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FACULTY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF GEOSCIENCE

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ARCTIC UNIVERSITY OF NORWAY cruise report

Longyearbyen – Longyearbyen 19-07-18 to 07-08-18

R/V Helmer Hanssen

Cruise CAGE-18-4

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

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INTRODUCTION AND OBJECTIVES

Cruise CAGE18-4 with UiT's research vessel R/V Helmer Hanssen is the 4th of several cruises in 2018 that is carried out to collect cross-disciplinary data for addressing the objectives of the Norwegian Centre of Excellence for Arctic Gas Hydrate, Environment and Climate, CAGE.

Cruise CAGE 18-4 is split into two legs with a port call in Longyearbyen in order to exchange scientific personnel. The first part of the cruise is dedicated to study gas hydrates and fluid flow on the western Svalbard margin (Fig. 1), the second part targets an active gas seepage field in the Leierdjupet Fault complex (LFC) in the SW Barents Sea (Fig. 2). The overall goal of cruise CAGE 18-4 is to collect seismic, multibeam, water column data, video imagery and sediment and water samples in order to better understand the occurrence of gas hydrates and fluid leakage, the source of the gas in these systems, and seafloor expressions of fluid seepage. In order to address these objectives we plan to carry out:

- 2D seismic acquisition over a complex leakage and source-to-sink plumbing system in the Leirdjupet Fault complex in the SW Barents Sea;
- Seafloor imaging of the seafloor in the Leierdjupet Fault complex using UiT's multi-corer tow cam system;
- Sediment and water sampling in the Leierdjupet Fault complex;
- P-Cable 3D seismic acquisition on the transition from the active eastern segment to the inactive western segment of the Vestnesa Ridge;
- 2D multi-channel seismic for reconnaissance and stratigraphic correlation on the western Svalbard margin;
- Multibeam mapping to fill in gaps and improve resolution of existing data using the upgraded EM302 system on R/V Helmer Hanssen.

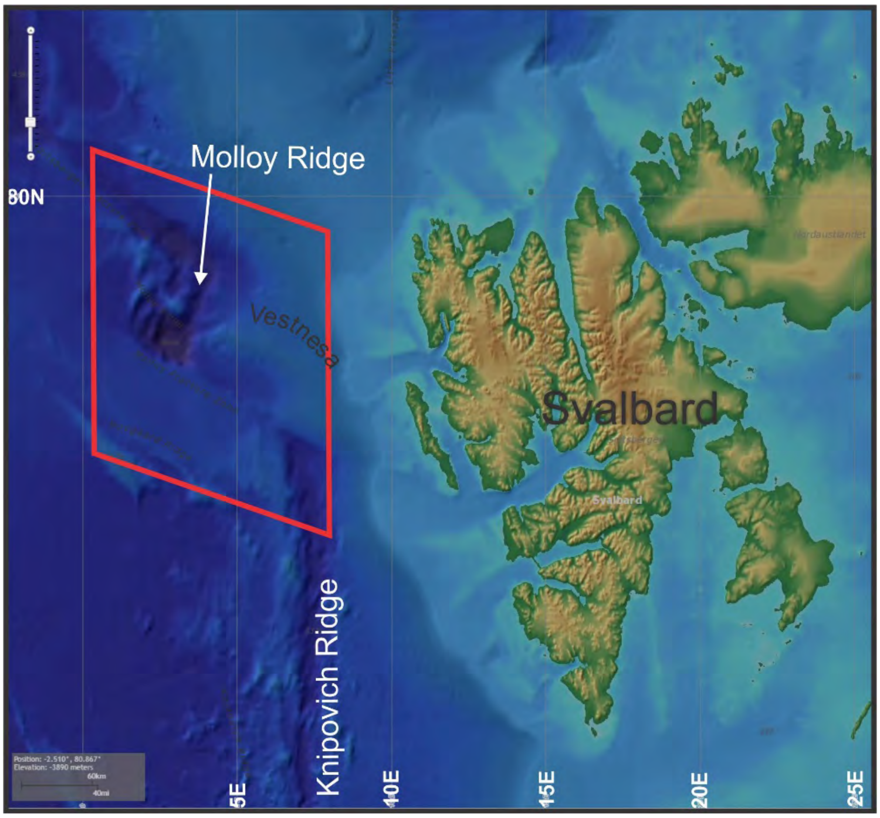


Figure 1: Location of the study areas on the W-Svalbard margin.

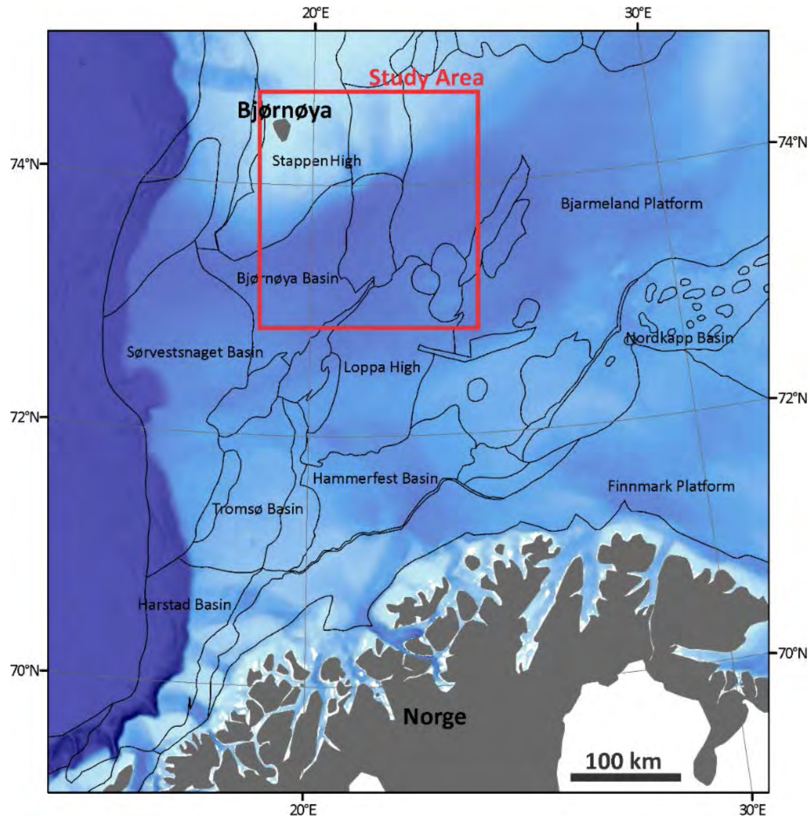


Figure 2: Location of the study areas along the northern flank of the Bear island trough.

METHODS

Seismic methods

The high-resolution P-Cable 3D seismic system was used together with a Granzow high-pressure (210bar) compressor and mini-GI or GI guns. Onboard seismic processing and QC of P-Cable seismic data provided preliminary 3D cubes and migrated 2D seismic sections for quality assessment and geofluid interpretations.

During this cruise we used the SIMRAD EM302 high-resolution multibeam system. The EM302 provides excellent seabed resolution with a maximum of 864 beams. In addition, the system allows mapping the water column in order to detect gas flares over active pockmarks.

Other acquisition systems that were partly used include SIMRAD EK 60 38 and 18 kHz echosounder, the Edgetech Discover penetration sub-bottom profiler and a CTD to extract information about different (T, S) properties of water masses to calculate the speed of sound for calibrating the EM302.

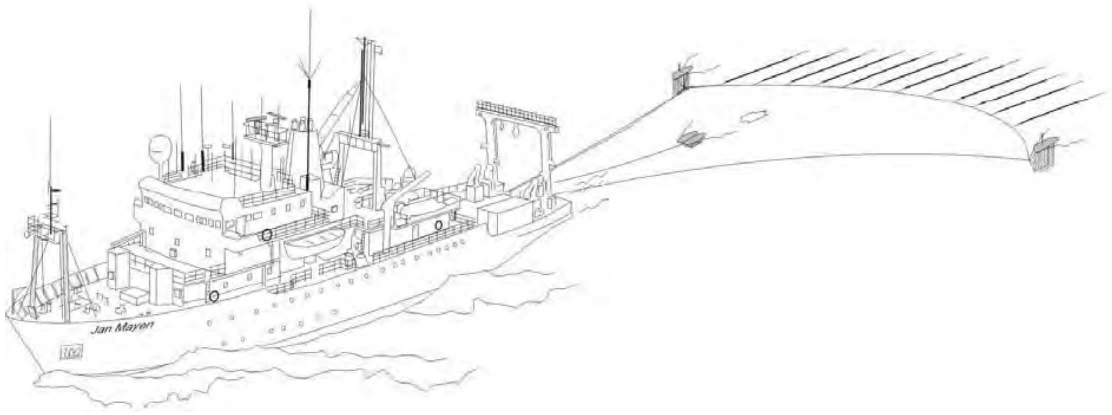
The P-Cable 3D (2D) seismic system

The P-Cable 3D high-resolution seismic system consists of a seismic cable towed perpendicular (cross cable) to the vessel's steaming direction (Figure 3 and 4). An array of multi-channel streamers is used to acquire many seismic lines simultaneously, thus covering a large area with close in-line spacing in a cost efficient way. The cross cable consists of two 62,5-m long and one 87,5-m long section with a total of 14 streamers attached to it. Including lead-in cables, the cross cable has a total length of 233 m between paravanes (doors) (Figure 2). The cross-cable is spread by two paravanes that due to their deflectors attempt to move away from the ship. The paravanes itself are towed using R/V Helmer Hanssen's large trawl winches. The spacing between the streamers is 12.5 m but due to curvature of the cross-cable, the effective spacing between the streamers may be shortened in cross line direction to about 6-12 m. Each digital streamer is 25 meters long and consists of an A/D-module and 8 channels. New Geometrics solid state streamers are used that are much less affected by sea swell and hence provide data with significantly less noise. The A/D-module converts the analogical signal from the channels to digital signals. The group spacing of channels along the streamer is of 3.125 m.

A 300-m long signal cable is run off the P-Cable winch and connects to the starboard termination of the cross cable (Figure 3). It contains wiring for power and data transmission. The data is transferred via Ethernet protocol. Ethernet-to-Coax switches at the ends of the signal cable allow data transmission over long distances. The digital data is recorded using Geometrics GeoEel software.

The P-Cable system can be reconfigured to a multi-channel 2D seismic streamer. During this cruise we used 4 streamer sections for a 100 m long active hydrophone cable with 32 channels at a receiver spacing of 3,25 m. The lead-in cable to the active streamer had a length of 80 m behind the ship. The streamer cable was towed at a depth of approximately 2 m.

Details on the acquisition parameters like recording length, sampling rates, etc. can be found in the seismic line log in the Appendix of this report.



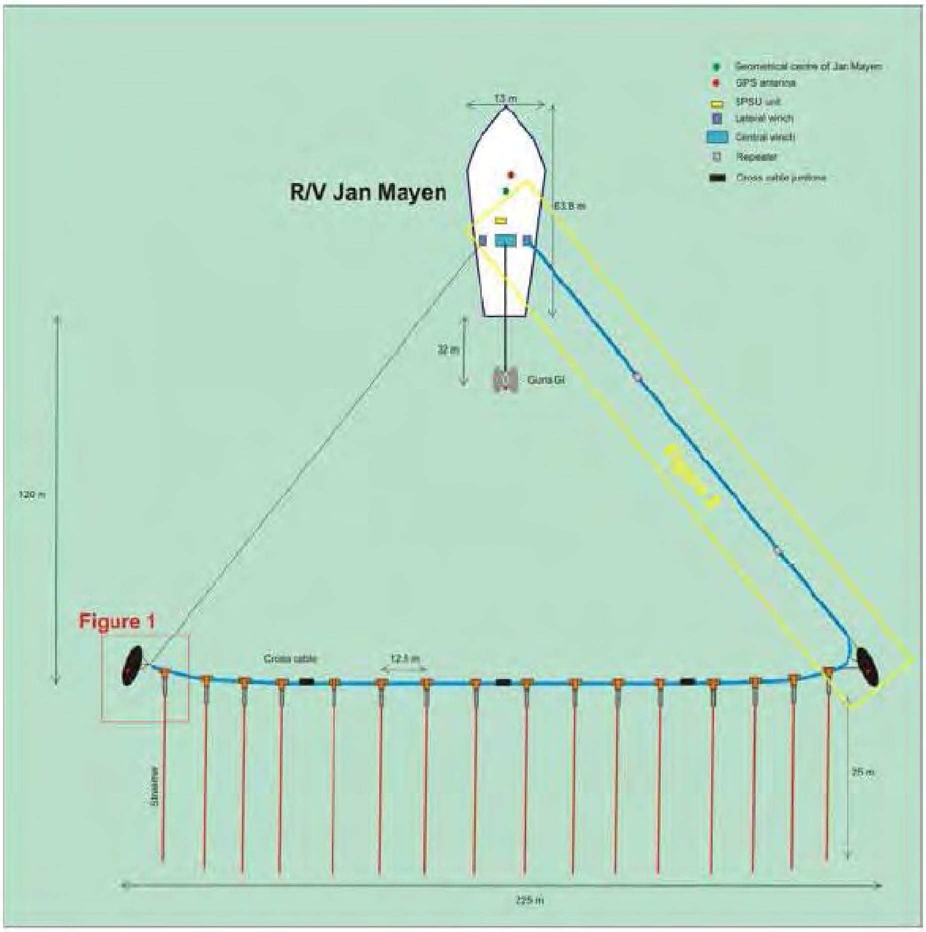


Figure 3: Schematic sketch (top) and technical drawing (bottom) of the P-Cable high-resolution 3D seismic system.

Figure 4: Images of the P-Cable system during deployment and recovery. Top left: the cross cable is being deployed, streamer sections are connected during deployment; top and bottom right: The cross cable is recovered and spooled back on the winch while streamers as disconnected from the cross cable. The small winch next to the cross cable holds the signal cable; bottom left: inspection of cross cable junction boxes during deployment and recover.

Multi-corer tow cam system

Video camera system

During the CAGE 18-4 cruise, the video camera system DSPL HD Flexlink (1080P resolution) video was used to record video to inspect the area. The camera is integrated to the fiber optic cable and provides real-time video, which are used to target the sampling.
The light is provided by 2 LED lights with 9000 lumen each. Sometimes, the light is switched off during the descending and ascending to save power.
The camera and laser point in the forward part of the multicorer.
The videos are recorded on a 256GB card. The videos are usually recorded from 1.5 m altitude although sometimes the altitude is higher to avoid obstacles or compensate up and down movement due to ship roll and pitch.
Power to the CAGECam system (TC) is provided by deep-sea batteries, each having ca 40 amp/hr capacity.
The TC#1 was done to test the system and also collect sediment samples. The configuration of the TC was with a video camera pointing inside the multicore to see the liners pushed into the sediment. (Figure 5). For the following TC deployment, the configuration has change, with camera pointing in a forward, downward 45^o angle. The lights were placed at 60 cm

from each side of camera. The observation during the TC lowering were done using the OFOP software and recorded each day.

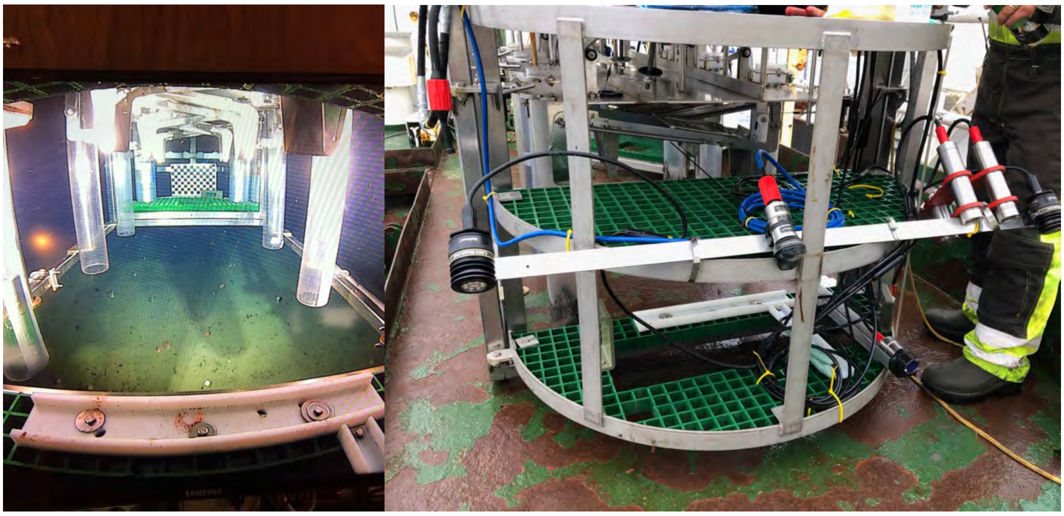


Figure 5: Different TC/MC configuration. On the left, the camera is pointing inside the multicorer. On the right, the camera and the two led are pointing forward.

Multicorer system

The multicore sampling is a KC Denmark DK8000 multicore acquiring 6 sample cores simultaneously. In 2015 the multicorer has been converted in a TowCam/Multicorer, TC, the frame has been used to place the CAGE video camera. The mutlicorer recover 6 parallel cores from the same spot at the seafloor. They are 70 cm long tubes with a diameter of 10 cm. the liner used are always transparent.

The liners are loaded with open upper and lower ends. When the multicorer lands on the seafloor, the tubes are pushed (Figure 6) into the soft sediment by lead weights, and closed ends. Up to 60 cm of sediments and the immediate overlying water can be samples. This allows the analyses of undisturbed faunal samples. Once on board, the core tubes filled with water and sediment are taken out the sediment device, the ends sealed, and the core moved in an upright position in the wet laboratory. Once in the lab, the sampling for porosity, head-space, micropaleontology starts. To sample the cores one extruder has been used. During this cruise. The real time video from the TC was used to guide the sampling.

Figure 6: Liners on the multicoring system.

Water column measurements

A Seabird 911+ CTD, attached to a water sampler rosette, was used for acquiring water column data. Sensors for temperature, pressure, oxygen concentration, turbidity, fluorescence and electric conductivity, giving salinity are attached to the CTD, which is lowered and heaved through the water column while sampling at 25 Hz. Post processing of the water column data includes conversion of raw data (voltage) using polynomes for each sensor into physical parameters, spike removal, low pass filtering, loop editing to compensate for ship heave and finally bin averaging over 25 cm bins. The CTD's water unit communicates through a wire and closes bottles for water sampling (nutrients and gas analyses) given a command from the PC in the instrument room via a deck unit.

Concentration of dissolved methane in the water

For measuring the concentration of dissolved methane in the water column, seawater samples were collected from the same Niskin bottles at different water levels depending on the water depth. Water samples were placed bubble-free into 160-ml glass vials. After adding 1 ml of NaOH solution (1 M) for preservation, bottles were sealed with rubber septa and crimped. Subsequently, 5 ml of nitrogen gas was added into each of the bottles to create a headspace where gasses, which are dissolved in the water can equilibrate. After shaking the water samples for several minutes, the concentration of methane in the headspace of each sample will be analyzed with a gas chromatograph from Thermo scientific Trace 1310 equipped with an FID.

Sediment sampling

A 3 m long gravity corer and a grab sampler were used to acquire additional sediment samples for sedimentological, geochemical and micropaleontological analysis. VBPR provided the gravity corer weight, 3 m long core barrels, plastic liners and underwater video camera system mounted on the gravity corer. The core liners are split in 1 m sections on deck, and carried to the wet lab for headspace gas sampling at each lines intersection. The sections are subsequently closed and stored in the cooling room and will be analyses further at the department. Headspace gas samples were also taken from all multicores.

In this survey VBPR wants to test an optimized sampling protocol to improve the quality of the headspace gas analysis. In order to validate the new sampling method, VBPR plans to compare the results from the new sampling method with the headspace gas results done by the CAGE scientific team.

Sediment chemistry

For measuring the concentration of methane in the sediment, conventional headspace sampling preparation technique was applied. 3 ml of bulk sediment was taken from the different sediment intervals by using a 3-ml cut-off plastic syringe. The sediment sample was transferred into a 20-ml headspace glass vials, containing 7 ml of NaOH solution (1 M) and 2 glass beads. The vials were immediately capped with rubber septa, sealed with aluminum crimp caps and shaken afterwards. Samples will be analyzed with a gas chromatograph from Thermo scientific Trace 1310 equipped with a FID.

For porosity measurements, 3 ml of bulk sediment was taken by using a 3-ml cut-off plastic syringe or a spatula and transferred into a 15-ml centrifuge tube. Samples were stored at room temperature until processing them in the home laboratory according to Boyce, (1973).

For total organic carbon (TOC) samples were taken at 1 cm intervals up to 10 cm. The sediment collected were stored in plastic bag and preserved in a cooling room. The samples will be analyzed in laboratory to measure the Total Organic Carbon (TOC), the Total Nitrogen (TN), the d13C and d15N of the organic matter. The TOC indicated the organic matter quantity, as food for benthic foraminifera, allowing the identification of the trophic regime of species. The TN provides information on the organic matter quality/degradation. The isotopes also indicate the degradation state of the organic matter as well as its source.

VBPR's headspace gas sampling method involves the collection of 40 ml of seabed sediments using syringes, and placed into a 120 ml glass container filled with fresh water. The glass vial is sealed and 30 ml of the water is flushed and replaced by nitrogen. The sample is subsequently shaken until the sediments are totally dissolved in the water. The sample is allowed to rest for at least 8 hours before the headspace gas is extracted in another glass vial. The extracted headspace gas is then stored upside-down in a container filled with water. This storage method is designed to remove potential contamination of the headspace gas by air after sample collection due to leakage during transport.

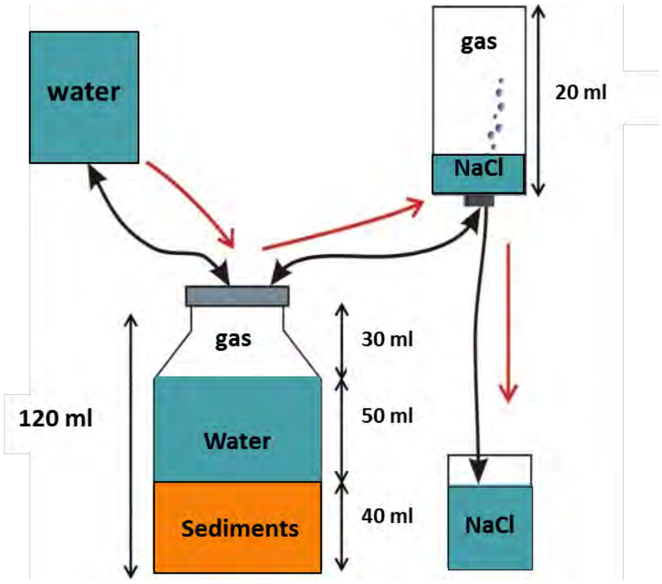


Figure 7: Sketch showing the principles of extracting the headspace gas from the seabed sediments into penicillin bottles.

The principle is to insert water into the sediment sample, which will displace the headspace gas into another vial filled with brine. The gas will displace the brine that will be flushed out.

Micropaleontology

For the characterization of the foraminiferal associations, sediment samples were collected from 8 multicore stations and 1 grab station. At each multicore station, one multicore was sliced every 0.5 cm from the top to 2 cm, from 2 to 10 cm. Half of sediment was fixed with Cell Tracker Green (CTG) and the other half with Rose Bengal (RB). The rest of the core was sampled every cm for investigation of fossil foraminifera.
Below the two staining methods described.

Cell Tracker Green - CTG labelling

On board, sediment cores collected using a multicorer were sliced into 0.5 cm intervals until 2 cm depth and into 1 cm intervals until 10 cm depth. A method based on enzymatic reactions was used to distinguish living foraminifera (Bernhard et al., 2006; Pucci et al., 2009; Langlet et al., 2013, 2014) on half of the core (the rest of the sediment was colored using Rose Bengal to compare both methodology). One milligram of Cell-Tracker™ Green (CTG 5 CMFDA: 5-chloromethylfluorescein diacetate) was dissolved in 1 mL of dimethylsulfoxide (DMSO) and diluted by 10 in in situ sea water. Samples were incubated for 12 h to 20 h at in situ temperature without light in a solution of seawater, with a CTG final concentration of 1 mmol L_1, as described by Bernhard et al. (2006). During this time, CTG passes through the cellular membrane of living organisms, and reaches the cytoplasm where hydrolysis with nonspecific esterases creates fluorogenic elements. After the death of the cell, esterases are decomposed in a few hours to some days at maximum, depending on environmental conditions (Bernhard et al., 2006), making the CTG method highly accurate to discriminate between living and dead organisms. After incubation, the samples were fixed in 96% ethanol and stored at room temperature.

Rose Bengal (RB)

The samples collected were stored in containers in a 2 g.L-1 solution of Rose Bengale in 96% ethanol, in order to be preserved and to stain the living organisms. The RB staining stains the proteins of the foraminifera cell. However, the proteins may be preserved in the cell from few days to several month. For this reason, this method is not accurate to determine the living foraminifera like the CTG staining methods (explained below). However, it is largely used to identify the recent living assemblage.

Phylogeny
On board freshly collected sediment was sieved using 125 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, washed with micro filtrated seawater (2µm) and stored in an Eppendorf vial.

Environmental DNA
Fresh sediments from multicore were sampled to determine the biodiversity of foraminifera using environmental DNA. Roughly 10 cm3 of the 2 first cm (0-1 and 1-2 cm) was sampled using a sterilized spoon in a sterilized plastic bag and stored to the freezer.

Fixation for TEM observation
On board freshly collected sediment was sieved using 125 µm mesh with in situ bottom water (T°C 2°C, Salinity 35). Foraminiferal specimens with colored cytoplasm located in all the chambers except in the last one (occurrence of vitality) were picked and put in an Eppendorf with in situ sediment. On August 7th, at Longyearbyen, sediment samples containing living foraminifera were chemically fixed with the fixative solution contained 4% glutaraldehyde and 2% paraformaldehyde (LeKieffre et al., 2018). Samples were then keep at cool temperature, transported to Angers laboratory (France) in order to perform imbedding and ultra-thin section and TEM observation. TEM observation of the foraminiferal cell may detect symbiosis or cytological adaptation.

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Oxygen profiles
Immediately after the recovery of the multicorer, one core was selected and immediately brought in a temperature-controlled room at 2°C which is the situ temperature and gently immersed in water from the sampling station. Depth profiles of O2 were measured using a Clark-type microelectrode with a 50 µm thick tip (OX50, Unisense, Denmark) connected to a multimeter (Unisense). Microelectrodes were calibrated at two points (O2 saturation was obtained bubbling seawater at in situ temperature and salinity and zero oxygen concentration was obtained by measuring deeper part of the sediment core). Profiling was difficult to measure due to the occurrence of numerous pebbles in the cores. One microelectrode was broken.

NARRATIVE OF THE CRUISE

Times in this report are given in local time (local time -2 hrs = UTC), seismic data are logged in UTC time and ship logs are given in UTC time. Weather at Svalbard was rather poor this summer with almost constant wave heights between 1,5 to 2 m making seismic acquisition challenging. Weather conditions in the Barents Sea were mostly very good with sea state and wave heights below 1 m. Air temperatures were between 1 ◦C and 8 ◦C. We started to prepare the cruise in Longyearbyen on July 19 with assembly of the equipment.

Thursday, 19.07.2018
The scientific personnel arrived by flight from Tromso at 14:00. We started to prepare lab areas and to assemble the equipment. Unfortunately, one of Helmer Hanssen's engineers was written sick by a doctor in Longyearbyen. Therefore , we could not leave port as planned as we have to wait for a substitute being flown in from Norway.

Friday, 20.07.2018
The substitute engineers was supposed to arrive at 01:00 but missed his flight in Oslo, which further delayed our departure from Longyearbyen. The engineer arrived at 14:00 and we finally left Longyearbyen for our working area on the Vestnesa Ridge.

Saturday, 21.07.2017
We arrive at the Vestnesa ridge area at around 03:30 early morning and run a CTD for calibration of sound velocity in the multibeam system. Thereafter, we deploy the 100 m long multi-channel 2D seismic streamer and two mini GI airguns configured with chamber volumes of 30/30 and 15/15 in^3. The system is tested and configured properly. We start acquiring the first 2D seismic line across the western end of the Vestnesa Ridge at 08:20. By midnight 5 2D seismic lines have been completed. For details of the seismic acquisition and additional information, please see the line log in the appendix. The weather is relatively calm with winds of ~6 m/s and 1 m waves.

Sunday, 22.07.2018
Five more 2D seismic lies have been completed during the early day and by 07:30 the 2D seismic system is back on deck. We then prepare the P-Cable 3D seismic system for an acquisition at the corner point of the Vestnesa Ridge between the eastern and western segment. Deployment starts at 10:00 and within about 1,5 h the system is in the water. Initial system configuration for the acquisition software fails several times. However, there is no leakage indicated along the cable so we keep trying to find the solution on the software end. By 14:00 we finally succeeded to detect all streamer sections. Problems were due to interference from a wireless network device on the acquisition computer and by not starting the software as administrator. Shortly after 14:00 we start our pre-survey warm-up program verifying acquisition parameters, testing guns and assessing data quality. Gun configuration stays unchanged with 2 mini-GI. Acquisition line 1 starts shortly after 15:00. By midnight, 6 acquisition lines have been completed. Weather is somewhat challenging for 3D seismic acquisition with about 10 m/s winds and 1,5 m waves.

Monday, 23.07.2018
3D seismic acquisition continues. See the 3D seismic line log in the appendix for further details. About an hour before midnight, we have completed 23 acquisition lines. Weather stays unchanged.

Tuesday, 24.07.2018
The 3D seismic acquisition is completed with line 31 at about 11:30. At about 12:30, the system is fully recovered and back on deck. We lost floatations along the cross cable between streamers 7 and 8 and between streamers 11 and 12. Initial analysis of depth measurement and frequency content shows that it likely happened on line 25. We reconfigure the acquisition system back to the 100 m long 2D seismic streamer. Shortly after 15:00, we start a long 2D seismic line from the Vestnesa Ridge towards and across the mid-oceanic Molloy Ridge. The line is meant to stop at the ice front on the eastern side of the Molloy Ridge. Weather is calmer towards the west with winds about 6-8 m/s and waves up to 1 m.

Wednesday, 25.07.2018
We only come across a narrow (<100 m) band of wide open ice floating at around 2.5° E. We easily can pass through this with our streamer and continue further west on the seismic line. Even the planned end of the line is ice-free and hence we decide to continue further west across sedimented basement structures of the western Molloy Ridge. At about 03:00, the line is terminated and we commence a multibeam survey back eastwards that is meant to fill data gaps. A CTD for calibration of sound velocity in the acoustic systems is taken at 08:30 in 2900 m water depth. The multibeam survey completes at 14:30 and we deploy the 2D seismic for additional seismic data from the western end of the Vestnesa Ridge. By 20:45, two 2D seismic lines have been acquired and the seismic equipment is being recovered. We then reconfigure to the 3D P-Cable and start to acquire another 3D seismic cube at the western termination of the Vestnesa Ridge.

Thursday, 26.07.2018
3D seismic acquisition line 1 starts at 00:50. During line 8, the gun stopped firing as the cooling system of the air compressor had shut down the compressor. The captain had accidentally shut down the water pump. The guns were shooting normal again after about 10 minutes. However, it left a data gap of about 1,5 – 2 km along this line that has to be filled in at the end of the survey. By the end of the day, 14 acquisition lines have been completed. The weather is still challenging for 3D seismic acquisition with 1.5 m wave heights and winds around 10 m/s.

Friday, 27.07.2018
During acquisition line 16, the smaller mini-GI (15/15) stopped shooting shortly after the start of the line. We nonetheless completed this line and recovered guns. A small piece of rubber had been trapped in the gun preventing it from closing the G-chamber and leaking air. The problem was fixes and we continued our survey. However, analysis of the data on line 16 showed that we would need to repeat it at the end of the survey. The last acquisition line 21 finished at 12:30. Thereafter line 22 filled in for line 16, and line 23 filled the gap on line 8. The P-cable 3D seismic survey was completed in the early afternoon and the P-Cable successfully recovered by 16:30. We sail a little further south to the Molloy Transform for further 2D seismic acquisition along the Molloy Transform and the Svyatogor Ridge. 2D seismic line 14 starts at about 19:30. Weather is still unchanged.

Saturday, 28.07.2018
Acquisition of 2D seismic data lasted throughout most of the day until approximately 18:00 when we recovered the seismic system after completion of 2D line 19. Our seismic program on the western Svalbard margin is completed and we sail back to Longyearbyen for exchange of some of the scientific party members before our departure to the SW Barents Sea working area.

Sunday, 29.07.2018
We arrive in Longyearbyen early morning at 07:00 and anchor at Bykaia. Over the course of the day, we change some of the instrumentation and set up labs for sediment and water sampling. After noon, 8 scientific party member left and 5 new ones arrived. In late afternoon, the engineers and the crew start to install the USBL pipe into the small moonpool on Helmer Hanssen that is normally used for gravity coring. We cannot leave port until this has been fixed and is working.

Monday, 30.07.2018
The work on the USBL pipe lasts until 05:00 when we finally can leave Longyearbyen for our working area in the SW Barents Sea.

Tuesday, 31.07.2018
We steam towards the working area at the Leierdjupet Fault Complex where we arrive at 13:00. We take one CTD for calibrating sound velocity in the acoustic systems. Thereafter, we launch the multicorer with the camera facing the core liners. On the second attempt we recover sediment in 5 out of 6 liners from an area that does not show any indication of seepage. At about 19:00, we start a 2 nm long tow cam track crossing several supposed seeps sites. We discover bacterial mats and gas bubbles at one of the major seepage sites at LFC and take one multi core, however, only one liner was filled. We re-enable the multicorer and dive again aiming to get another multi-core sample and more video footage from the previously discovered seepage area. We see more bacterial mats and bubbles and take a core directly over these features. However, only two liner were filled but one of them is still bubbling onboard, and the smell strongly after H_2S. At 23:00 we complete multi corer / tow cam operations for the day, take one CTD at the seepage site and acquire multibeam data over the night extending existing coverage northward into a small field with crater-like structures. Sea and wind conditions have been very good.

Wednesday, 01.08.2018
The multibeam survey finishes in the morning at around 11 in the northern area of the LFC seepage field. We take another CTD and shortly before 12:00, we deploy the tow-cam for a 2,5 nm long track through several seep sites in the northern area. The most important discovery is made 2/3rd into the survey where we discover bubbles and structures at the seabed that look like carbonate slabs, very typical for a seepage site. At the end of the track, the tow cam is recovered without any attempt to sample. We redeploy at the seepage site and after half an hour find more carbonates, bacterial mats and gas bubbling from the seafloor. A multicore is taken at this site and recovers two full liners. Another CTD is taken directly at the seepage site. After that, we take three 3 m long gravity cores, two inside the seepage and one outside as reference. Then, we start a CTD transect of 2 perpendicular lines of altogether 11 stations that cover the main seepage field.

Thursday, 02.08.2018
The CTD transect is finished at 06:10 in the morning. A small multibeam survey fills in some data gaps. Network communication problems on the MUX interface of the multicorer (no video images or access to the switchboard of the light) did not allow us to immediately start another tow-cam survey. The MUX was broad up for inspection. While the tow cam electronics are being inspected, we take the opportunity to acquire 4 Van Veen grab samples to obtain a greater portion of surface sediments from an active seepage site. The tow cam is repaired at about 15:00. We anchor the ship as we intend to drift slowly forward and

backward over the most active seepage site in the southern part of the survey area. We identify several additional areas with bacterial mats, one of them being quite extensive with mats extending over several square meters. Several small bubble trains are also identified. We finish the tow-cam surveys at 21:00. Unfortunately, both multicoring attempts over bacterial mats do not recover much material, the second attempt being completely empty. We take another 3 VanVeen grab samples at the location that had extensive bacterial mats. Thereafter, we start acquiring several 2D seismic lines in the southern part of the study area. Sea conditions are still very good for our scientific program.

Friday, 03.08.2018
The first seismic line heading SW starts at midnight. By 09:30, 4 seismic lines have been acquired and we interrupt our seismic survey to commence several additional tow cam dives. We anchor the ship again several 100s of m east of the main seepage filed in order to better control our drift across it. The main aim is to take a multicore over an area with bacterial mats. Several times we come across areas with small mats (up to ~50cm). We also identify several spots where the multicorer touched the seafloor or was deployed to take sediments. Sometimes the drift is a bit unlucky and challenges our patience. At the end of the tow cam surveys three multicores have been taken but recovery is small, only the last mlticorer had two liners filled up to 50 cm. After the tow-cam operations we take 5 gravity cores from the seepage area. However, all cores do not penetrate more than half a meter. Initial analysis shows very hard and compacted clay at the bottom of the recovered cores that didn’t allow the corer to penetrate any further. Subsequently, we start acquiring two additional seismic lines to complete the seismic program. Weather conditions are still good, though some wave with long wavelengths are passing through the area and are making some of the tow cam operations more challenging.

Saturday, 04.08.2017
The seismic survey is completed at 06:00. We commence a small multibeam survey to fill in gaps in coverage that also brings us to the norther part of the survey area. Between about 12:30 to 20:30, we complete three more tow-cam tracks covering areas with gas flares, depressions typical for a fluid flow feature and an area with crater-like structures. Although we clearly pass through active seepage recognised on echosounder data, we don’t find an active bubble stream nor detect any bacterial mats. Unfortunately, the planned gravity coring after the tow cam surveys has to be abandoned as weather conditions have worsened. Winds close to 10 m/s and waves up to 1,5 m do not allow to deploy instrumentation from the geology platform as it constitutes a too high risk for the crew. We carry out a CTD station for calibration of sound velocity in the acoustic systems and start a multibeam survey over the night extending existing coverage.

Sunday, 05.08.2018
At 08:00 in the morning, weather conditions have even worsened further and forecasts are grim. It is obvious that we will not be able to commence any more tow-cam or coring operations during the day. Hence, we continue with the mutlibeam survey. At about 11:00 our work program in this area is completed. We are heading back towards the Storfjorden Fan where we plan to acquire a few sediment samples. Three grab samples are taken just west of Bear Island at around 16:00.

Monday, 06.08.2018

At 03:00, we take a gravity core in a channel on the fan of Storfhorden Trough, and then continue our journey back to Longyearbyen. Wheather is a little rough during the transit. We arrive in Longyearbyen at 19:00 and start to demobilize.

Tuesday, 07.08.2018
Demobilizing finished at 11:00. Cruise concluded.

Preliminary results

Data Acquisition on the western Svalbard Margin

CAGE cruise CAGE18-4 acquired 2D and 3D seismic data, multibeam and water-column imagery on the western Svalbard Margin (Figure 8). Data acquisition started with the acquisition of a dense grid of 10 2D seismic lines across the western termination of the Vestnesa Ridge investigating fluid and hydrate dynamics and rock interactions. In between 3D seismic acquisitions we acquired additional 2D seismic data across the Molloy Ridge and the Molloy Transform for regional understanding. Two 3D seismic cubes were acquired at the corner of the Vestnesa Ridge between the eastern and western segment and at the western termination of the Vestnesa Ridge in order to study fluid flow and tectonic interactions.

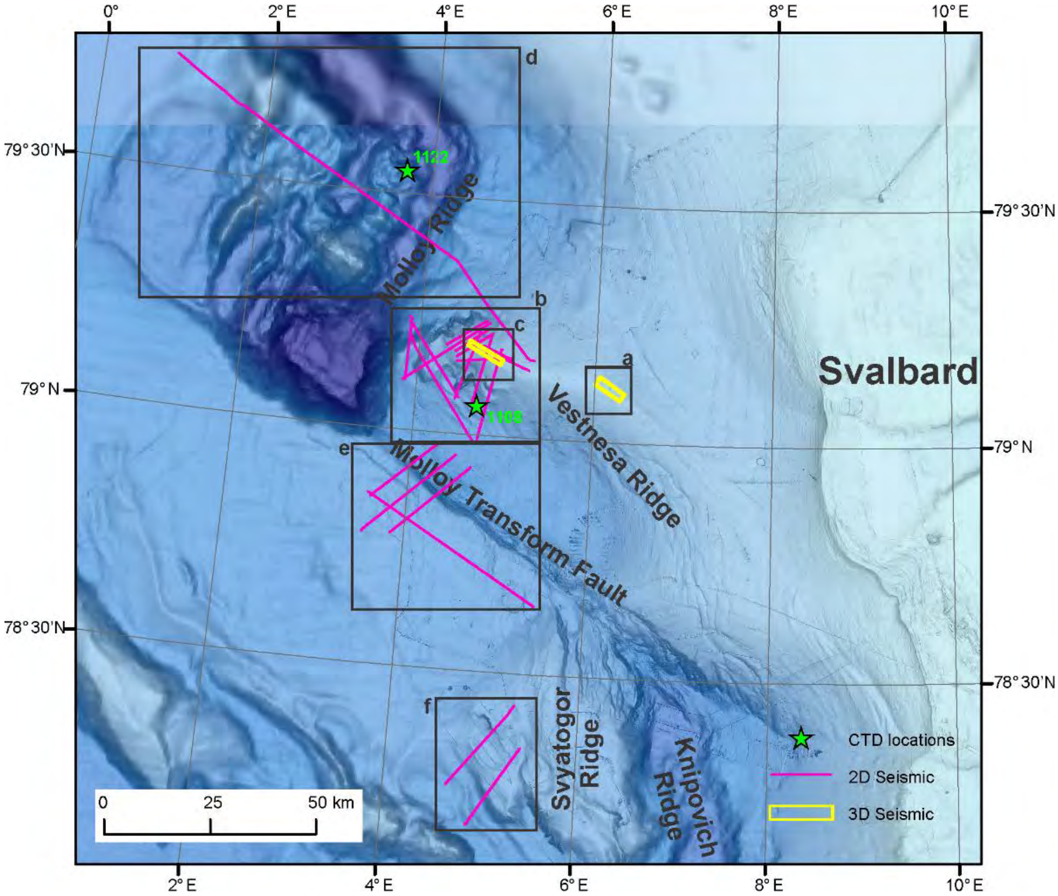


Figure 8: Detailed overview of the study area on the western Svalbard Margin showing the seismic data and CTD that has been acquired. a: Central Vestnesa 3D survey, b: West Vestnesa 2D survey c: West Vestnesa 3D survey, d: Molloy Ridge 2D survey, e: Molloy Transform 2D survey, f: West Svyatogor 2D survey.

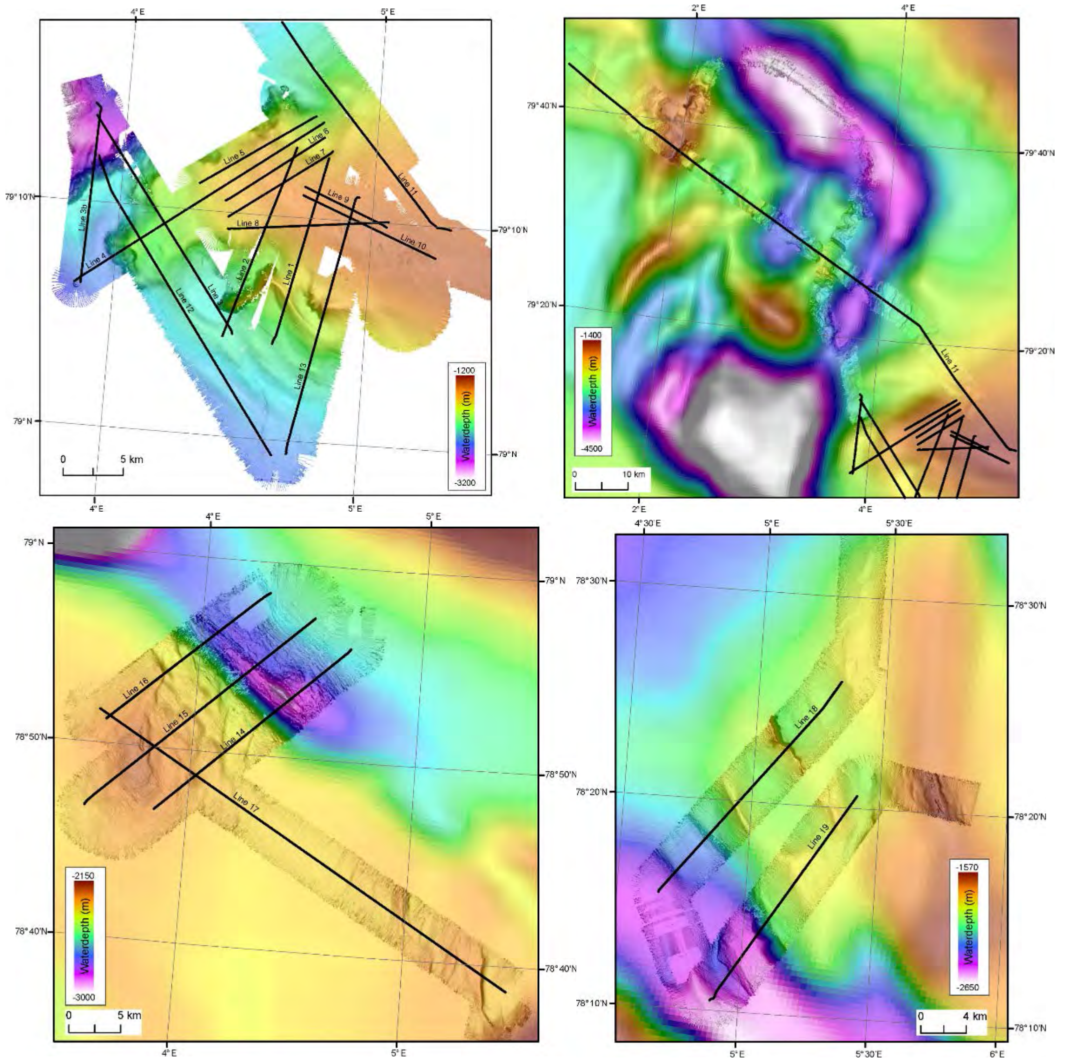


Figure 9: Multibeam data and network of 2D seismic lines acquired om the western Svalbard Margin (see Figure 8 for location).

2D seismic acquisition

A total of 19 2D seismic lines were acquired on the western Svalbard Margin (Figures 8 & 9). The multi-channel seismic streamer was configured with 4 25-m-long Geoeel solid state sections, providing a total of 32 channels with 3,125 m receiver group spacing. For a detailed list of survey parameters and survey configuration, refer to the Table and Figure below (Table 1, Figure 10).

The incoming data was QC'd in realtime using RadexRealtime processing flows. Some examples of the QC plots are shown in Figure 11 and include shot gathers, noise plots that show amplitude in the water column for all channels and shots, similar plots that show amplitude windowed below autopicked seafloor. We also generate a realtime stack using autopicked direct wave to calculate offset and correct for NMO. Frequency spectra are also generated for a large window around the seabed for both individual channels (one plot) and summed for all channels on a streamer (another plot).

Table 1: Detailed survey parameters

Survey parameters	
Deployment / recovery	1 - 3 hrs
Survey speed	5 kt
Turn time	-
Source	2 mini GI 30/30 in^3 & 15/15 in^3
Shooting rate	6 s (except a few shots line 11, shooting rate 7 s)
Shooting pressure	170 bar
Source towing depth	2 m
Dominant frequency (bandwidth)	100-150 Hz (20-400 Hz)
Positioning	GPS transponder on gun raft
Streamer length	100 m
Active section	-
Number of channels	32
Receiver group spacing	3.125 m
Streamer towing depth	2-3 m
Sampling rate / interval	4000 Hz / 0.25 ms
Recording length	4-6 s

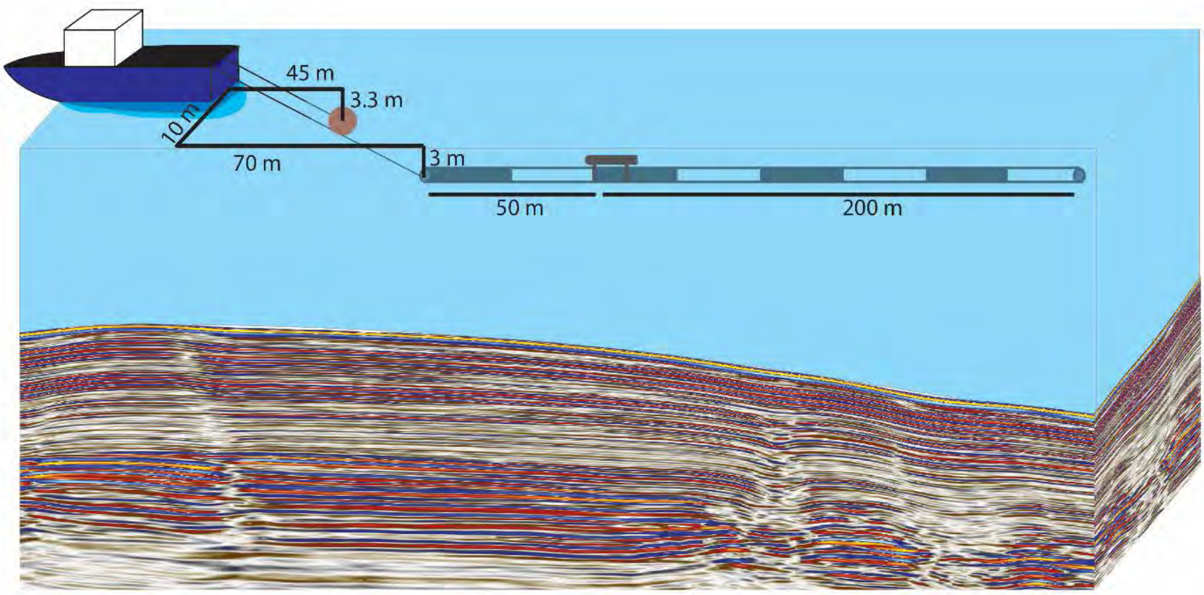


Figure 10: Acquisition geometry of the 2D multi-channel seismic streamer. Notice that in this cruise we used only 4 streamer. Hence, the active section was 100 m instead of 200 m.

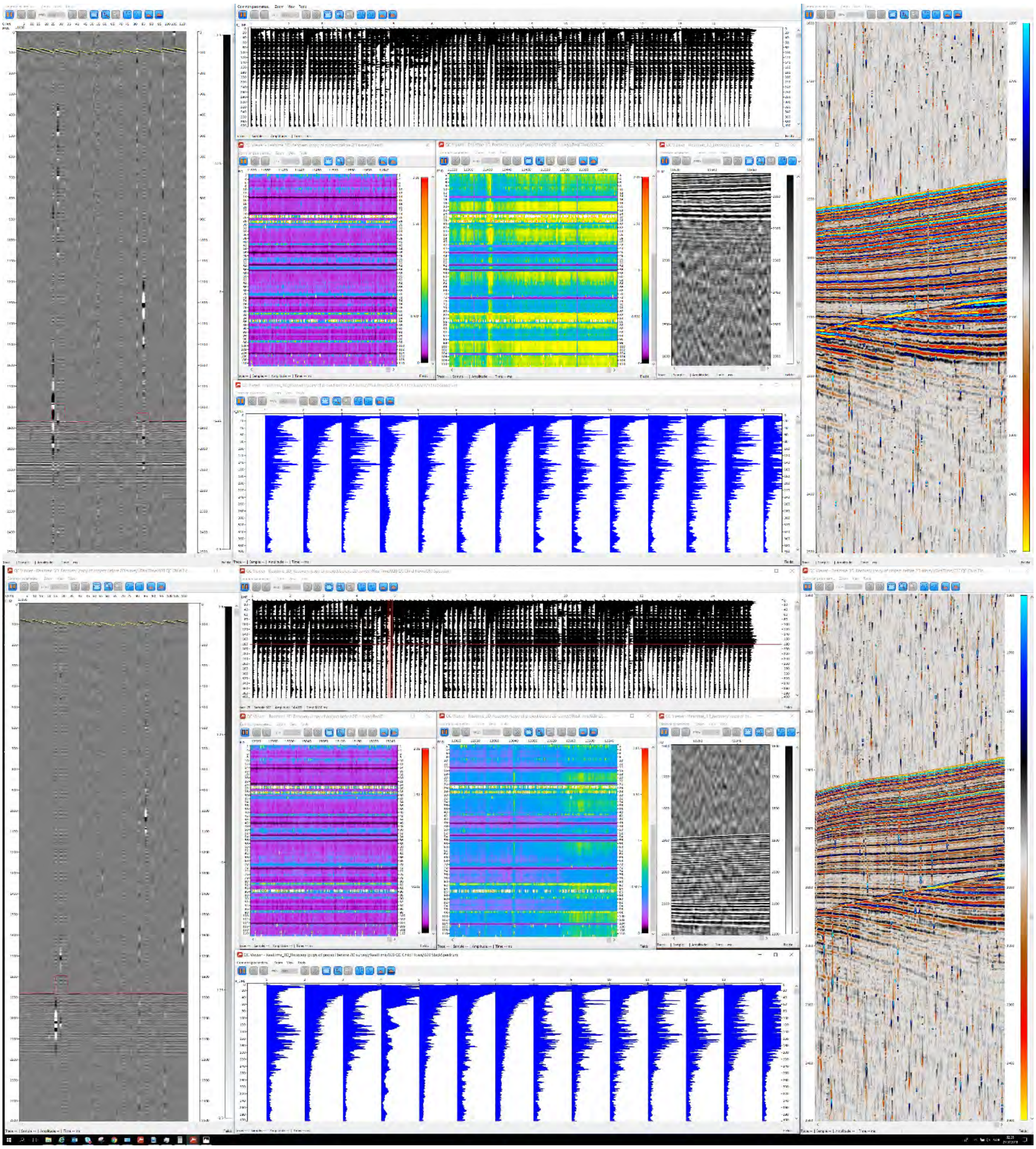


Figure 11: Radex Realtime QC screenshots from Vestnesa 3D no.2 top – line 15, both mini GI guns firing (30,15in3) and bottom – line 16, only one gun (30in3) firing, the other gun stopped during turn between lines. Higher amplitudes at end of line from increasing pressure 150 to 180bar by closing valve to leaking gun.

2D seismic processing

The raw data was processed using the RadexPro Professional 2018.2 software. The 2D seismic lines were binned to 3.125 m. This binning generated a nominal fold of ca. 8-12 traces. The seismic processing flow, as listed in the table below, consists sequentially of: geometry assignment (after processing navigation files using Python code) initial filtering to improve signal-to-noise ratio and spherical divergence correction (band pass, burst, f-k), de-ghosting (alternative), f-x (alternative) NMO correction, stacking and Stolt or Kirchhoff migration.

Seismic processing flow	
SEG-D import and geometry assignment	Input of SEG-D files Geometry assignment and offset calculation
Filtering in the shot gathers	Removal of bad channels Spherical divergence Simple bandpass filter of 18-25-800-1000 Hz Burst noise removal F-K filtering
Deghosting in channel gathers	Resample to 0.1 ms SharpSeis Deghosting of the source ghost estimated to arrive at ca. 190 Hz (no deghosting applied for 11-19) Resample back to 0.25 ms F-X predictive filtering (lines 11-19 and tested on 2 and 6)
NMO and stacking	NMO using constant velocity of 1500 m/s, ensemble equalization, ensemble Stack using mean stack mode
Migration	Produced one or two versions depending on the result. Kirchhoff migration (Pre and post stack algorithm) and Stolt F-K with a velocity of 1.4-1.5. K. Time Migration using a constant velocity of 1600 m/velocity picks from velocity analysis (several apertures tested, 1000-1200 show best result for the crust). 2D velocity models were tested on some lines, resulting in improvement of the migration of the upper sediments. Additional tests of velocity and migration aperture can be done for further improvement.
SEG-Y output	IBM floating point CDP_X,4R,IBM,181/ CDP_Y,4R,IBM, 185 Coordinate system: WGS84-UTM32N

The initial filtering included a basic band pass filter, burst noise removal and an F-K filter. Burst noise removal is a standard procedure to diminish spikes in the data that are not generated by a waveform. Bursts appear on single channels, and in this case are caused by electric interference. Burst removal requires a window in which average amplitude values are estimated, and those above a certain percentage threshold rejected. Coherent signal that may be behind bursts is then averaged across a window. True reflection amplitudes are enhanced, and the burst noise removed. The F-K filter is applied to remove coherent noise and out of plane energy. A more broadly defined F-X predictive filter is further applied to suppress additional random noise. An example of this sequence is shown in Figure 12.

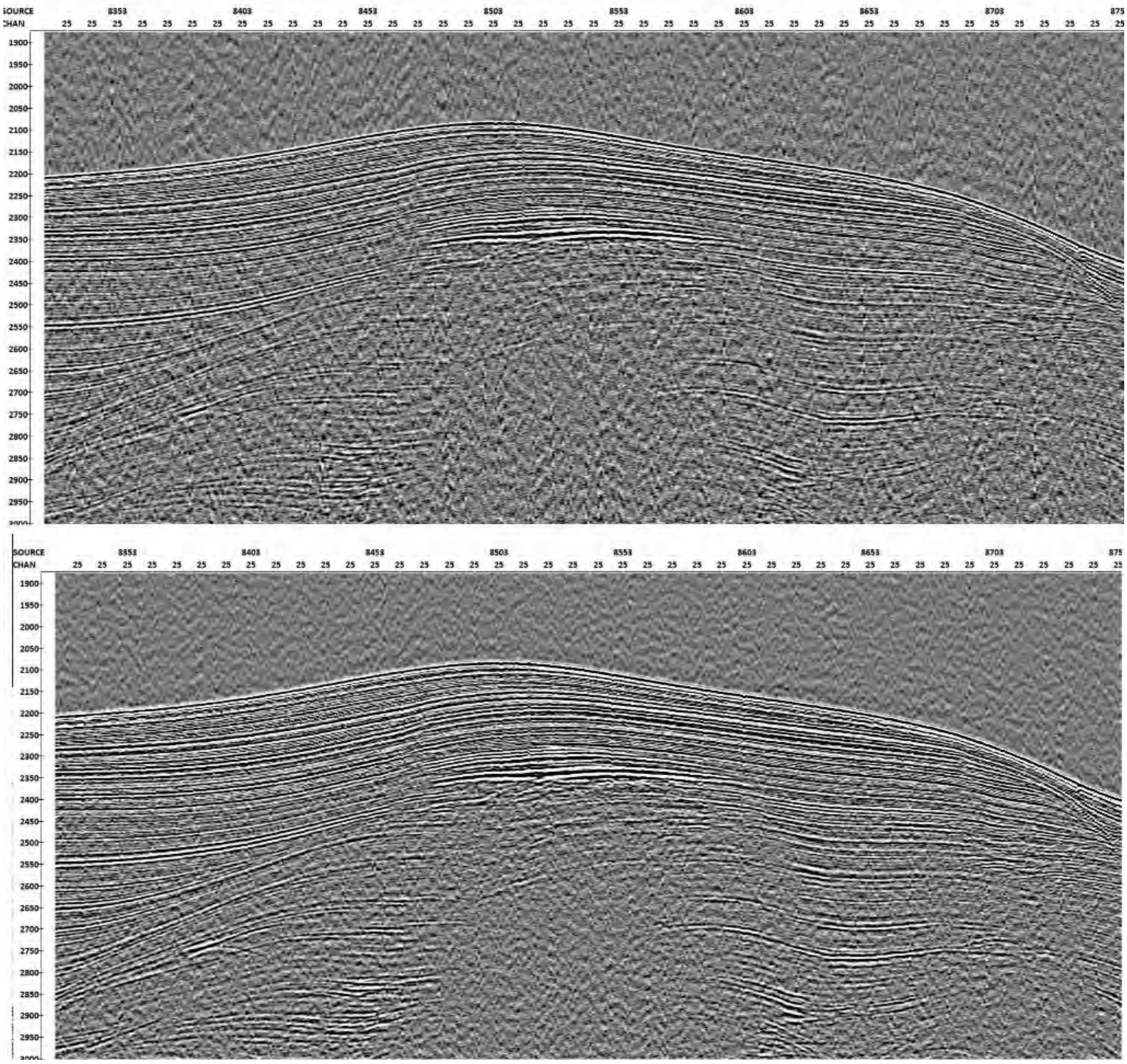


Figure 12: Line 6 example of raw data with a broad band pass filter (above) and burst noise removal plus f-k filtering in addition to band pass filtering (below).

Deghosting is a broadband processing step to recover lost bandwidth due to destructive interference of reflections from the sea surface, intending to enhance the seismic resolution and improve imaging (Wills et al., 2015). Ghost reflectors are caused by energy which has been reflected by the sea-surface either at the source or receiver. However, they arrive at predictable delays from primary reflections and are subtracted from the data using a Radex routine called SharpSeis Deghosting. Figure 13 shows an example of a non-deghosted and deghosted version of line 6. The final version of the seismic data for each line was output in Standard SEG-Y format (Figure 14).

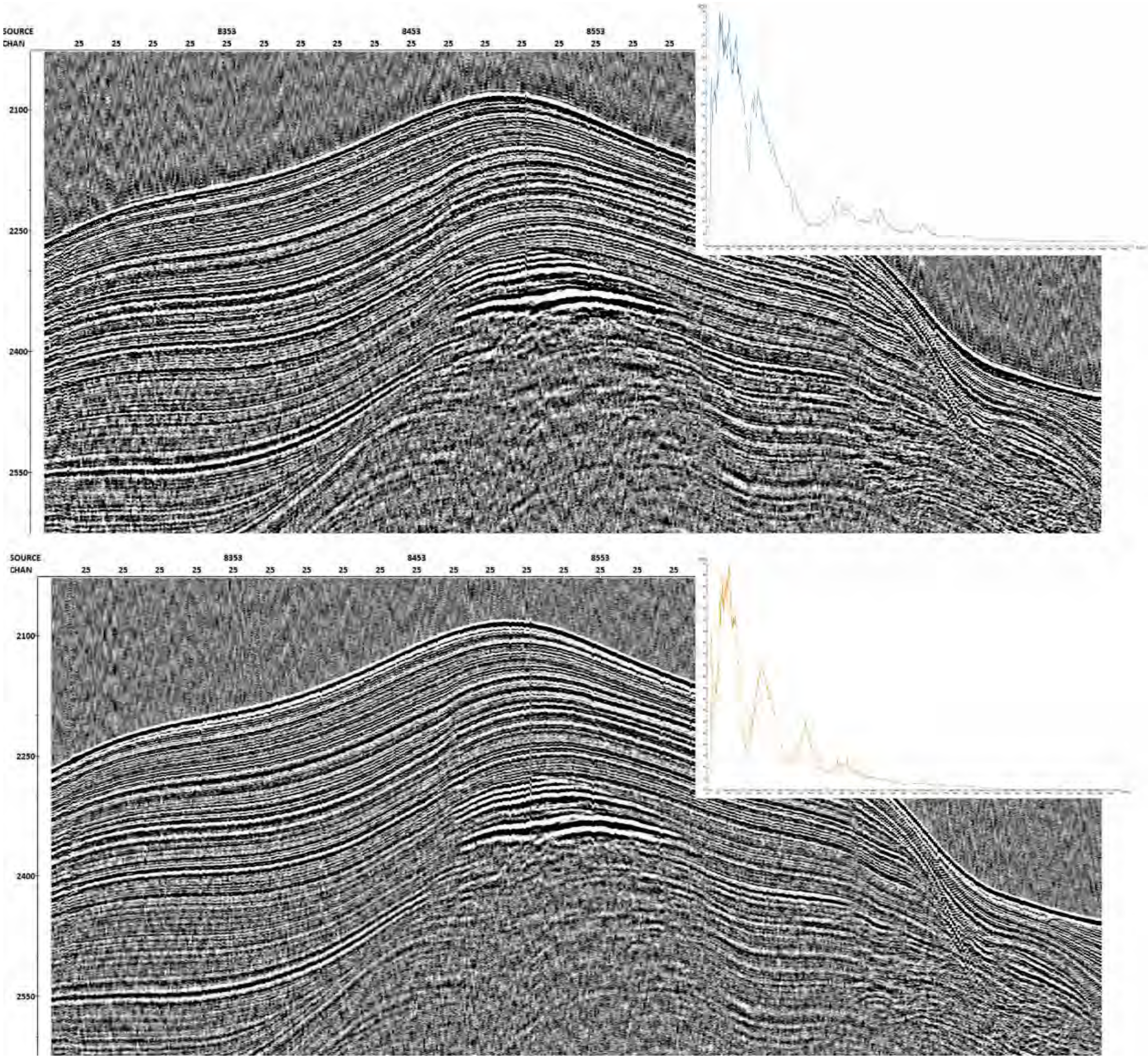


Figure 13: Line 6 example of deghosted (above) and non deghosted (below) with respective frequency spectrums.

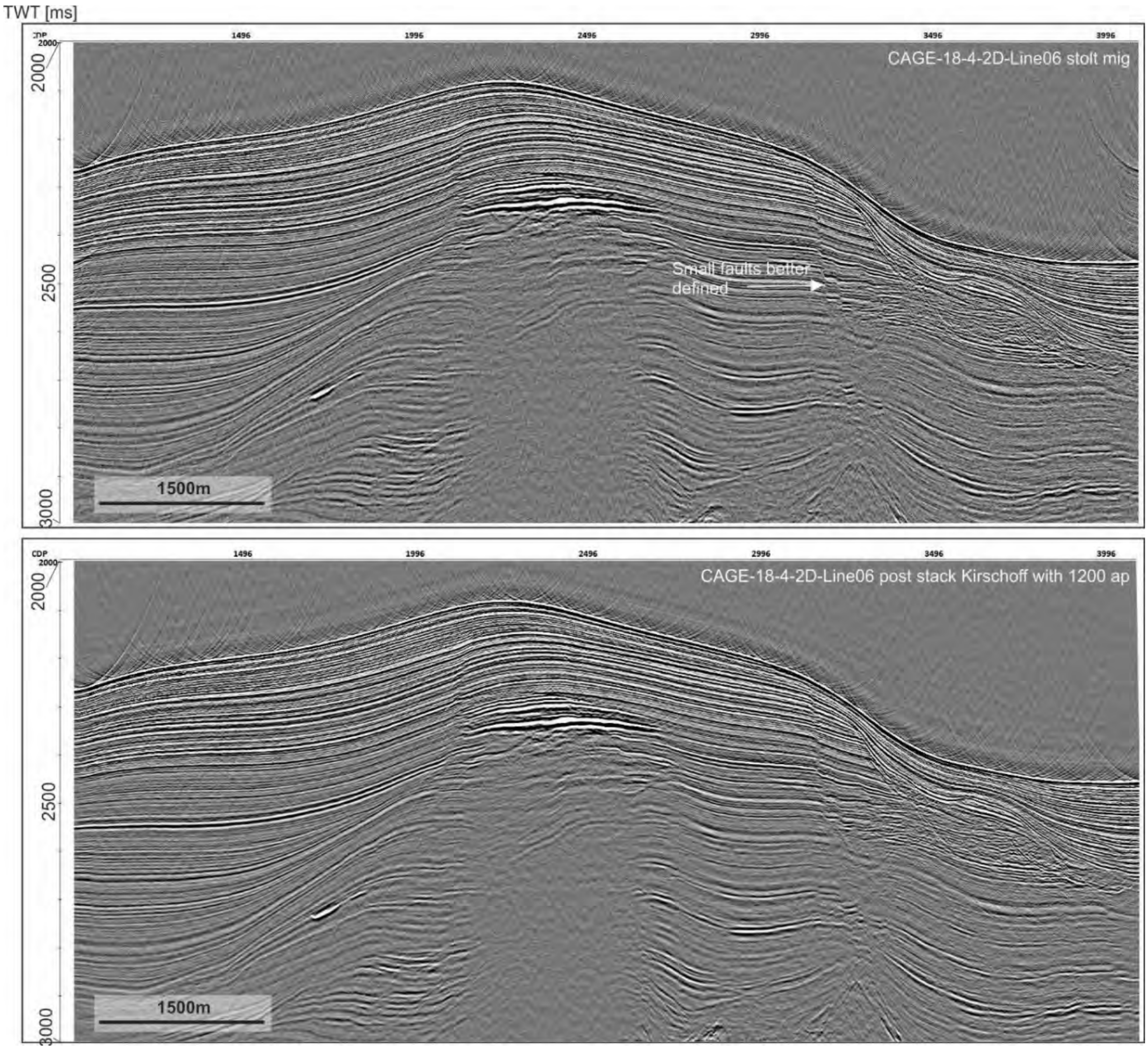


Figure 14: The final version of the seismic data of Line 6 outputted in Standard SEG-Y format.

3D seismic acquisition at Vestnesa Ridge

Two-3D P-Cable volumes were acquired along the Vestensa Ridge in areas complementary to the two already available locations with 3D seismic data (Figure 1). For 3D acquisition, we used the same source set-up as during the 2D survey in the area (see table in chapter above).

3D seismic processing

The seismic data processing sequence includes SEG-D input, geometry assignment and quality control, initial noise filtering, burst noise removal and deghosting on channel gathers, NMO using water velocity, stacking, interpolation to fill empty bins, F-XY filtering and migration. All sailing lines are initially processed individually and subsequently merged for 3D seismic processing. The geometry of the survey is initially assigned through GPS positions of both paravanes and the gun. The direct wave is picked for quality checking the assigned geometry (Figure 15). Deviations are then fitted through a least-squares approach. The final geometry perfectly matches first breaks of the direct wave. This approach ensures uncertainties of receiver positions by only ±1m.
The 3D data is binned to 6.25 m x 6.25 m. This generates a nominal fold of 6-8 traces on average (Figure 16). In areas, where there is an overlap of the acquisition geometry, the fold may be higher (10-15 traces). Deghosting of the data is applied to channel gathers for each acquisition line and generally worked very well, except for some very noisy channels. By line 25 the frequency spectrum was significantly changed: two buoyancies on the cross-cable were lost and the streamer' depth increased (the deghosting parameters were not changed).

Interpolation is necessary to fill in empty bins in the coverage between sailing lines. However, such gaps are most often only 1 bin and occasionally 2 bins in size. After interpolation, we performed additional signal-to-noise ratio enhancement before migration. In the final step, we applied a time variant amplitude gain and an additional F-X predictive filter to enhance deeper reflectors and further increase the signal-to-noise ratio. The final output was exported as standard SEG-Y (available as well are a brute stack and migrated volumes without deghosting or statics). An example inline is shown in Figure 17.

Seismic processing flow	
SEG-D import and geometry assignment	Input of SEG-D files Geometry assignment and offset calculation
Filtering in the shot gathers	Removal of bad channels Bandpass filter of 18-25-1000-1500 Hz Sperical divergence correction / Trace equalization Burst noise removal F-X Predictive filtering
Deghosting in channel gathers	Seafloor picking TopMute (mute above seafloor) Resample to 0.1 ms SharpSeis Deghosting of the receiver ghost Resample back to 0.25 ms TopMute Seafloor picking
Merge and statics	Merge, bin data (6.25x6.25m) and resample to 0.35 ms

	Hi-res static corrections (needs more work, some residual statics remains)
NMO and stacking	NMO using 1500 m/s Ensemble equalization Ensemble Stack using mean stack mode
Profile interpolation	Empty bins filled in by interpolation
Post-Stack noise	Bandpass filtering Ensemble equalization F-X Filter
Migration	Migration using 3D Stolt with a velocity of 1440 and 1480 m/s. Poststack Kirchhoff Time Migration was tested but not finished on the whole cube. (crashed due to empty traces). 2D Kirchhoff worked well on one inline with 200m aperture and 1480 m/s velocity.
SEG-Y output	IBM floating point, big-endian RECNO,4I,,181/SOURCE,4I,,185/ILINE_NO,4I,,189/ XLINE_NO,4I,,193/CDP_X,4R,IBM,197/CDP_Y,4R,IBM, 201 Coordinate system: WGS84-UTM 32N

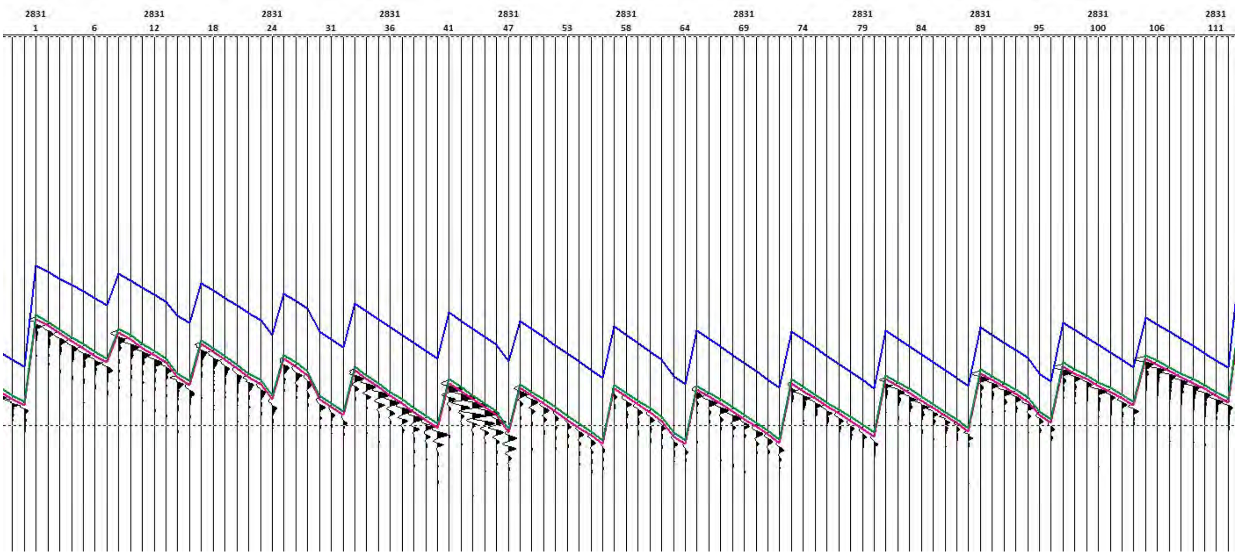


Figure 1: Direct wave arrivals of one shot on acquisition line 1. The blue pick corresponds to the travel time of the assigned geometry from GPS positions plus a bulk shift of xx to help the automatic picker. The red pick is an automatic pick of the direct wave arrival. The green pick corresponds to the arrival time of the geometry fitted through a least-squares approach and perfectly matches the first break of the direct wave.

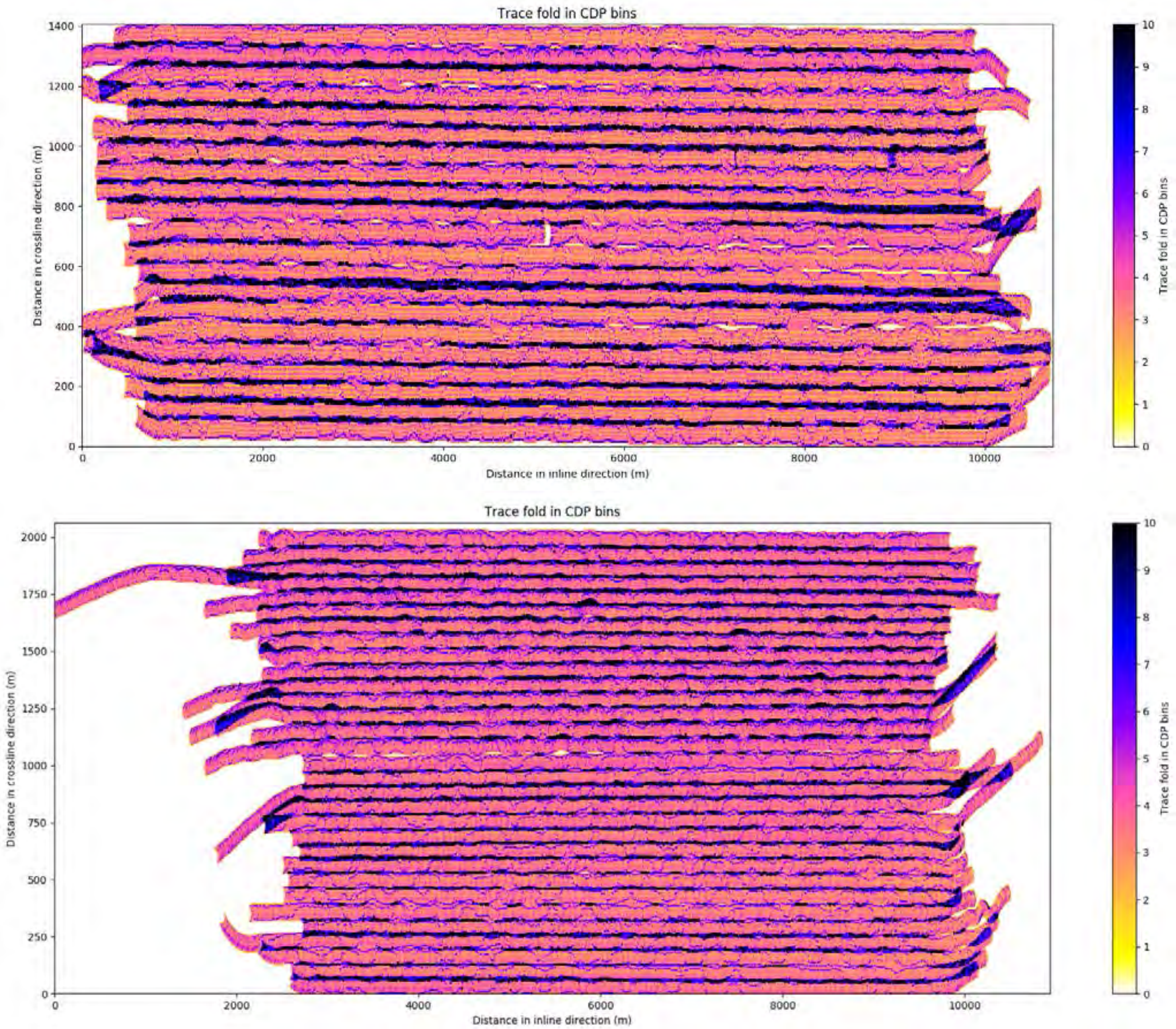


Figure 26: Fold map for volumes Vestnesa18-2 (above) and Vestnesa18-TEW (below).

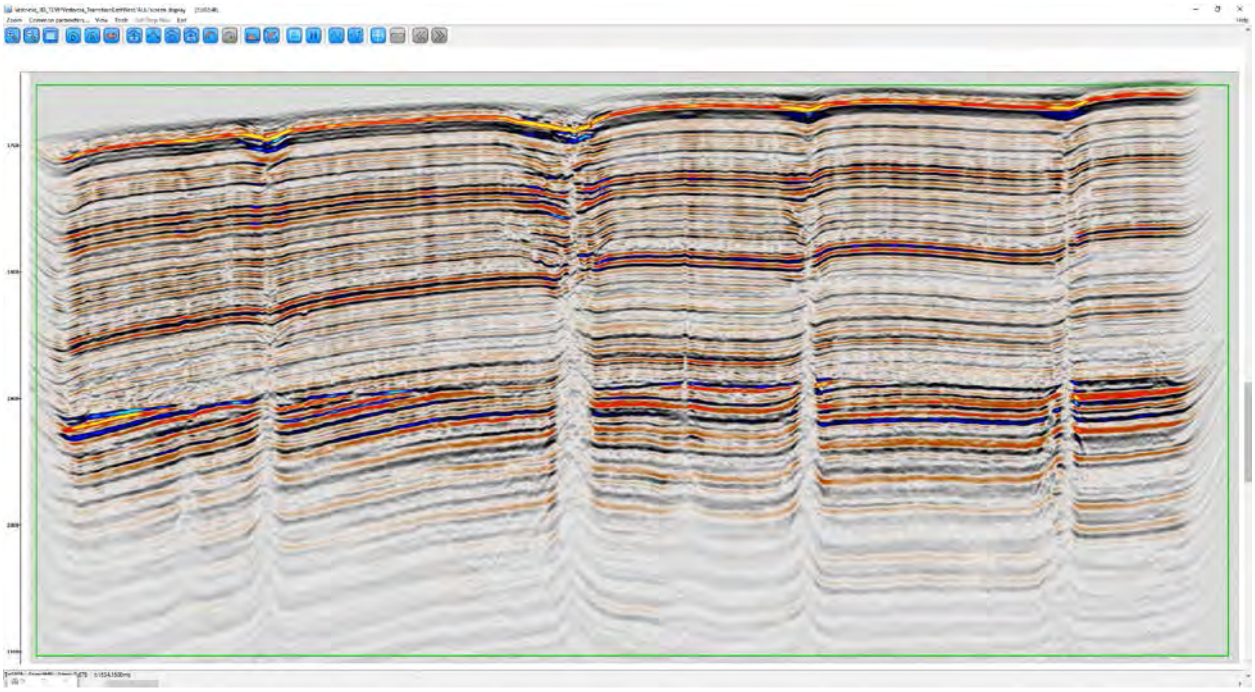


Figure 17: Seismic inline example of the final processed 3D seismic volume.

Data Acquisition in the Leierdjupet Fault Complex, SW Barents Sea

Data acquisition at the Leierdjupet Fault Complex (LFC) focused mainly on tow-cam dives, and sediment and water sampling (Figure 18 and 19). In addition, 6 high-resolution 2D seismic profiles were acquired and the multibeam bathymetry was extended whenever possible.

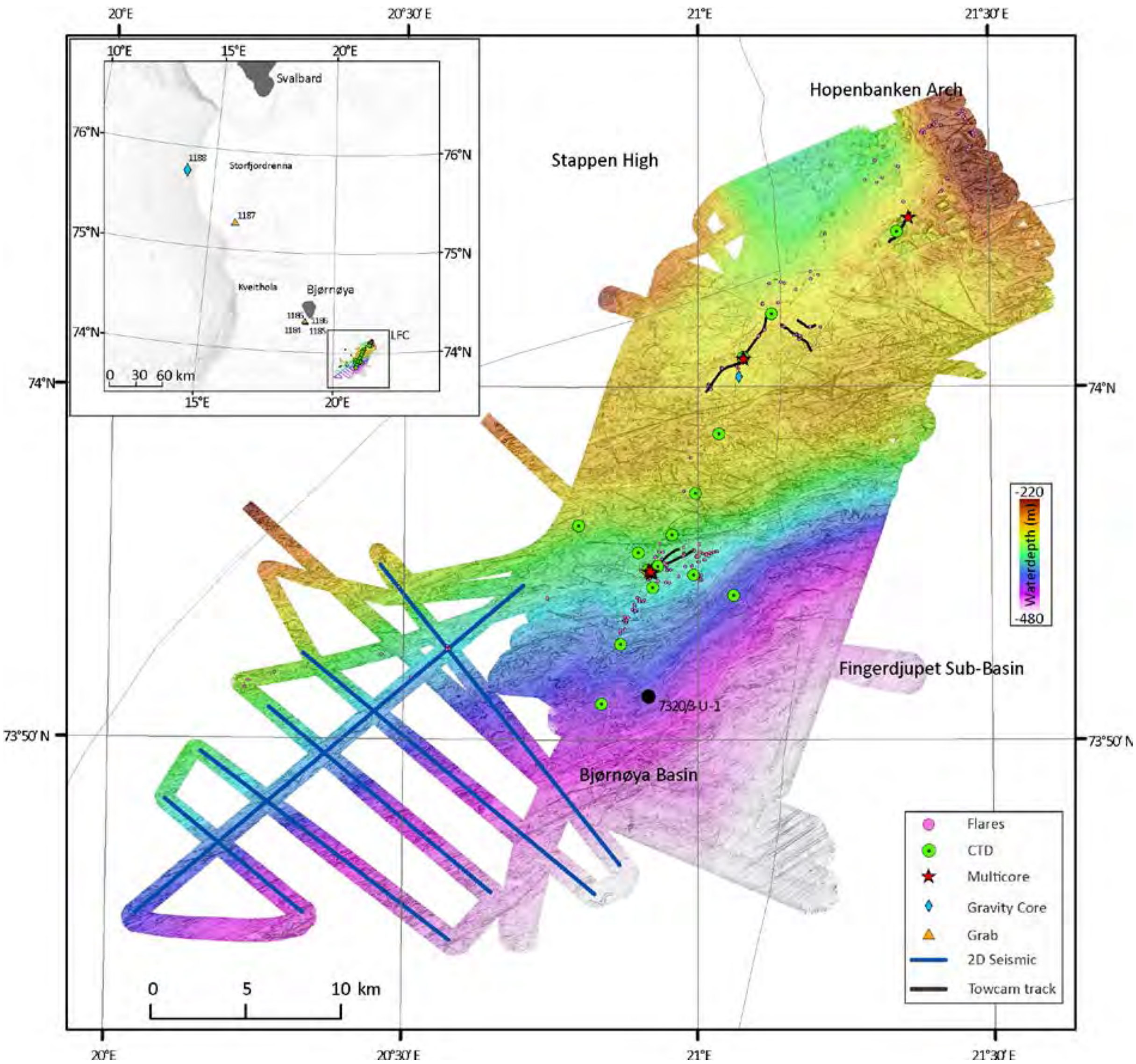


Figure 18: Overview of data acquisition in the Leierdjupet Fault complex.

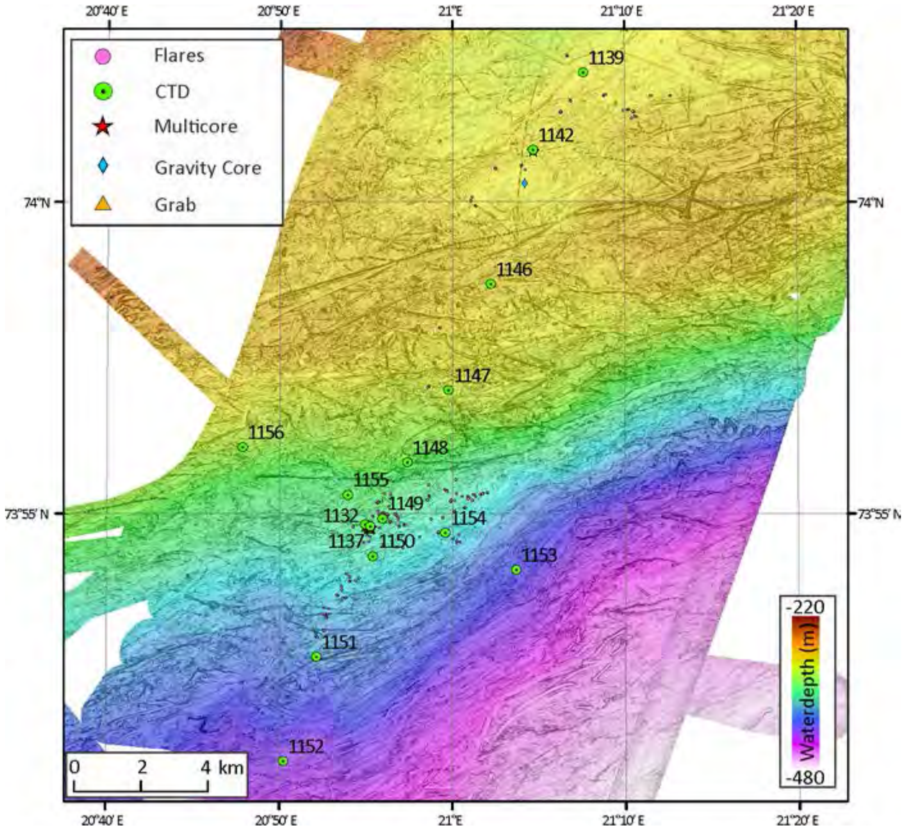


Figure 19: Close-up of the main working area with the most intense gas flaring and samples taken.

Seafloor observations

A total of 14 dives (ca 13 hours) with the CAGEcam video survey were conducted on the Leierdjupet Fault Complex. The seafloor of the investigated area is characterized by soft clay, except some areas where it is covered by debris of rock fragments described like pebbles (0.4 - 6.4cm in diameter) and cobbles (6.5 - 25cm), and boulders (> 25cm) in the logging file using the OFOP software. After preliminary observations on board done on material collected with the grab, the dominant type of lithology of those pebbles is black shale. The fragments are angular to planar, varying in size. Sometimes largest fragment, planar and angular, probably sandstone occur.

Almost all the rocks at the seafloor are colonized by sessile fauna, like anemone, crinoids, sponges and polychaetas (Figure 20). The area is extensively bioturbated, with trails of bivalves and gastropods, and clusters of fish holes (Figure 21). Fish, flat fish like skates, and rare brittle starts are also present. Some area present numerous trawl marks that seems to rework deeper sediment of rock fragments and black shale (Figure 22).

Indication of active seepage was observed in several of TC dives and is characterized by either isolated centimetric bacterial mats (Figure 23) or large bacterial mats (ca 10 square meters) (Figure 24) with associated presence of bubbles and occasionally carbonate crusts (Figure 25). Tube worms, most likely Siboglinids tubeworms (Figure 26), were abundant

In a couple of dives, abundant shrimps were observed in the water column immediately above large bacterial mats.

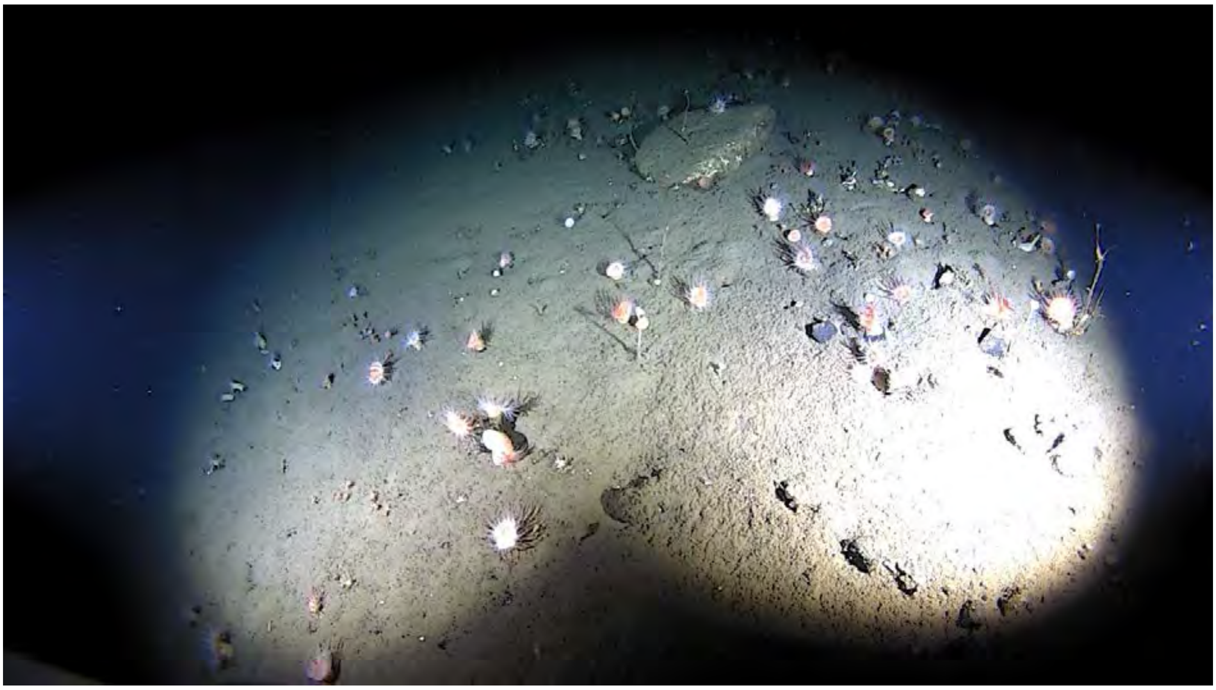


Figure 20: Sessile fauna (HH1169_TC09_00-43-22-00).

Figure 21: Bioturbation with trails of bivalve or gastropods and fish holes (HH1141_TC_06_00-05-07-29).

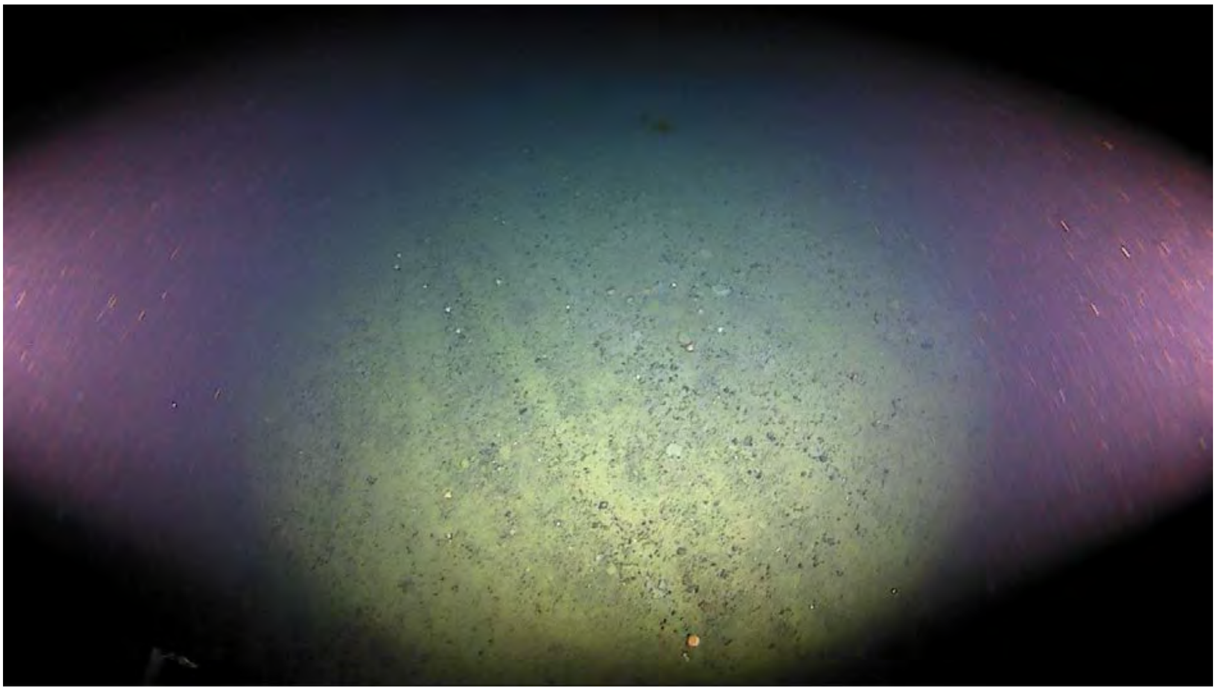


Figure 22: Trawl marks and debris of pebbles (HH1136_TC_04_00-18-14-14-15).

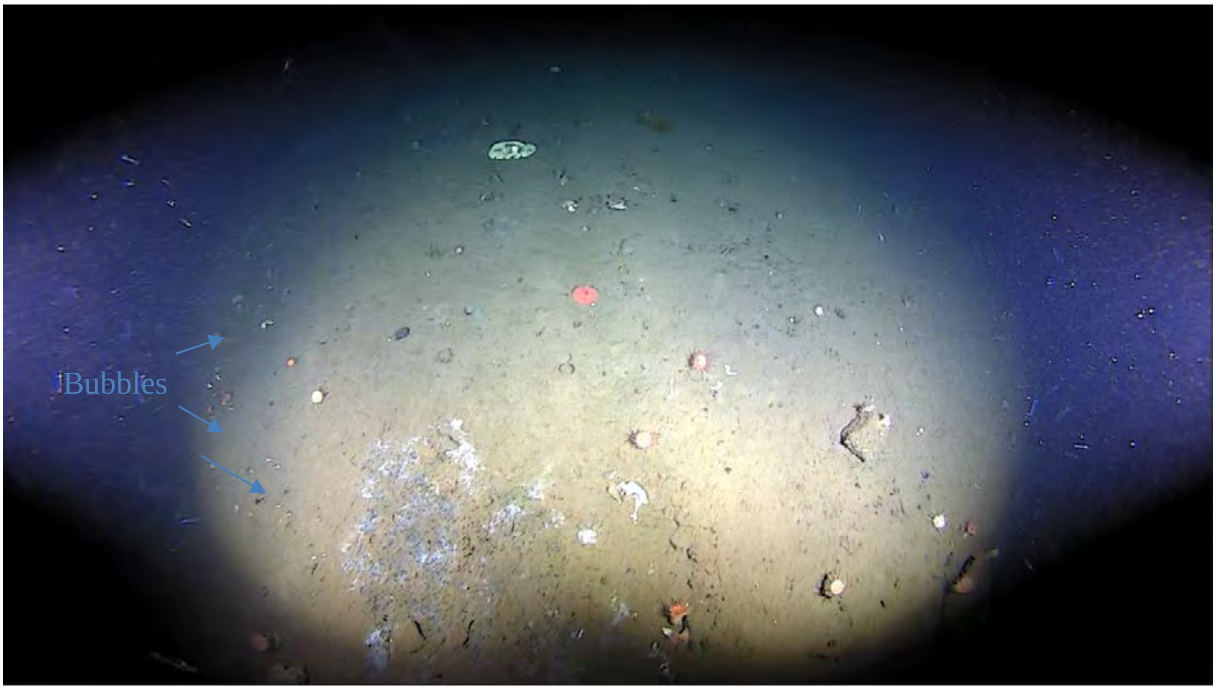


Figure 23: Isolated bacterial mats, ca 30 cm in diameter (HH1135_TC_03_01-59-47-00).

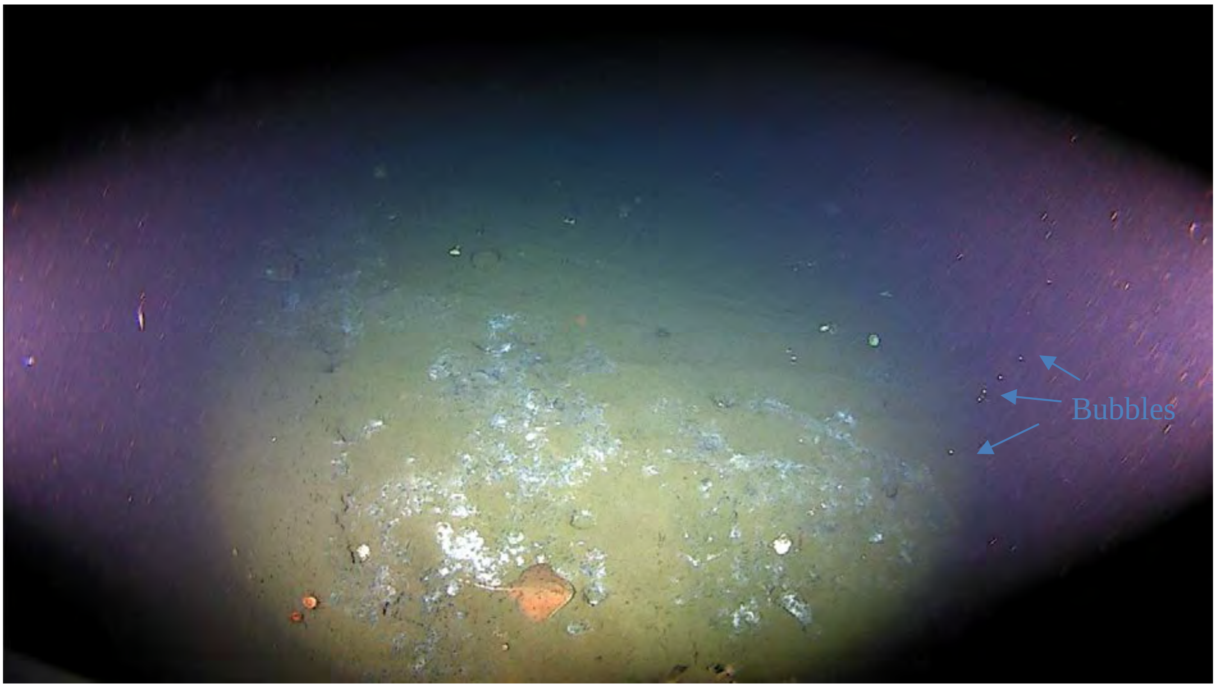


Figure 24: Large bacterial mats (ca 10 square meters) with bubbling gas. A skate sits on it (HH1164_TC4_08-24-50-10).

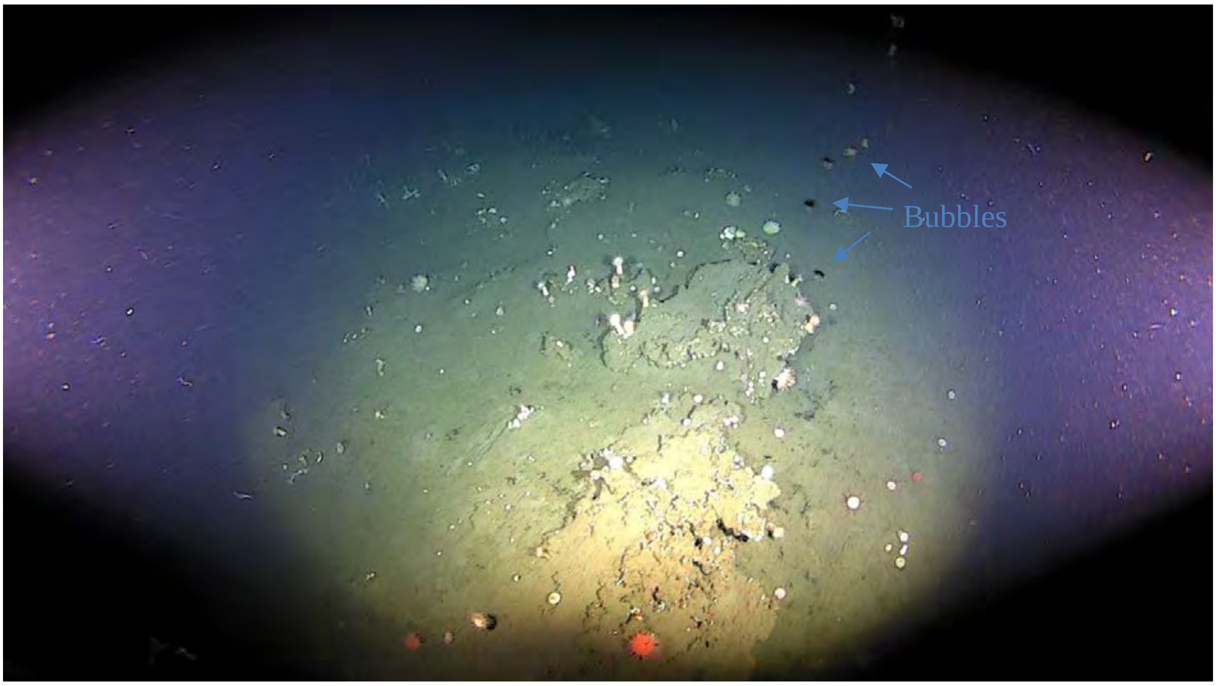


Figure 25: Carbonate crust in an area characterized by flares. The crust is colonized by sessile organisms like anemones and crinoids (HH1141_TC_06_00-05-38-22).

Figure 26: Tube worms (most likely Siboglinids tubeworms) collected in a multicore (10 cm diameter) from HH 1136 site.

Unfortunately, one of the two lasers on the multicorer TC system did not work. To provide an indication about the area that can be seen with the video camera, below there is the fingerprint of the multicorer, with is 11.80 m long and 1.25 m width (Figure 27). The dimension of the area seen changes depending on the altitude.

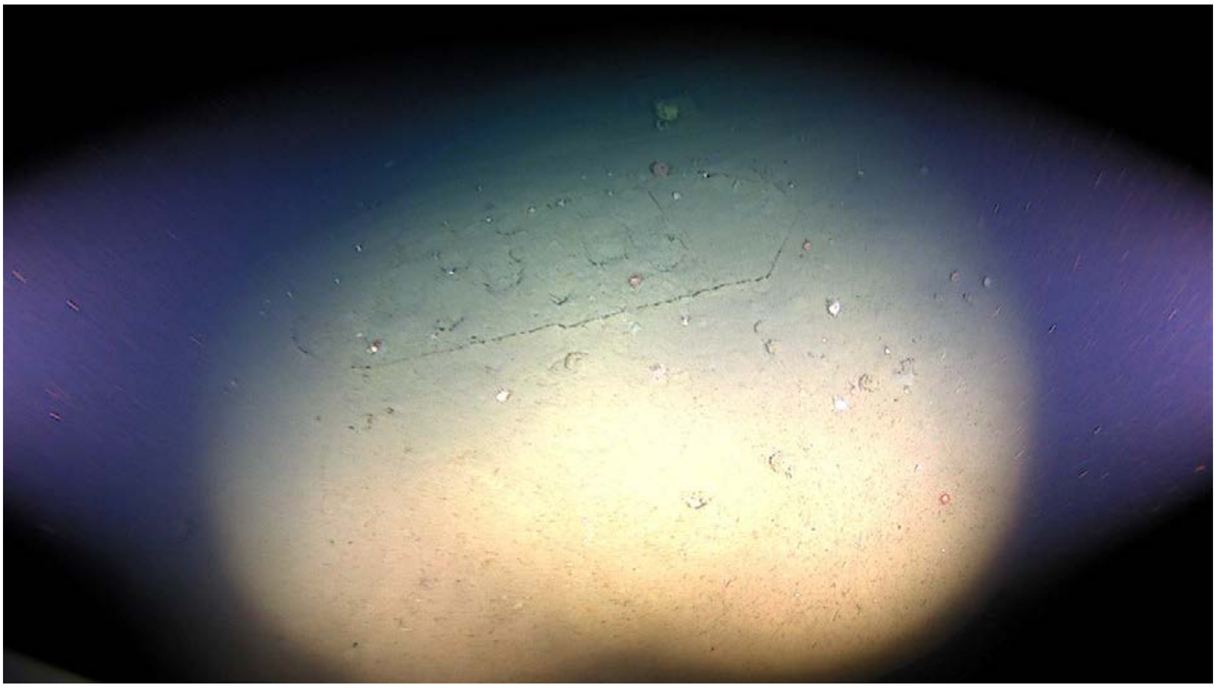


Figure 27: Finger print of the multicorer

Sediment

Sediments collected in multicore is mostly clay, silty clay with sand admixture and rock fragments (2-7 cm in diameter). The multicores collected at bacterial mats or their vicinity exhibit a strong H_2S odor and very dark/black clay. Abundant tubeworms were observed on top of the MC1136 (Figure 9).

During the observation performed on board of sediment samples from the top layer of the grab HH1187 small fragments of green plastic were observed.

Micropaleontology

Micropaleontological observations were made on the surficial sediment (0-0.5 or 0-1 cm) of all stations sampled during the cruise. Evidence of alive forams were found in all the stations, although the number of living foraminifera is very low. Some living calcareous foraminifera appear to have a cist surrounding the shell, or all the chambers occupied by the cell except the last one. Also, porcellaneous, agglutinated, and allogromids forams were found alive.
The color of the cell is green in Cassidulina teretis-neoteretis, brown to green in Nonionella labradorica, dark brown in Robertinoides bradyi and Stainforthia so. Melonis barleanuus has transparent shell. During the observation of the sediment, one porcellaneous specimens was seen moving.

The foraminiferal association is mostly composed by Cassidulina spp., N. labradorica, Melonis barleeanus, Lobatula lobatula, Cibidides spp, Cibicidoides spp., Hoeglundina elegans. Agglutinated species were abundant and diverse in grab HH1187. Occasionally, epiphytic specimens (Cibicides) were attached to either agglutinates forams or small sediment grains. One specimen was found attached to a Siboglinid tubeworms from sample HH1136). Rare Brizalinids and other trochoidal taxon were observed.
In none of the samples investigated on board planktonic foraminifera were found.

During the observation of sediment samples from the top layer of the multicorer and in the grabs, small fragments of green plastic were observed.

Grab Sampling Results

CAGE 18-4 HH1159
Approximately 1 kg of rock fragments were sieved from the sediments in this grab (Figure 28). The largest fragment is a sub-angular finely laminated greenish grey siltstone (8x8x3cm). The laminations are observed by the weathering style of the rock fragment, although some of the laminae have a lighter color. The dominant type of lithology is black shale. The rock fragments are angular to planar, varying in size between 3 cm to less than 0.5 cm in diameter. Most of these shale fragments are indurated, and can be scratched with a knife, but not with a nail, suggesting metasediments with a low degree of metamorphism. About 5-10% of the black shale fragments are very soft, typically 1-2 cm or less in diameter, and planar to angular in shape. These fragments could not have survived extensive glacial transport, and hence are likely locally derived. Remnants of crust material are enclosing a heterogeneous mixture of small 2-5 mm rounded grains of black shale/metasediments. The remaining of the recovered material consists of a mixture of sand to 3 mm sized fragments, including greening sandstone and black to brown metasediments.

Figure 28: Rock fragments from CAGE18_4 HH1159

CAGE 18-4 HH1160
The recovery consists of approximately 750 g of rock fragments sieved from the sediments (Figure 29). The largest piece of rock is an angular black, indurated, finely laminated, and fine grained metasediment (cannot be scratched with the nail). Other metasediments, from sub-rounded to angular, varying in color from brown to black for the dominating type of lithological group. One fragment displays faint (glacial?) striations. One lithological group consists of rounded to sub-rounded soft dark grey shale fragments that can easily be scratched with the nail. These soft shale fragments are probably locally derived, as these could not have survived glacial erosion and transport. One small (3 mm) bivalve was identified in the sieved fraction.


Figure 29: Rock fragments in CAGE18-4 HH1160

CAGE 18-4 HH1161
Approximately 5 kg of rock fragments were sieved from the sediments in this grab (Figure 30). The largest fragment (23x15x7 cm in diameter) is a planar an angular metamorphosed sandstone displaying glacial striations (Figure 31). Metasediments are the dominant lithology

in this grab, with a metamorphosed siltstone (9x9x5 cm in diameter), and black fine grained that are finely laminated, angular to rounded. Two fragments of crust material (5x5 and 3x3 cm) are enclosing and heterogeneous mixture of small 2-5 mm grains. The smaller of the two fragments has some remains of white tube worms and foraminifera.

Figure 30: Rock fragments from CAGE18-4 HH1161

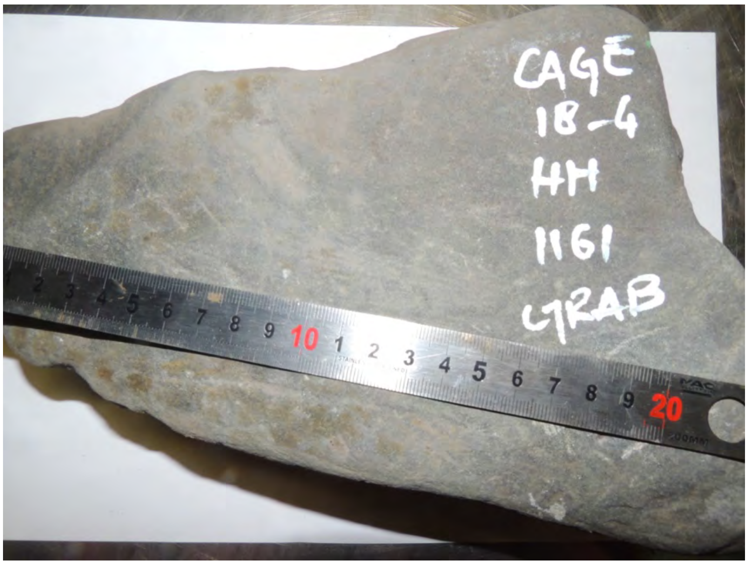


Figure 31: Sandstone from GAGE18-4 HH1161

CAGE 18-4 HH1162

Approximately 1 kg of rock fragments were sieved from the sediments at this location (Figure 32). The largest fragments is a porous greenish to brown coarse sandstone, well lithified (metasediments?). The exposed surface to the seawater display small tube worms and agglutinated white calcareous material. Several small (up to 3 cm diameter) of soft black shale are present, the largest are planar in shape. These fragments are finely laminated. Other fragments include one greenish sub-rounded sandstone with red coating (3 cm in diameter), one well rounded metamorphic sandstone with black laminae, and small angular black fragments of metasediments.

Two small fragments of crust are also present, which consist of an heterogeneous mixture of small rock fragments encase in the fine grained crust. Small live fauna (worms?) can be seen on the surface.

Figure 32: Rock fragments from CAGE15-2 HH1162

CAGE 18-4 HH1165
Grab did not open.

CAGE 18-4 HH1166
The rock fragments that were handpicked from the seafloor sediments in this grab include four lithological groups (Figure 33): sandstone, black shale, metasediments, and siltstone. The three sandstone fragments are coarse grained and sub-angular. Two fragments are large (7-6 cm) and one is 3 cm in diameter. The color varies from dark to light green. The smallest fragment is poorly lithified (locally derived?), while the other two are more indurated. The metasediments are black and angular, with the largest displaying laminations and occasional glacial striations, indicating these samples to have been transported by ice. Soft black shale fragments were also identified. These fragments are between 4 to 2 cm in diameter, and all are planar. The softness of these fragments indicate these samples to be potentially locally derived, or transported from a nearby source. The last group consists of one green and sub-rounded siltstone fragment that displays cross cutting lineations, likely indicating transport by ice.

Figure 33: Rock fragments from CAGE18-4 HH1166

CAGE 18-4 HH1167
Grab almost empty. Few rock fragments were handpicked from the soft sediments, and include four fragments of angular black or brownish metasediments (Figure 34).

Figure 34: Rock fragments from CAGE 18-4 HH1167

ACKNOWLEDGEMENT

We thank the captain and his crew of R/V Helmer Hanssen of the University of Tromsø for their excellent support during the scientific surveys. This part of the cruise was conducted under the framework of the Centre of Excellence on Gas Hydrates, Environment and Climate (CAGE) (Norwegian Research Council (NFR) project number 223259/F5 at the University of Tromsø and also supported by DEA Norge AS.

APPENDIX

2D seismic log CAGE18-4

Site/Area	Line Name	Line Id	Date (UTC)	Time (UTC)	Latitude	North/South	Longitude	East/West	End Time (UTC)	Latitude (end)	North/South (end)	Longitude (end)	East/West (end)	Pulse Mode / Equipment	Shot Rate (hz)	Speed (kn)	Notes
Vestnesa	1109	CAGE_18_4_HH_001_2D	21.07.2018	06:22:41	79.0728	N	4.6436	E	08:19:16	79.2136	N	4.8135	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.25 ms, record length 4s, Preamp gain 18dB. Wind 1 m/s Airtemp 6degC, Seatemp 6degC, wave 1 m. After the end of the line, guns and streamers were taken aboard to check the source of the noise appearing in the records. From 1695- 2179 are test shots.
Vestnesa	1110	CAGE_18_4_HH_002_2D	21.07.2018	11:30:06	79.2174	N	4.6802	E	13:24:54	79.0735	N	4.4427	E	2 mini GI (30/30 & 15/15)	6	5	Guns and streamers taken aboard to check noise source, quality of data improved. Wind 5 m/s Airtemp 3degC, Seatemp 6degC, wave 1.5 m. sampling rate 0.25 ms
Vestnesa	1111	CAGE_18_4_HH_003_2D	21.07.2018	13:47:07	79.0780	N	4.4806	E	16:11:06	79.2318	N	3.8769	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.5 ms, record length 5s.
Vestnesa	1112	CAGE_18_4_HH_003b_2D	21.07.2018	16:21:54	79.2391	N	3.8789	E	18:02:30	79.1050	N	3.8708	E	2 mini GI (30/30 & 15/15)	6	5	Transit line southward to start of line 4. Sampling interval 0.5 ms, record length 5s.
Vestnesa	1113	CAGE_18_4_HH_004_2D	21.07.2018	18:10:35	79.1071	N	3.8523	E	20:46:54	79.2399	N	4.7828	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.5 ms, record length 5s.
Vestnesa	1114	CAGE_18_4_HH_005_2D	21.07.2018	20:54:18	79.2424	N	4.7436	E	22:03:30	79.1864	N	4.3046	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.5 ms, record length 5s.
Vestnesa	1115	CAGE_18_4_HH_006_2D	21.07.2018	22:29:12	79.1762	N	4.4236	E	23:31:18	79.2278	N	4.7947	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.25 ms, record length 4s.

Vestnesa	1116	CAGE_18_4_HH_007_2D	21.07.2018	23:44:48	79.2168	N	4.8196	E	00:49:23	79.1629	N	4.4275	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.25 ms, record length 4s.
Vestnesa	1117	CAGE_18_4_HH_008_2D	22.07.2018	01:07:35	79.1544	N	4.4397	E	02:39:48	79.1682	N	5.0705	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.25 ms, record length 4s.
Vestnesa	1118	CAGE_18_4_HH_009_2D	22.07.2018	02:51:24	79.1647	N	5.0530	E	03:38:48	79.1904	N	4.7205	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.25 ms, record length 4s. For the first 60 shots, the ship was running at 6.5 knots
Vestnesa	1119	CAGE_18_4_HH_010_2D	22.07.2018	03:53:30	79.1831	N	4.7278	E	05:14:59	79.1428	N	5.2626	E	2 mini GI (30/30 & 15/15)	6	5	Sampling interval 0.25 ms, record length 4s.
Molloy Ridge transect	1121	CAGE_18_4_HH_011_2D	24.07.2018	13:13:01	79.1667	N	5.2545	E	00:56:00	79.7402	N	0.8403	E	2 mini GI (30/30 & 15/15)	6	5	Starting with sampling interval 0.25 ms, record length 4s, shooting interval 6s.From shot 13047 sampling interval is 0.5 ms, record length 5s. From shot 14050 shot interval changed to 7 sec, recording length at 6 sec, sampling rate 0.5 ms. From 14201 preamp gain set to 30 db. From 15681 changed shooting rate back to 6 sec and rec length to 5 sec. Record length changed to 4s from shot number 17029. Sampling rate 0.25 ms. record length changed to 4s ans sampling interval to 0.5 ms from shot 17476. some channels towards the end of the line are very noisy with very high amplitude due to sea ice. shot numbers 18653 - 18707 are test shots prior to the start of the line 12, should be discarded.
Vestnesa	1123	CAGE_18_4_HH_012_2D	25.07.2018	13:02:41	79.1998	N	3.9032	E	16:12:41	78.9878	N	4.6721	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;
Vestnesa	1124	CAGE_18_4_HH_013_2D	25.07.2018	16:24:00	78.9915	N	4.7284	E	18:45:29	79.1842	N	4.9450	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;

Molloy Transform	1126	CAGE_18_4_HH_014_2D	27.07.2018	17:37:25	78.9283	N	4.6663	E	20:39:25	78.7568	N	3.7156	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;
Molloy Transform	1127	CAGE_18_4_HH_015_2D	27.07.2018	21:10:55	78.7810	N	3.5463	E	00:06:40	78.9550	N	4.5069	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;
Molloy Transform	1128	CAGE_18_4_HH_016_2D	28.07.2018	00:48:46	78.9732	N	4.2900	E	03:01:10	78.8539	N	3.6051	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;
Molloy Transform	1129	CAGE_18_4_HH_017_2D	28.07.2018	03:27:52	78.8615	N	3.5820	E	08:17:00	78.6447	N	5.4663	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;
West Svyatogor Ridge	1130	CAGE_18_4_HH_018_2D	28.07.2018	10:11:52	78.4317	N	5.3188	E	12:45:00	78.2566	N	4.6663	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;
West Svyatogor Ridge	1131	CAGE_18_4_HH_019_2D	28.07.2018	13:48:34	78.1757	N	4.8944	E	16:00:34	78.3442	N	5.4129	E	2 mini GI (30/30 & 15/15)	6	5	Sampling rate 0.5 ms; recording length 5 s; preamp gain 18 db;
Leierdjupet Fault Complex	1168	CAGE_18_4_HH_020_2D	02.08.2018	22:00:44	73.9063	N	20.7035	E	00:47:08	73.7506	N	20.0506	E	1 GI (105/105)	10	5	Sampling rate 0.5 ms; recording length 2 s; preamp gain 18 db; Channel 4 is dead. Seatemp 8.7 degC windspeed 6.5 m/s
Leierdjupet Fault Complex	1168	CAGE_18_4_HH_021_2D	03.08.2018	01:50:21	73.7517	N	20.3333	E	02:53:50	73.8046	N	20.0984	E	1 GI (105/105)	10	5	Sampling rate 0.5 ms; recording length 2 s; preamp gain 18 db; Channel 4 is dead. Seatemp 9.8 degC windspeed 2.0 m/s
Leierdjupet Fault Complex	1168	CAGE_18_4_HH_022_2D	03.08.2018	03:15:50	73.8273	N	20.1583	E	05:01:20	73.7390	N	20.5799	E	1 GI (105/105)	10	5	Sampling rate 0.5 ms; recording length 2 s; preamp gain 18 db; Channel 4 is dead. Seatemp 9.8 degC windspeed 2.0 m/s
Leierdjupet Fault Complex	1168	CAGE_18_4_HH_023_2D	03.08.2018	05:28:18	73.7616	N	20.6505	E	07:09	73.8483	N	20.2725	E	1 GI (105/105)	10	5	Sampling rate 0.5 ms; recording length 2 s; preamp gain 18 db; Channel 4 is dead. Seatemp 9.8 degC windspeed 2.0 m/s. On recovery, it was found that gun 1 (which was shooting) is hanging from a single chain, instead of two.

Leierdjupet Fault Complex	1177	CAGE_18_4_HH_024_2D	03.08.2018	23:12:00	73.8763	N	20.3353	E	01:23	73.7608	N	20.8258	E	1 GI (105/105)	10	5	Sampling rate 0.5 ms; recording length 2 s; preamp gain 18 db. Seatemp 9.8 degC windspeed 2.5 m/s
Leierdjupet Fault Complex	1177	CAGE_18_4_HH_025_2D	04.08.2018	01:42:08	73.7747	N	20.8684	E	03:43	73.9212	N	20.4798	E	1 GI (105/105)	10	5	Sampling rate 0.5 ms; recording length 2 s; preamp gain 18 db. Seatemp 9.4 degC windspeed 2.5 m/s

CTD stations

Site/Area	Ship Station	Station Id	Date (UTC)	Time (UTC)	Latitude	North/South	Longitude	East/West	Water Depth
Vestnesa	1108	CAGE_18_4_HH_1108_CTD	21.07.2018	03:10	79.06283	N	4.69113	E	2198
Molloy Ridge	1122	CAGE_18_4_HH_1122_CTD	25.07.2018	06:36	79.54783	N	3.68771	E	3120
Leierdjupet Fault Complex	1132	CAGE_18_4_HH_1132_CTD	31.07.2018	11:02	73.91403	N	20.91524	E	346
Leierdjupet Fault Complex	1137	CAGE_18_4_HH_1137_CTD	31.07.2018	21:35	73.91365	N	20.92045	E	349
Leierdjupet Fault Complex	1139	CAGE_18_4_HH_1139_CTD	01.08.2018	08:50	74.03495	N	21.12642	E	290
Leierdjupet Fault Complex	1142	CAGE_18_4_HH_1142_CTD	01.08.2018	15:33	74.01434	N	21.07770	E	290
Leierdjupet Fault Complex	1146	CAGE_18_4_HH_1146_CTD	01.08.2018	20:32	73.97843	N	21.03646	E	279
Leierdjupet Fault Complex	1147	CAGE_18_4_HH_1147_CTD	01.08.2018	21:09	73.95017	N	20.99581	E	295
Leierdjupet Fault Complex	1148	CAGE_18_4_HH_1148_CTD	01.08.2018	21:44	73.93067	N	20.95639	E	322
Leierdjupet Fault Complex	1149	CAGE_18_4_HH_1149_CTD	01.08.2018	22:14	73.91571	N	20.93207	E	342
Leierdjupet Fault Complex	1150	CAGE_18_4_HH_1150_CTD	01.08.2018	22:55	73.90561	N	20.92320	E	358
Leierdjupet Fault Complex	1151	CAGE_18_4_HH_1151_CTD	01.08.2018	23:38	73.87882	N	20.86879	E	379
Leierdjupet Fault Complex	1152	CAGE_18_4_HH_1152_CTD	02.08.2018	00:33	73.85082	N	20.83700	E	418
Leierdjupet Fault Complex	1153	CAGE_18_4_HH_1153_CTD	02.08.2018	01:45	73.90200	N	21.06088	E	404
Leierdjupet Fault Complex	1154	CAGE_18_4_HH_1154_CTD	02.08.2018	02:30	73.91185	N	20.99278	E	364
Leierdjupet Fault Complex	1155	CAGE_18_4_HH_1155_CTD	02.08.2018	03:26	73.92207	N	20.89857	E	341
Leierdjupet Fault Complex	1156	CAGE_18_4_HH_1156_CTD	02.08.2018	04:01	73.93482	N	20.79695	E	313
Leierdjupet Fault Complex	1182	CAGE_18_4_HH_1182_CTD	04.08.2018	18:50	74.07381	N	21.34140	E	312

Coring stations

Ship Station	Activity	Station Id	Date (UTC)	Time (UTC)	Latitude	North/South	Longitude	East/West	Water Depth	Notes
1133	Multicore	CAGE_18_4_HH_1133_MC	31.07.2018	13:05	73 54.8384	N	20 54.9717	E	343	
1134	Multicore	CAGE_18_4_HH_1134_MC	31.07.2018	14:01	73 54.813	N	20 55.203	E	348	
1135	Multicore	CAGE_18_4_HH_1135_MC	31.07.2018	18:55	73 54.800	N	20 55.252	E	347	
1136	Multicore	CAGE_18_4_HH_1136_MC	31.07.2018	20:27	73 54.798	N	20 55.209	E	352	gassy sediments
1140	Multicore	CAGE_18_4_HH_1140_MC	01.08.2018							tow cam survey only
1141	Multicore	CAGE_18_4_HH_1141_MC	01.08.2018	13:50	74 00.932	N	21 04.266	E	285	
1143	Gravitycore	CAGE_18_4_HH_1143_GC	01.08.2018	17:19	74 00.847	N	21 04.725	E	296	strong smell of H2S
1144	Gravitycore	CAGE_18_4_HH_1144_GC	01.08.2018	18:33	74 00.851	N	21 04.634	E	296	strong smell of H2S
1145	Gravitycore	CAGE_18_4_HH_1145_GC	01.08.2018	19:44	74 00.319	N	21 04.217	E		
1158	Multicore	CAGE_18_4_HH_1158_MC	02.08.2018	09:21		N		E		Aborted due to communication failure with lamps
1159	Grab	CAGE_18_4_HH_1159_Grab	02.08.2018	10:21	73 54.7812	N	20 55.1739	E	345	
1160	Grab	CAGE_18_4_HH_1160_Grab	02.08.2018	10:50	73 54.7708	N	20 55.2462	E	349	
1161	Grab	CAGE_18_4_HH_1161_Grab	02.08.2018	11:10	73 54.7783	N	20 55.1756	E	349	
1162	Grab	CAGE_18_4_HH_1162_Grab	02.08.2018	11:35	73 54.7735	N	20 55.1578	E	345	

1163	Multicore	CAGE_18_4_HH_1163_MC	02.08.2018	16:14	73 54.788	N	20 55.206	E	345	tow cam track, core taken at the end, ships position. For core pos refer to USBL log
1164	Multicore	CAGE_18_4_HH_1164_MC	02.08.2018	18:17	73 54.799	N	20 55.141	E	348	No recovery
1165	Grab	CAGE_18_4_HH_1165_Grab	02.08.2018	18:53	73 54.7973	N	20 55.1310	E	344	Empty
1166	Grab	CAGE_18_4_HH_1166_Grab	02.08.2018	19:05	73 54.7941	N	20 55.1544	E	344	
1167	Grab	CAGE_18_4_HH_1167_Grab	02.08.2018	09:23	73 54.7979	N	20 55.1635	E	344	
1169	Multicore	CAGE_18_4_HH_1169_MC	03.08.2018	09:39	73 55.151	N	20 56.643	E		tow cam survey only, track through flares, position is start of track running in SW direction
1170	Multicore	CAGE_18_4_HH_1170_MC	03.08.2018			N		E		tow cam track, core taken at the end, ships position. For core pos refer to USBL log
1171	Multicore	CAGE_18_4_HH_1171_MC	03.08.2018	14:40	73 54.827	N	20 55.243	E		
1172	Gravitycore	CAGE_18_4_HH_1172_GC	03.08.2018	18:11	73 54.8178	N	20 55.2270	E	345	likely position of the core 73 54.806, 20 55.192
1173	Gravitycore	CAGE_18_4_HH_1173_GC	03.08.2018	19:02	73 54.8100	N	20 55.2540	E	350	likely position of the core 73 54.8076, 20 55.2047
1174	Gravitycore	CAGE_18_4_HH_1174_GC	03.08.2018	19:31	73 54.8045	N	20 55.2407	E	351	likely position of the core 73 54.8044, 20 55.1941

1175	Gravitycore	CAGE_18_4_HH_1175_GC	03.08.2018	20:15	73 54.814	N	20 55.241	E	350	likely position of the core 73 54.8040, 20 55.2186; station doesn't exist in stasjonslapper because captain deleted a double station 1174 which should have been 1175, while he wanted to delete en empty core station 1173, our numbers and positions are correct.
1176	Gravitycore	CAGE_18_4_HH_1176_GC	03.08.2018	20:55	73 54.805	N	20 55.303	E	350	likely position of the core 73 54.7938, 20 55.3079
1179	Multicore	CAGE_18_4_HH_1179_GC	04.08.2018							tow-camera track only
1180	Multicore	CAGE_18_4_HH_1180_GC	04.08.2018							tow-camera track only
1181	Multicore	CAGE_18_4_HH_1181_GC	04.08.2018	16:20	74 04.869	N	21 21.738	E	298	Position is position of multicore at the end of tow cam track
1184	Grab	CAGE_18_4_HH_1184_Grab	05.08.2018	13:51	74 18.5616	N	18 56.5439	E	43	Empty
1185	Grab	CAGE_18_4_HH_1185_Grab	05.08.2018	13:58	74 18.7496	N	18 55.8795	E	35	
1186	Grab	CAGE_18_4_HH_1186_Grab	05.08.2018	14:07	74 18.8659	N	18 55.5778	E	38	Empty
1186	Grab	CAGE_18_4_HH_1186_Grab	05.08.2018	14:12	74 18.9370	N	18 55.1220	E	40	
1187	Grab	CAGE_18_4_HH_1187_Grab	05.08.2018	20:56	75 16.7960	N	16 00.6800	E	205	
1188	Gravitycore	CAGE_18_4_HH_1188_GC	06.08.2018	02:24	75 45.428	N	13 51.413	E	787	

Video Log of tow-cam dives

				Infodisplay				
				VIDEO CLIP	**VIDEO CLIP**	**TIME CODE**		
Station #	TC/MC #	VID	UTC Date	UTC Start Time	UTC End Time	Elapsed Time	Note	notes
1133	1	1	31.07.2018			00:00:00:03	beacon 1; lat long from the ship; no laser on	short video showing the descending
1133	1	2	31.07.2018	12:58:59	13:05:51	00:00:10:15	beacon 1; lat long from the ship; no laser on	station for sediment recovery; no seabed anomalies; no recovery
1134	2	1	31.07.2018	13:58.24	14:03:36	00:00:05:17	beacon 1; lat long from the ship; no laser on; one core lost during recovery	station for sediment recovery; no seabed anomalies; video show the multicore sampling
1135	3	1	31.07.2018	16:55:11	18:56:41	2:01:26:00	beacon 4; lat long from the USBL; no laser on	Multicore transect; at the end of the lowering there are several mats (metric in diameter) MC landed on bacterial mats with bubbles
1136	4	1	31.07.2018	19:49:52	20:28:14	00:37:55:28	beacon 4; lat long from the USBL; no laser on	repeat 1135 station location; bacterial mats and bubbling; MC landed on bacterial mats; core bubbling once on deck and strong H2S smell
1140	5	2	01.08.2018	12:37:52	12:58:32	00:20:44:13	beacon 4; lat long from USBL, lasers: one of the two laser does not work	MC not taken
1141	6	1	01.08.2018	14:07:57	14:17.30	00:07:00:00	beacon 2 and 4; lat long from USBL, no laser	looking for evidences of methane emissions
1141	6	2	01.08.2018	14:17:31	14:32:10	00:16:30:00	beacon 2 and 4; lat long from USBL, no laser	looking for evidences of methane emissions

1141	6	3	01.08.2018	14:32:10	14:41:22	00:07:23:02	beacon 2 and 4; lat long from USBL, no laser	carbonate crusts and bubbles; MC taken few meters next to carbonate crust with strong bubbling
1141	6	4	01.08.2018	14:53:41	14:56:59	00:03:44:13	beacon 2 and 4; lat long from USBL, no laser	recovery
1163	7	1	02.08.2018			00:10:00:00	beacon 2 and 4; lat long from USBL, no laser	10 seconds video to check that all connection and comunications work
1163	7	2	02.08.2018	15:46:00	15:46:33	00:02:28:18	beacon 2 and 4; lat long from USBL, no laser	video of the propeller of HH
1163	7	3	02.08.2018	15:54:06	16:10:31	00:17:25:10	beacon 2 and 4; lat long from USBL, no laser	bacterial mats and bubbling
1164	8	1	02.08.2018	14:16:50	18:18:33	01:04:53:12	beacon 2 and 4; lat long from USBL, no laser	finger print of MC, bacterial mats and bubbling
1169	9	1	03.08.2018	09:22:05	10:44:02	01:21:56:02	beacon 2 and 4; lat long from USBL, no laser	bacterial mats at 9:57 UTC. Debris of pebbles, and sometimes rocks colinized by sessile organisms
1170	10	1	03.08.2018			01:05:48:13	beacon 2 and 4; lat long from USBL, no laser	MC taken few meters from baterial mats and bubbling area; TC hits the seafloor few times; two cables disconnected from the MC frame and we saw in the video
1171	11	1	03.08.2018	14:53:00	16:10:21	01:17:14:03	beacon 2 and 4; lat long from USBL, no laser	MC taken 2-3 meters from site MC1163; massive schimps close to seafloor, mostly close to mats. Fingerprint of the MC1164
1179	12	1	04.08.2018	11:14:30	12:33:30	01:22:56:25	beacon 2 and 4; lat long from USBL, no laser	within the depression there is soft sediments, no pebbles, no sessile organisms, only bioturbation of fish. Around the depression, soft seafloor with debris of pebbles colonized

								by sessione ornganisms, few fish observed. MC not taken
1180	13	1	04.08.2018	13:28:10	14:49:50	01:21:38:16	beacon 2 and 4; lat long from USBL, no laser	same characteristics of the previous dives. Within the second depression, the seafloor is caracterized by soft sediments, strongly bioturbated, and rare sessile fauna colonizing prebbles. Clear trawl marks. Finger print of our anchor (?)
1180	13	2	04.08.2018	13:08:50	15:10:27	00:02:33:03	beacon 2 and 4; lat long from USBL, no laser	TC at the surface, recovery and seagall
1181	14	1	04.08.2018	16:25:05	17:19:09	00:53:50:11	beacon 2 and 4; lat long from USBL, no laser	survey on craters further north; similar characteristics as in the previuous dives; soft sediment, rare pebbles colonized by sessile fauna; high bioturbation

3D seismic line log

Expedition: Helmer Hanssen CAGE_18_4 July 2018 Survey: Vestnesa 22.07 – 24.07 Sheet #: 1 - 6

3D seismic over west Vestnesa on the transition between west and east segment.

Survey configuration: see end of document Times are UTC

3D line number:	Date: Start - end	Time (UTC): Start - end	Shot point number First - last	Shot point number when crossing planned start and end of line	Comments (sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)
0000	22.07-22.07	12:09 – 13:07	1-351	N/A	Pre-survey warm-up and test. Disabled channels: 14,23,48,94,104 From shot 230, testing with one gun. Noisy channels: 8,28,29,46,57,62,81,87,102,103
0001	22.07-22.07	13:08-14:05	352-921	356-918	Record length 3 sec at 0.25 ms sampling rate. Shot interval 6 sec. Sailing SE to NW, wind 12.3 m/s, seatemp 6.3 degC, wave 1.1 m Noisy channels: 8,28,29,46,57,62,81,87,102,103
0002	22.07-22.07	14:46-15:52	922-1587	992-1582	Shot interval 6 sec. Sailing NW to SE, wind 12.3 m/s, seatemp 6.1 degC, wave 1.1 m Noisy channels: 8,28,29,46,57,62,81,87,102,103
0003	22.07-22.07	16:23-17:18	1588-2137	1598-2130	Shot interval 6 sec. Sailing SE to NW, wind 13 m/s, seatemp 6.4 degC, wave 1 m Noisy channels: 8,28,29,46,57,62,81,87,102,103
0004	22.07-22.07	17:54-18:57	2138-2765	2165-2746	Shot interval 6 sec. Sailing NW to SE, wind 10 m/s, seatemp 6.1 degC, wave 1.1 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0005	22.07-22.07	19:18-20:26	2766-3437	2806-3349	Shot interval 6 sec. Sailing SE to NW, wind 12 m/s, seatemp 6.8 degC, wave 1 m Noisy channels: 8,25,28,29,46,47,57,62,73,81

0006	22.07-22.07	20:51-21:59	3438-4118	3501-4055	Shot interval 6 sec. Sailing NW to SE, wind 13 m/s, seatemp 6.1 degC, wave 1.4 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0007	22.07-22.07	22:11-23:16	4119-4770	4200-4730	Shot interval 6 sec. Sailing SE to NW, wind 12 m/s, seatemp 5.9 degC, wave 1.3 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0008	22.07-23.07	23:39-00:47	4771-5454	4860-5396	Shot interval 6 sec. Sailing NW to SE, wind 13 m/s, seatemp 6.6 degC, wave 1.1 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0009	23.07-23.07	01:02-02:04	5455-6075	5512-6038	Shot interval 6 sec. Sailing SE to NW, wind 14 m/s, seatemp 6.2 degC, wave 1.2 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0010	23.07-23.07	02:24-03:30	6076-6739	6167-6730	Shot interval 6 sec. Sailing NW to SE, wind 11 m/s, seatemp 6.0 degC, wave 1.3 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0011	23.07-23.07	03:52-04:47	6740-7288	6746-7268	Shot interval 6 sec. Sailing SE to NW, wind 12 m/s, seatemp 6.3 degC, wave 1.2 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0012	23.07-23.07	05:12-06:14	7289-7902	7309-7882	Shot interval 6 sec. Sailing NW to SE, wind 11 m/s, seatemp 6.1 degC, wave 1.1 m Noisy channels: 8,25,28,29,46,47,57,62,73,81
0013	23.07-23.07	06:35-07:30	7903-8450	7914-8434	Shot interval 6 sec. Sailing SE to NW, wind 12 m/s, seatemp 6.5 °C, wave 1.2 m Noisy channels: 8,28,29,46,57,62,73,102
0014	23.07-23.07	07:52-08:51	8451-9058	8478-9038	Shot interval 6 sec. Sailing NW to SE, wind 12 m/s, seatemp 6.5 °C, wave 1.2 m Noisy channels: 8,28,29,46,57,62,73,102
0015	23.07-23.07	09:13-10:07	9059-9633	9069-9605	Shot interval 6 sec. Sailing SE to NW, wind 11 m/s, seatemp 6.5 °C, wave 1.0 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,81,102
0016	23.07-23.07	10:32-11:30	9634-10231	9658-10208	Shot interval 6 sec. Sailing NW to SE, wind 12 m/s, seatemp 6.5 °C, wave 1.0 m

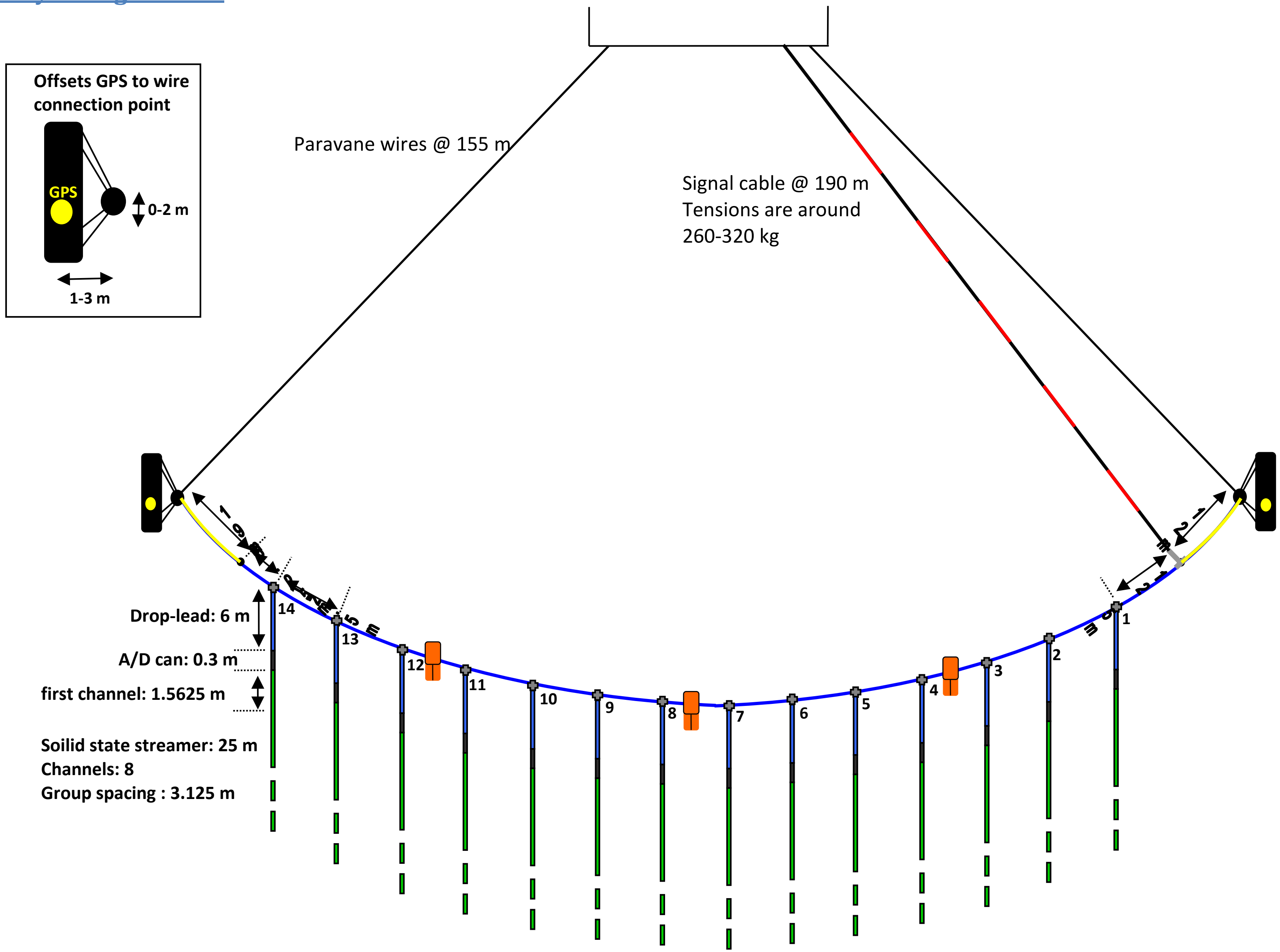
					Noisy channels: 8,24,25,28,29,46,57,61,62,73,81,102
0017	23.07-23.07	11:51-12:46	10232-10783	10248-10761	Shot interval 6 sec. Sailing SE to NW, wind 11.5 m/s, seatemp 6.5 °C, wave 0.95 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,81,102
0018	23.07-23.07	13:08-14:10	10784-11405	10831-11382	Shot interval 6 sec. Sailing NW to SE, wind 11.5 m/s, seatemp 6.5 °C, wave 1.2 m Noisy channels: 8,24,28,29,46,57,61,62,73,81,102
0019	23.07-23.07	14:31-15:26	11406-11959	11412-11946	Shot interval 6 sec. Sailing SE to NW, wind 9 m/s, seatemp 6.5 °C, wave 1 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,81,102
0020	23.07-23.07	15:50-16:48	11960-12545	11965-12525	Shot interval 6 sec. Sailing NW to SE, wind 10 m/s, seatemp 6.5 °C, wave 1.4 m Noisy channels: 8,24,28,29,46,57,61,62,73,81,102
0021	23.07-23.07	17:11-18:10	12546-13143	12564-13090	Shot interval 6 sec. Sailing SE to NW, wind 9 m/s, seatemp 6.5 °C, wave .9 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,81,102
0022	23.07-23.07	18:27-19:39	13144-13861	13222-13800	Shot interval 6 sec. Sailing NW to SE, wind 8 m/s, seatemp 6.5 °C, wave 0.7 m Noisy channels: 8,24,28,29,46,57,61,62,73,81,102 Gun location missing for some part of the line.
0023	23.07-23.07	19:52-20:52	13862-14459	13916-14453	Shot interval 6 sec. Sailing SE to NW, wind 7 m/s, seatemp 6.7 °C, wave .8 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,81,102 Gun location missing for most of the line as GPS was under water due to problem with the gun frame. Gun taken out and the problem fixed at the end of the line.

0024	23.07-23.07	22:23-22:48	14460-15307	14685-15255	Shot interval 6 sec. Sailing NW to SE, wind 8 m/s, seatemp 6.5 °C, wave 0.7 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,80,87,102
0025	24.07-24.07	00:04-01:09	15308-15961	15348-15888	Shot interval 6 sec. Sailing SE to NW, wind 5 m/s, seatemp 6.7 °C, wave .7 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,80,87,102
0026	24.07-24.07	01:27-02:34	15962-16637	16020-16598	Shot interval 6 sec. Sailing NW to SE, wind 5 m/s, seatemp 6.5 °C, wave 0.7 m Noisy channels: 8,24,25,28,29,46,57,61,62,73,80,87,102
0027	24.07-24.07	02:51-03:50	16638-17220	16670-17182	Shot interval 6 sec. Sailing SE to NW, wind 5 m/s, seatemp 6.7 °C, wave .7 m Noisy channels: 8, 28,29,46,57,61,62,73,80,87,102
0028	24.07-24.07	04:13-05:18	17221-17870	17266-17832	Shot interval 6 sec. Sailing NW to SE, wind 5 m/s, seatemp 6.6 °C, wave 0.8 m Noisy channels: 8, 28,29,46,57,61,62,73,80,87,102
0029	24.07-24.07	05:36-06:33	17871-18445	17900-18430	Shot interval 6 sec. Sailing SE to NW, wind 5 m/s, seatemp 6.7 °C, wave .7 m Noisy channels: 8,28,29,46,57,61,62,73,102,103
0030	24.07-24.07	07:06-08:04	18446-19080	18471-19055	Shot interval 6 sec. Sailing NW to SE, wind 9.5 m/s, seatemp 6.5 °C, wave .4 m Noisy channels: 8,28,29,46,57,61,62,73,102,103
0031	24.07-24.07	08:29-09:30	19081-19673	19101-19651	Shot interval 6 sec. Sailing SE to NW, wind 9 m/s, seatemp 6.5 °C, wave 0.5 m Noisy channels: 8,28,29,46,57,61,62,102,103

Comment:

Lost the floatation along the cross cable between streamers 7 and 8 and between streamers 11 and 12. Initial analysis of depth measurement and frequency content shows that it likely happened on line 25.

Survey configuration:



Observed spread of paravanes: 160 -165 m

Observed distance between gun and paravanes: 98 – 113 m, deviations between distances to both paravanes up to 5 m

Ship's speed: 4 kn ± 0,3 kn
Gun system: Two mini-GI (30/30 in^3 and 15/15 in^3)
Shooting pressure: ~170-180 bar
Shooting interval: 6 sec
Recording window: 3 sec
Recording delay: 0 sec
Sampling interval: 0.25ms
Streamer depth: 1.5m

Switch no	6013	6196	6031	6012	6017	6028	6011	6030	6183	6034	6033	6187	6022	6019
Depth reading on deck after survey (m)														

Yellow: kind of okay
Red: Wrong. Recalibration required

3D seismic line log

Expedition: Helmer Hanssen CAGE_18_4 July 2018 Survey: Vestnesa 25.07 – 27.07 Sheet #: 1 - 6

3D seismic at western end of Vestnesa Ridge over buried chimney structures and faults.

Survey configuration: see end of document Times are UTC

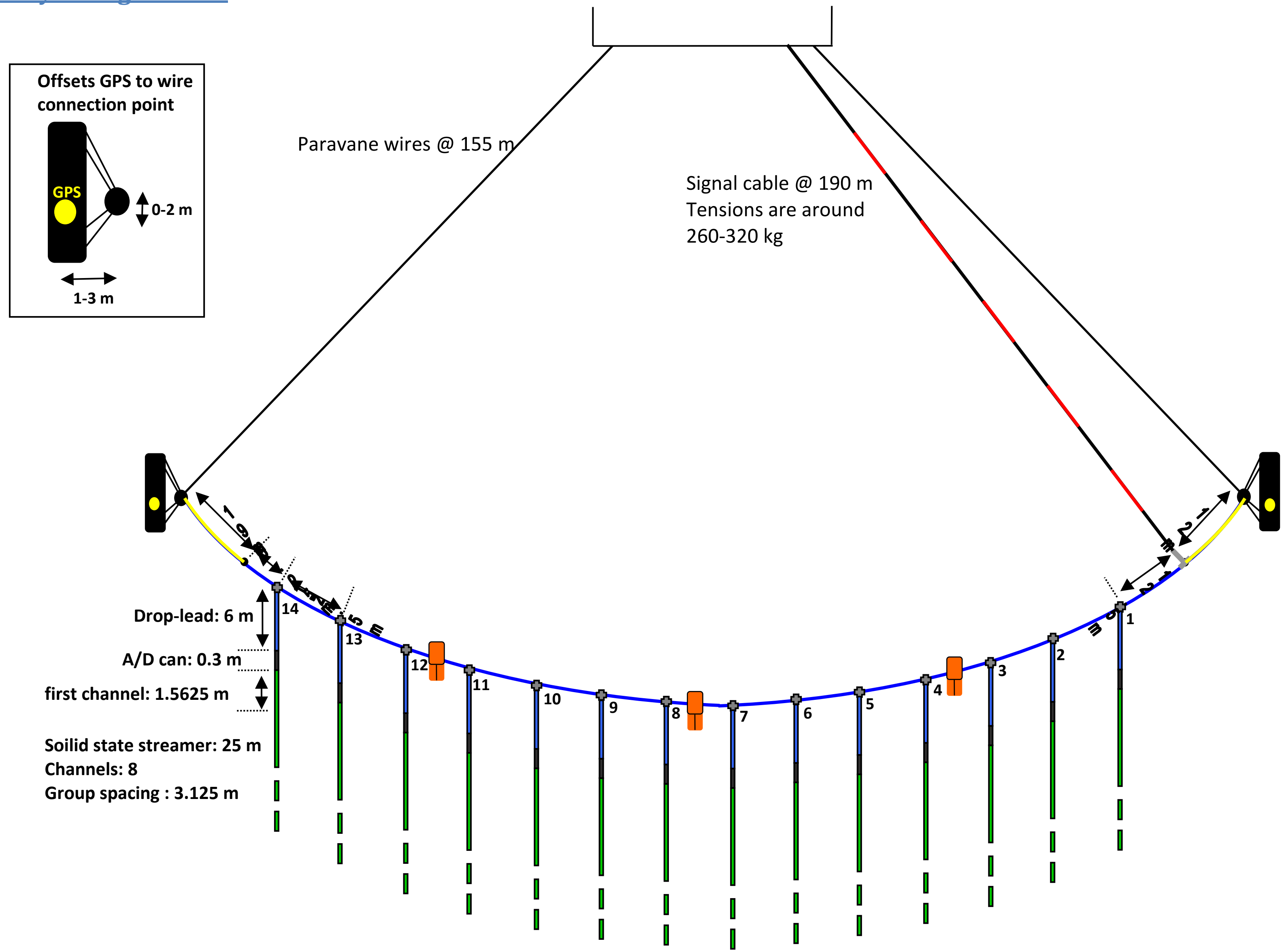
3D line number:	Date: Start - end	Time (UTC): Start - end	Shot point number First - last	Shot point number when crossing planned start and end of line	Comments (sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)
0000	25.07-25.07	21:19 –	1-758	N/A	Pre-survey warm-up and test. Disabled channels: 14,23,46,53,56,72,104 Noisy and bursty channels: 25,29,54,55,70,71,86 Long lead in to first line, Line 0000 could be processed as swath
0001	25.07 - 26.07	22:51 – 00:11	759 - 1555	801 - 1526	Sailing ESE to WNW, wind 11 m/s, seatemp 6.4 degC, air temp 4.8 degC Noisy and bursty channels: 25,29,54,55,70,71,86
0002	26.07 - 26.07	00:36-01:53	1556-2324	1592-2290	Sailing WNW to ESE, wind 12 m/s, seatemp 6 degC, air temp 3.8 degC Noisy and bursty channels: 25,29,54,55,70,71,86
0003	26.07 - 26.07	02:14-03:28	2325-3068	2382-3044	Sailing ESE to WNW, wind 12 m/s, seatemp 6.0 degC, air temp 2.4 degC Noisy and bursty channels: 25,29,54,55,70,71,85,86
0004	26.07 - 26.07	03:48-05:02	3069-3813	3107-3795	Sailing WNW to ESE, wind 7 m/s, seatemp 6 degC, air temp 2.2 degC Noisy and bursty channels: 25,29,54,55,70,71,85,86
0005	26.07 - 26.07	05:23-06:35	3814-4561	3826-4531	Sailing ESE to WNW, wind 9 m/s, seatemp 5.8 degC, air temp 3.3 degC Noisy and bursty channels: 25,29,31,54,70,71,85,86

0006	26.07 - 26.07	07:11-08:25	4562-5343	4598-5306	Sailing WNW to ESE, wind 10 m/s, seatemp 5.8 °C, air temp 1.9 °C Noisy and bursty channels: 25,29,31,54,70,(71),(81),85,86
0007	26.07 - 26.07	08:45-10:03	5344-6148	5386-6115	Sailing ESE to WNW, wind 9 m/s, seatemp 6.2 °C, air temp 2.2 °C Noisy and bursty channels: 25,29,31,54,70,(76),(81),85,86
0008	26.07 - 26.07	10:32 – 11:46	6149 - 6811	6187 - 6790	Sailing WNW to ESE, wind 10 m/s, seatemp 5.8 °C, air temp 2.5 °C Noisy and bursty channels: 25,29,31,54,70,(76),(81),85,86 Between shot 6640-6650 gun stopped shooting, cooling corrupted, disarmed Geoeel at 6725, guns back up firing at normal pressure after about 10 min, continued shooting with shot number 6726. Analyse gap in data, probably about 1500-2000 m.
0009	26.07 - 26.07	12:02-13:28	6812-7674	6842-7598	Sailing ESE to WNW, wind 10 m/s, seatemp 5.7 °C, air temp 2.9 °C Noisy and bursty channels: 25,29,31,54,70,(76),(81),85,86
0010	26.07 - 26.07	13:35-14:50	7675 - 8411	7709 - 8385	Sailing WNW to ESE, wind 10.4 m/s, seatemp 5.8 °C, air temp 2.3 °C Noisy and bursty channels: 25,29,31,54,70,(76),(81),85,86
0011	26.07 - 26.07	15:08-16:20	8412-9175	8467-9160	Sailing ESE to WNW, wind 10.5 m/s, seatemp 5.5 °C, air temp 2.7 °C Noisy and bursty channels: 25,29,31,54,70,(81),85,86
0012	26.07-26.07	16:41-17:58	9176-9947	9186-9911	Sailing WNW to ESE, wind 12.5 m/s, seatemp 5.5 °C, air temp 2.3 °C

					Noisy and bursty channels: 25,29,31,54,70,(76),(81),85,86
0013	26.07-26.07	18:14-19:40	9948-10815	10009-10735	Sailing ESE to WNW, wind 12.5 m/s, seatemp 6.2 °C, air temp 2.4 °C Noisy and bursty channels: 25,29,31,54,70,81,85,86,111
0014	26.07-26.07	19:54-21:20	10816-11670	10882-11607	Sailing WNW to ESE, wind 11.5 m/s, seatemp 5.9 °C, air temp 2.1 °C Noisy and bursty channels: 25,29,31,54,70,81,85,86,111
0015	26.07-26.07	21:34-22:56	11671-12490	11715-12442	Sailing ESE to WNW, wind 9.5 m/s, seatemp 5.8 °C, air temp 2.3 °C Noisy and bursty channels: 25,29,31,54,70,81,85,86,111
0016	26.07-27.07	23:13-00:30	12491-13257	12540-13250	Sailing WNW to ESE, wind 8.5 m/s, seatemp 5.9 °C, air temp 1.6 °C Noisy and bursty channels: 25,29,31,54,70,81,85,86,111 Gun2 stopped firing since the beginning of line. Guns recovered at the end of the line. Opened the gun, cleaned and put it back.
0017	27.07-27.07	02:38-03:56	13258-14032	13315-14000	Sailing ESE to WNW, 8 wind m/s, seatemp 6°C, air temp 2.1 °C Noisy and bursty channels: 25,29,31,54,70,81,85,86,111
0018	27.07-27.07	04:15-05:40	14033-14879	14099-14836	Sailing WNW to ESE, wind 8.5 m/s, seatemp 5.9 °C, air temp 2.3 °C Noisy and bursty channels: 25,29,31,54,70,81,85,86,111
0019	27.07-27.07	05:58-	14880-15626	14907-15600	Sailing ENE to WNW, wind 12.7 m/s, seatemp 6.1 °C, air temp 3.3 °C Noisy and bursty channels: 25,29,31,54,70,81,85,86,111

0020	27.07-27.07	07:37-08:51	15627-16371	15647-16344	Sailing WNW to ENE, wind 10.8 m/s, seatemp 5.7 °C, air temp 3.6 °C Noisy and bursty channels: 25,29,31,54,70, 76,81,85,86,111
0021	27.07-27.07	09:15-10:27	16372-17149	16406-17120	Sailing ENE to WNW, wind 13.8 m/s, seatemp 5.4°C, air temp 4.5°C Noisy and bursty channels: 25,29,31,54,70,81,85,86
0022	27.07-27.07	10:52-12:06	17150-17907	17187-17889	Additional line replacing line 16, which had a gun failure Sailing WNW to ENE, wind 13 m/s, seatemp 5.8°C, air temp 3.5°C, waves ~2 m Noisy and bursty channels: 25,29,31,54,70,81,85,86
0023	27.07-27.07	13:05-13:31	17908-18169	17955-18160	Additional line replacing part of line 8, which had a gun failure Sailing WNW to ENE, wind 11 m/s, seatemp 5.8°C, air temp 4.4°C, waves ~2.5 m Noisy and bursty channels: 25,29,31,54,70,81,85,86,111 28 was flat

Survey configuration:



Observed spread of paravanes: 160 -165 m

Observed distance between gun and paravanes: 98 – 113 m, deviations between distances to both paravanes up to 5 m

Ship's speed: 4 kn ± 0,3 kn
Gun system: Two mini-GI (30/30 in^3 and 15/15 in^3)
Shooting pressure: ~170-180 bar
Shooting interval: 6 sec
Recording window: 3.5 sec
Recording delay: 0 sec
Sampling interval: 0.25ms
Streamer depth: 1.5m

Switch no	6013	6196	6031	6012	6017	6028	6011	6030	6183	6034	6033	6187	6022	6019
Depth reading on deck after survey (m)														

Yellow: kind of okay
Red: Wrong. Recalibration required