the seafloor (Figure 19). By knowing distances between the ROV camera, the bubble stream and the checkerboard, bubble sizes and rising speeds can be estimated based on Thales' theorem using image correction in post-processing steps.

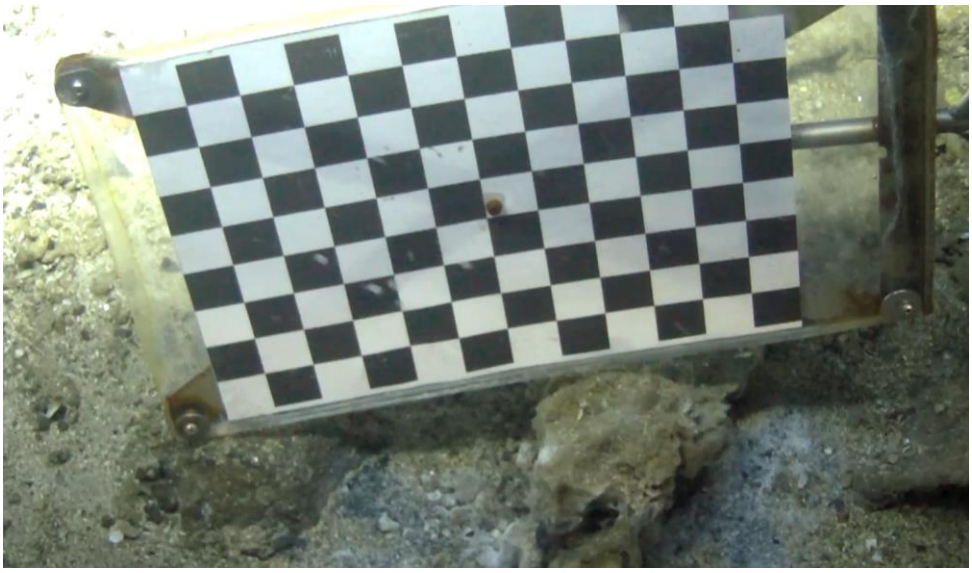

Figure 19. Checkerboard deployment during ROV dive 17.

5.10 IMMERSIVE outreach film

As an extension of a Momentum (UiB) funded outreach project for Thibaut Barreyre on Hydrothermalism, I was able to join the EMAN7 cruise to continue recording footage to complete the film. It proved useful to show a sequence of the film to its first audience and the feedback received has assisted the direction in the final stages. In addition to this, I was able to contribute to the EMAN7 project by being present with a microphone and camera to record the research being conducted onboard.

5.11 Hydrologic Sensibilities in Fragile Ecologies

The history of scientific mapping and the potential of developing new aesthetic approaches to environmental research and experience

Art historian Michael Kjær participated on the EMAN7 cruise together with artist Rhoda Ting and Mikkel Dahlin Bojesen. The purpose was twofold.

1: The participation in the EMAN7 cruise was an integral part of the postdoc project 'Hydrologic Sensibilities in Fragile Ecologies' (Michael Kjær, 2021-2023). The project is placed in an intersecting field of art and the natural sciences. The overall aim of this project is to explore the possibilities for developing new environmental sensibilities with a special focus on the hydrosphere. The aim of participating in the cruise was to get a better understanding of the methods and knowledge systems of contemporary marine sciences with a special focus on environmental issues. Of particular interest was the application of sensitive ways of collecting and treating data on and in relation to the cruise. In a world of acute climate change, man's relationship to the three-quarters of the globe covered by water is of vital importance. The historic as well as present development of an *aquatic sensibility* in the twentieth century is important and of urgency in this context: a sensibility that can be traced in the marine sciences as well as in the history of art. Common to these fields is that they both consider the hydrosphere as the best indicator of the climatic and ecologic state of the earth. With this line of thinking, the agency to represent the state of the earth is no longer that of man; man becomes a sensitive translator of the indications given by the matter of the earth. In this dynamic between indication, sensation and translation, the development of new hydrologic sensibilities is crucial.

Michael Kjærs research project therefore aims 1) to contribute to the writing of an art history of this hydrologic sensibility, and 2) to work with marine geophysicists and artists to understand the contemporary potential of a hydrologic sensibility.

Michael Kjær observed and helped out with the scientific work carried out during the cruise. He gave a presentation of his research and findings at the last day of the cruise. He will, after the cruise is finished, work on a peer-reviewed article to be published in an internationally ranked journal.

2: Rhoda Ting and Mikkel Dahlin Bojesen participated in the cruise in close collaboration with Michael Kjær. The aim of RT and MDBs participation in the cruise was to get a better understanding of the possibilities for developing new imaginaries for a future better suited to care for and understand the non-human environments, that we live in and are dependent on. During the cruise RT and MDB collected sediment with a gravity core with the helpful assistance from Guiliana Panieri and Claudio Argentino, collected plancton with a plancton net with the assistance from Bénédicte Ferré and received data from hydrophonic recordings as well as bathymetric images. They presented a video work in process at the last day of the cruise. The work consisted of microscopic images and footage of the samples collected with the plancton net and the gravity core. In collaboration with Michael Kjær they will present an insight into their work derived from the cruise at CAGE International Conference 'Methane in a Changing Arctic' (Tromsø 14-16th September).

6 ROV ÆGIR6000 DIVES

7 CRUISE NARRATIVE

The times specified here are in local time. ROV dive numbers are referred to with #.

June 8th 2022

The rig for the piezometer needed to be assembled before putting on deck. After a safety briefing at 10:00, we could leave Myre. We arrive at the first CTD station at 14:05. The 10 stations were finished by midnight.

June 9th 2022

8.00: preparation of the ROV, need for calibration of the navigation system (HiPAP). The ROV places the beacon on the seafloor (dive #1), but its signal is jumping so the ROV must go back down to check if it has tipped over due to strong currents. After the test (dive #2), the surveyor is satisfied and we will not need further calibration. The multibeam survey for microbathymetry (dive #3) starts at 10:25. Visual inspection prior photomosaic around node 7. ROV on deck at 16:15 for dismounting the MB and cameras.

June 10th 2022

Night activities: GC for reference, but after 6 attempts no sediment was recovered. We finish the night with MB survey.

Early morning: two CTDs to fill tanks where corals will be placed.

8.00: preparation of the ROV for rig/piezometer deployment. The ROV is deployed (dive #4) and the rig is lowered. The ROV disconnects the weights of the rig and the piezometer penetrates the sediment. The ROV has to install the datalogger, but something seems to be blocking it. The screws holding the datalogger eventually broke. We clean it when the ROV is recovered, we recover the rig

for a second piezometer deployment, and the second datalogger is installed successfully during dive #5. At 12:10 we change location for coral sampling. End of operations at 20:00 and we head to Myre to drop off the NGI engineer (Axel Walta) who was helping us with the rig.

June 11th 2022

Night activities: Gravity core on the north of the Barchan sandwaves for reference. Good recovery (4.7m). We continue the night by followed the multibeam survey, and head to node 1 early morning where we first perform three CTD for reference for geochemistry and microbiology.

8.00: installation of cameras for photomosaic at node 1 followed by photomosaic on coral reef at node 1 (Dive #7). At 10:45 the ROV goes up for preparation for node 1 recovery that could not be done during leg 1 due to strong winds and high waves. The ROV is deployed at 12:30 to start the operation (Dive #8). The operation finishes successfully at 20:00, and the ROV dives back at 20:40 for coral collection at node 1 (Dive #9). The corals from node 7 are placed on their holder for transplant, and the ROV dives back to transplant them at node 1 (Dive #10).

June 12th 2022

We test the methane sensor on the CTD. The sensor needs to warm up for 45/60min prior profiling and stay at the surface for 15min. We then need to lower it to a speed of 0.5m/s. The test is successful. Follows a plankton net for the artists on board.

We start ROV operation at 8:00 (Dive #11). After looking for nice bubbles for a while, we decide to do a CTD grab where the methane sensor on the ROV indicate higher methane concentration (~40nmol/L). We do another CTD grab since 2 teams needs water and they both want sample at several depths. The ROV comes back on deck to pick up corals for further transplants at node 7 (Dive #12), push cores, blade cores and carbonate crust collection. The ROV come back on deck to move location further north and collect corals (Dive #13).

June 13th 2022

Night activities: sub-bottom profiler, repetition of MB lines where interferences were making the interpretation difficult, continuation of MB lines across the trough

8:00: CTD for collecting water for coral experiment. Meanwhile, the ROV team prepares for multibeam and photomosaicing (dive #14). The ROV comes back on deck to remove the multibeam and change the camera system (to 68.9176°N and 14.2838°E), and is redeployed at 13:53 (dive #15). We check for a better location for the camera, and chose an area covered with bacterial mats (no bubble). We fill the bubble catcher slowly from several bubbles streams made by moving carbonate crust, but the device is leaking and twice we lose most gas. We close it keeping at least the remaining 200 ml. The ROV moves the camera and comes back up (19:10) to fix the arm that doesn't close properly.

The Instrumentsjef and the captain communicate in order to calibrate the singlebeam from node 7. The operation last until 23:10. We redo one of the sub-bottom profiler because of noise, and finish the night with multibeam lines.

June 14th 2022

ROV operation starts at 8am (dive #16) to retrieve the datalogger and temperature probes deployed the first day of the cruise. The ROV immediately comes back on deck so Thibaut can download the data and deploy the instruments again for a longer recording time. The temperature probe shows

unstable data and is not redeployed. The datalogger for the piezometer is redeployed as planned (dive #17), and our CONTROS methane sensor is installed on the ROV. This will provide a comparison between the Franatech sensor mounted on the ROV and the data collected at node 7.

We stay in the node 7 area, and focus on bacterial mats to find bubbles. We do not want to touch the seafloor to prevent from influencing the size of the bubbles, so it is difficult to find them. Eventually we find two nice bubbles stream showing very small bubbles, so we deploy the checkerboard.

The operations end at 16:00 to give enough time for the ROV team to dismount all equipment, and we head to Tromsø.

8 ACKNOWLEDGEMENTS

9 REFERENCE

Bøe, R., Bellec, V. K., Dolan, M. F. J., Buhl-Mortensen, P., Buhl-Mortensen, P, Slagstad, D., Rise, L. "Giant sandwaves in the Hola glacial trough off Vesterålen, North Norway", Marine Geology 267:1, 36–54 (2009)

Chand, S., et al., Active Venting System Offshore Northern Norway. Eos, Trans. Amer. Geophys. Union, 2008. 89(29): p. 261-262.

Crémière, A., et al., Timescales of methane seepage on the Norwegian margin following collapse of the Scandinavian Ice Sheet. Nat. Comm., 2016. 7: p. 11509.

Dittmar, T., Koch, B., Hertkorn, N., and Kattner, G. 2008. "A Simple and Efficient Method for the Solid-Phase Extraction of Dissolved Organic Matter (SPE-DOM) from Seawater." Limnol. Oceanogr. Methods 6(6):230–235.

Ferré et al., CAGE 18-2. LoVe site – exploration around node 7. Cruise report 2018, UIT2018

Appendix 1. ACOUSTIC SURVEYS

Multibeam

Location	Line ID	Date	Time (UTC) START	Lat. [N] Long. [E] START	Time (UTC) STOP	Lat. [N] Long. [E] STOP
Node7	CAGE22-3-KH-01_1-MB	08.06	23:36	68°54.562' 14°15.965'	00:23	68°54.643' 14°15.595'
Node7	CAGE22-3-KH-01_2-MB	09.06	00:43	68°53.220' 14°10.755'	02:14	68°58.019' 14°23.832'
Node7	CAGE22-3-KH-01_3-MB	09.06	02:21	68°57.908' 14°24.141'	03:46	68°53.120' 14°10.940'
Node7	CAGE22-3-KH-01_4-MB	09.06	03:50	68°52.989' 14°11.104'	05:15	68°57.777' 14°24.401'
Node7	CAGE22-3-KH-01_5-MB	09.06	05:21	68°57.687' 14°24.699'	06:02	68°55.022' 14°17.200'
Node7	CAGE22-3-KH-01_6-MB	09.06	22:19	68°54.997' 14°17.228'	22:59	68°52.931' 14°11.487'
Node7	CAGE22-3-KH-01_7-MB	09.06	23:06	68°52.799' 14°11.577'	00:39	68°57.562' 14°24.882'
Node7	CAGE22-3-KH-01_8-MB	10.06	00:46	68°57.458' 14°25.033'	02:20	68°52.728' 14°12.022'
Node7	CAGE22-3-KH-01_9-MB	10.06	02:24	06°85.255' 14°12.094'	03:53	68°57.345' 14°25.324'
Node7	CAGE22-3-KH-01_10-MB	10.06	03:58	68°57.297' 14°25.687'	04:29	68°55.591' 14°21.039'
Node7	CAGE22-3-KH-01_11-MB	10.06	04:38	68°56.305' 14°22.981'	04:53	68°55.521' 14°20.833'
Node7	CAGE22-3-KH-01_12-MB	10.06	23:57	68°55.829' 14°21.556'	01:06	68°52.525' 14°12.447'
Node7	CAGE22-3-KH-01_13-MB	11.06	01:12	68°52.405' 14°12.745'	02:46	68°57.183' 14°25.964'
Node7	CAGE22-3-KH-01_14-MB	12.06	04:13	68°55.659' 14°18.644'	04:35	68°54.836' 14°16.273'
Node7	CAGE22-3-KH-01_15-MB	12.06	04:13	68°55.635' 14°18.553'	04:35	68°54.836' 14°16.272'
Node7	CAGE22-3-KH-01_16-MB	12.06	04:39	68°54.808' 14°16.340'	05:00	68°55.678' 14°18.762'
Node7	CAGE22-3-KH-01_17-MB	12.06	04:40	68°54.810' 14°16.349'	05:00	68°55.678' 14°18.761'
Node7	CAGE22-3-KH-01_18-MB	13.06	01:03	68°55.917' 14°17.869'	01:22	68°54.936' 14°15.039'
Node7	CAGE22-3-KH-01_19-MB	13.06	01:34	68°54.668' 14°16.045'	01:52	68°55.630' 14°18.652'
Node7	CAGE22-3-KH-01_20-MB	13.06	02:05	68°55.365' 14°19.363'	02:23	68°54.448' 14°16.850'
Node7	CAGE22-3-KH-01_21-MB	13.06	02:39	68°55.056' 14°15.180'	02:50	68°54.464' 14°16.940'
Node7	CAGE22-3-KH-01_22-MB	13.06	03:01	68°54.789' 14°17.866'	03:12	68°55.382' 14°16.260'
Node7	CAGE22-3-KH-01_23-MB	13.06	03:23	68°55.802' 14°17.280'	03:35	68°55.200' 14°18.946'
Node7	CAGE22-3-KH-01_24-MB	13.06	04:12	68°53.141' 14°10.542'	05:45	68°58.015' 14°23.817'
Node7	CAGE22-3-KH-01_25-MB	13.06	21:37	68°55.373' 14°16.168'	21:48	68°54.796' 14°17.819'
Node7	CAGE22-3-KH-01_26-MB	13.06	22:23	68°55.412' 14°16.382'	22:35	68°54.798' 14°18.095'
Node7	CAGE22-3-KH-01_27-MB	14.06	00:08	68°57.939' 14°24.067'	01:45	68°53.109' 14°10.914'
Node7	CAGE22-3-KH-01_28-MB	14.06	01:56	68°52.985' 14°11.033'	03:40	68°57.776' 14°24.364'
Node7	CAGE22-3-KH-01_29-MB	14.06	03:48	68°57.690' 14°24.702'	05:28	68°52.936' 14°11.498'

Sub-bottom profiler

Location	Line ID	Date	Time (UTC) START	Lat. [N] Long. [E] START	Time (UTC) STOP	Lat. [N] Long. [E] STOP
Node7	CAGE22-3-KH-01_7-CHIRP	13.06	01:22:40.7	68°55.916' 14°17.869'	01:22:40.7	68°54.935' 14°15.038'
Node7	CAGE22-3-KH-01_8-CHIRP	13.06	01:52:38.6	68°54.667' 14°16.045'	01:52:38.6	68°55.630' 14°18.651'
Node7	CAGE22-3-KH-01_9-CHIRP	13.06	02:23:16.9	68°55.364' 14°19.363'	02:23:16.9	68°54.448' 14°16.850'
Node7	CAGE22-3-KH-01_10-CHIRP	13.06	02:50:08.4	68°55.055' 14°15.180'	02:50:08.4	68°54.464' 14°16.939'
Node7	CAGE22-3-KH-01_11-CHIRP	13.06	03:12:57.9	68°54.788' 14°17.865'	03:12:57.9	68°55.382' 14°16.261'
Node7	CAGE22-3-KH-01_12-CHIRP	13.06	03:35:56.0	68°55.801' 14°17.279'	03:35:56.0	68°55.199' 14°18.946'
Node7	CAGE22-3-KH-01_13-CHIRP	13.06	21:48:59.3	68°55.373' 14°16.168'	21:48:59.3	68°54.796' 14°17.819'
Node7	CAGE22-3-KH-01_14-CHIRP	13.06	22:35:06.5	68°55.411' 14°16.382'	22:35:06.5	68°54.798' 14°18.095'

Appendix 2. GRAVITY CORES

Location	Station Id	Date	Time (UTC)	Lat. [N] Long. [E]	Recovery [cm]	Water Depth [m]	Notes
Node 7	CAGE22-3-KH-01-GC-01	09.06	18:22	68°55.123' 14°17.194'		220	
Node 1	CAGE22-3-KH-01-GC-02	10.06	22:57	68°54.504' 14°23.048'		210	Reference
Node 7	CAGE22-3-KH-01-GC-03	12.06	22:42	68°55.122' 14°17.190'		220	
Node 7	CAGE22-3-KH-01-GC-04	12.06	23:19	68°55.122' 14°17.191'		220	

Appendix 3. CTD STATIONS

Location	Station Id	Date	Time (UTC)	Lat. [N] Long. [E]	Bottles fired [#]	Water Depth [m]	Notes
Node 7	CAGE22-3-KH-01-CTD-80	08.06	12:05	68°55.961' 14°14.683'	12	205	
Node 7	CAGE22-3-KH-01-CTD-81	08.06	13:44	68°55.528' 14°15.896'	12	217	
Node 7	CAGE22-3-KH-01-CTD-82	08.06	14:40	68°54.470' 14°18.348'	12	234	
Node 7	CAGE22-3-KH-01-CTD-83	08.06	15:55	68°57.050' 14°24.119'	12	158	
Node 7	CAGE22-3-KH-01-CTD-84	08.06	16:41	68°56.572' 14°22.356'	12	231	
Node 7	CAGE22-3-KH-01-CTD-85	08.06	17:32	68°56.557' 14°20.578'	12	245	
Node 7	CAGE22-3-KH-01-CTD-86	08.06	18:36	68°55.542' 14°18.811'	12	230	
Node 7	CAGE22-3-KH-01-CTD-87	08.06	19:33	68°54.388' 14°17.091'	12	222	
Node 7	CAGE22-3-KH-01-CTD-88	08.06	20:40	68°54.394' 14°15.291'	12	212	
Node 7	CAGE22-3-KH-01-CTD-89	08.06	21:28	68°53.774' 14°13.509'	12	180	
Node 7	CAGE22-3-KH-01-CTD-90	10.06	05:07	68°55.070' 14°17.194'	12		
Node 7	CAGE22-3-KH-01-CTD-91	10.06	06:00	68°55.082' 14°17.180'	12		
Node 1	CAGE22-3-KH-02-CTD-92	11.06	03:14	68°54.439' 14°23.090'	12	257	
Node 1	CAGE22-3-KH-02-CTD-93	11.06	04:35	68°54.439' 14°23.089'	12	212	
Node 1	CAGE22-3-KH-02-CTD-94	11.06	05:17	68°54.439' 14°23.087'	12	57	
Node 1	CAGE22-3-KH-02-CTD-95	11.06	22:44	68°54.508' 14°22.931'	12	254	
Node 1	CAGE22-3-KH-02-CTD-96	12.06	00:07	68°54.509' 14°22.932'	12	254	
Node 7	CAGE22-3-KH-01-CTD-97	12.06	12:15	68°55.100' 14°17.046'	12		CTD grab
Node 7	CAGE22-3-KH-01-CTD-98	12.06	14:40	00°68.918' 00°14.284'	12		
Node 1,7	CAGE22-3-KH-03-CTD-99	13.06	06:12	68°56.053' 14°21.636'		228	
Node 1,7	CAGE22-3-KH-03-CTD-100	13.06	07:02	85°54.810' 31°16.349'		227	
Node 7	CAGE22-3-KH-01-CTD-101	13.06	18:18	68°57.690' 14°24.702'		219	

Appendix 4. ROV DIVES INCLUDING STATIONS (CHECKERBOARD, GAS AND SEDIMENT SAMPLES)

Location	Station Id	Date	Time (UTC)	Lat. [N] Long. [E]	Filter in Column H or hide	Water Depth [m]	Notes
Node 7	CAGE22-3-KH-01-PusC-01	09.06	16:32	68°55.056' 14°17.112'		219	ROV Push Core - bacterial mat
Node 7	CAGE22-3-KH-01-PusC-02	09.06	16:45	68°55.056' 14°17.112'		219	ROV Push Core - bacterial mat
Node 7	CAGE22-3-KH-01-PusC-03	09.06	16:50	68°55.056' 14°17.112'		219	ROV Push Core - bacterial mat
Node 7	CAGE22-3-KH-01-PusC-04	09.06	16:56	68°55.056' 14°17.112'		219	ROV Push Core - bacterial mat
Node 7	CAGE22-3-KH-01-PusC-05	09.06	17:06	68°55.056' 14°17.112'		219	ROV Push Core - bacterial mat
Node 7	CAGE22-3-KH-01-BlaC-01	09.06	17:36	68°55.164' 14°17.052'		218	ROV Blade Core - reference
Node 7	CAGE22-3-KH-01-PusC-06	10.06	17:30	68°55.098' 14°16.842'		200	ROV Push Core - mat around corals,loose sediment put in a bag
Node 1	CAGE22-3-KH-02-BlaC-01	11.06	19:56	68°54.498' 14°22.992'		248	ROV Blade Core - ~2 m from corals
Node 1	CAGE22-3-KH-02-BlaC-02	11.06	20:18	68°54.504' 14°22.944'		251	ROV Blade Core - ~10 m from corals; reworked, put in a bag
Node 7	CAGE22-3-KH-01-GasS-01	12.06	07:07	68°55.092' 14°17.046'	12		ROV Gas Sampling - CTD grab
Node 7	CAGE22-3-KH-01-BlaC-02	12.06	17:53	68°55.056' 14°17.034'		217	ROV Blade Core - mat
Node 7	CAGE22-3-KH-01-CarC-01	12.06	18:01	68°55.056' 14°17.034'		217	Carbonate crust
Node 7	CAGE22-3-KH-01-CarC-02	12.06	18:06	68°55.056' 14°17.034'		217	Carbonate crust
Node 7	CAGE22-3-KH-01-BlaC-03	12.06	18:24	68°55.056' 14°17.124'		219	ROV Blade Core - mats, bubbles wile sampling
Node 7	CAGE22-3-KH-01-PusC-07	12.06	18:27	68°55.056' 14°17.124'		219	ROV Push Core - mats, bubbles wile sampling (next to BlaC3);kept as frozen archive
Node 7	CAGE22-3-KH-01-GasS-02	13.06	15:39	68°55.104' 14°16.992'	12	219	Gas sample
Node 7	CAGE22-3-KH-01-PusC-08	13.06	18:30	68°55.056' 14°17.118'		219	ROV Push Core - bubbles while sampling
Node 7	CAGE22-3-KH-01-CarC-03	13.06	18:37	68°55.056' 14°17.118'	1	219	ROV Carbonate Crust Collection - close to PusC9; bacteria on one of the edges
Node 7	CAGE22-3-KH-01-PusC-09	13.06	18:42	68°55.056' 14°17.118'	1	219	ROV Push Core - mat on top, close to PusC8
Node 7	CAGE22-3-KH-01-BubQ-01	14.06	10:45	68°55.166' 14°16.973'		217	Checkerboard
Node 7	CAGE22-3-KH-01-BubQ-02	14.06	12:04	68°55.059' 14°17.027'		217	Checkerboard
Node 7	CAGE22-3-KH-01-BubQ-03	14.06	13:12	68°55.114' 14°16.996'		217	Checkerboard

Appendix 5. CORAL OPERATIONS

	date	NODE	TIME	LAT	LONG
CORAL 1	10.06.2022	7	10:28:01	68,918191	14,281157
MICRO 1	10.06.2022	7	10:32:45	68,918177	14,281209
CORAL 2	10.06.2022	7	10:45:28	68,918190	14,281202
MICRO 2	10.06.2022	7	10:48:18	68,918176	14,281206
CORAL 3	10.06.2022	7	10:53:11	68,918174	14,281194
MICRO 3	10.06.2022	7	10:56:35	68,918198	14,281214
CORAL 4	10.06.2022	7	11:01:36	68,918188	14,281203
MICRO 4	10.06.2022	7	11:33:38	68,918188	14,281214
CORAL 5	10.06.2022	7	11:14:59	68,918173	14,281234
MICRO 5	10.06.2022	7	11:39:31	68,918188	14,281176
CORAL 6	10.06.2022	7	11:24:12	68,918193	14,281205
MICRO 6	10.06.2022	7	X		
CORAL 7	10.06.2022	7	11:52:15	68,918178	14,281188
MICRO 7	10.06.2022	7	X		
deployment of rigs and sensor	12.06.2022	7	15:48:54	68,918204	14,281656

	date	NODE	TIME	LAT	LONG
CORAL 1	11.06.2022	1	19:02:44	68,908476	14,382228
MICRO 1	11.06.2022	1	19:04:13	68,908471	14,382171
CORAL 2	11.06.2022	1	19:07:40	68,908491	14,382196
MICRO 2	11.06.2022	1	19:11:11	68,908492	14,382189
CORAL 3	11.06.2022	1	19:13:29	68,908474	14,382197
MICRO 3	11.06.2022	1	19:17:39	68,908483	14,382176
CORAL 4	11.06.2022	1	19:20:13	68,908471	14,382185
MICRO 4	11.06.2022	1	19:26:15	68,908466	14,382192
CORAL 5	11.06.2022	1	19:30:50	68,908464	14,382194
MICRO 5	11.06.2022	1	19:32:32	68,908456	14,382178
CORAL 6	11.06.2022	1	19:37:19	68,908481	14,382181
MICRO 6	11.06.2022	1	X		
CORAL 7	11.06.2022	1	19:42:00	68,908485	14,382160
MICRO 7	11.06.2022	1	X		
deployment of rigs and sensor				68,908400	14,383700

	date	NODE	TIME	LAT	LONG
CORAL 1	12.06.2022	X	20:14:39	68,933370	14,359034
MICRO 1	12.06.2022	X	20:14:39	68,933370	14,359034
CORAL 2	12.06.2022	X	20:34:45	68,933377	14,359041
MICRO 2	12.06.2022	X	20:34:45	68,933377	14,359041
CORAL 3	12.06.2022	X	20:39:34	68,933379	14,359041
MICRO 3	12.06.2022	X	20:39:34	68,933379	14,359041
CORAL 4	12.06.2022	X	20:48:44	68,933368	14,359043
MICRO 4	12.06.2022	X	20:48:44	68,933368	14,359043
CORAL 5	12.06.2022	X	21:06:18	68,933369	14,359018
MICRO 5	12.06.2022	X	21:06:18	68,933369	14,359018
CORAL 6	12.06.2022	X	21:11:59	68,933377	14,359026
MICRO 6	12.06.2022	X	X		
CORAL 7	12.06.2022	X	21:17:31	68,933368	14,359021
MICRO 7	12.06.2022	X	X		
deployment of sensor				68,933780	14,357118

	date	NODE	TIME	LAT	LONG
Sponge 1	13.06.2022	7	12:59:35	68,91741528	14,2850732
Sponge 2	13.06.2022	7	13:05:49	68,91740403	14,28502087
Sponge 3	13.06.2022	7	13:08:14	68,91740873	14,28503752
Sponge 4	13.06.2022	7	13:17:45	68,91741172	14,28503163
Sponge 5	13.06.2022	7	13:17:56	68,91740965	14,28502752
Sponge 6	13.06.2022	7	13:19:04	68,91741428	14,28503822