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**R/V Helmer Hanssen**

04-08-0 to 18-08-20

Tromsø – Tromsø

# CAGE-20-4 Cruise Report

# High-resolution 2D and 3D seismic investigations on the Møre and Vøring Margins

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**Report prepared by: Bünz, Stefan**

With contributions by cruise participants

**DOI:**

**Key words**: Vøring Basin, Møre Basin, basalts, magmatic intrusions, hydrothermal vent, fluid flow, IODP



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# PREFACE and ACKNOWLEDGEMENT

This document reports on the acquisition and processing of the seismic, subbottom-profiling and multibeam data acquired during a cruise with the Arctic University of Norway's research vessel RV Helmer Hansen from 4-18th August 2020. This expedition targeted areas on the outer margins of the Møre and Vøring basins, with emphasis on IODP drilling proposal P944 sites (Huismans et al., 2019). The seismic acquisition was conducted under the framework of cruise *CAGE20-4* of the *Centre of Excellence for Arctic Gas Hydrates, Environment and Climate (CAGE)* (Norwegian Research Council (NFR) project number 223259/F5 at the University of Tromsø in collaboration with the *Centre for Earth Evolution and Dynamics (CEED)* at the University of Oslo (NFR project number 223272).

We sincerely acknowledge the Norwegian Petroleum Directorate for their support for data acquisition, processing, and forthcoming data analysis and TGS and VBPR for access to seismic data and interpretations for planning of the IODP proposal P944. We also thank the captain and his crew of R/V Helmer Hanssen of UiT the Arctic University of Norway for their excellent support during the scientific surveys.

Tromsø, 21.08.2020

# INTRODUCTION AND OBJECTIVES

The overall goal of this expedition is the acquisition of geophysical data in the outer part of the Møre and Vøring basins in order to improve the understanding of subsurface structure and geological processes at sites where drilling has been applied for within the International Ocean Discovery Program (IODP), proposal 944 (Huismans et al., 2019). This expedition is part of a collaboration between the Center for Arctic Gas Hydrate, Environment and Climate (CAGE) at UiT Norway's Arctic University, and the Center for Earth Evolution and Dynamics (CEED) at the University of Oslo. Amongst the geophysical data, the main aim of the expedition is the acquisition of high-resolution 2D and P-Cable 3D seismic data (Lebedeva-Ivanova et al., 2018).

The scientific objectives of the cruise are linked to the objectives of the drilling applied through IODP (Proposal 944-Full), which investigates the cause and climate consequences of magmatism during the Northeast Atlantic continental break-up (Berndt et al., 2019) (Figure 1). Among these, the high-resolution studies focus in particular on the structure of igneous deposits and how tectonic and igneous events have affected the Paleogene and global climate through gas production from organic-rich sediments and release into the atmosphere via hydrothermal vents. The main target areas for this expedition were the three southern drill sites at Kolga High, Modgunn Arch and Mimir High (Figure 1).

The collected data has been processed on board but will be post-processed and quality controlled after the cruise and will be part of a doctoral project supervised in a collaboration between UiT / CAGE and UiO / CEED.

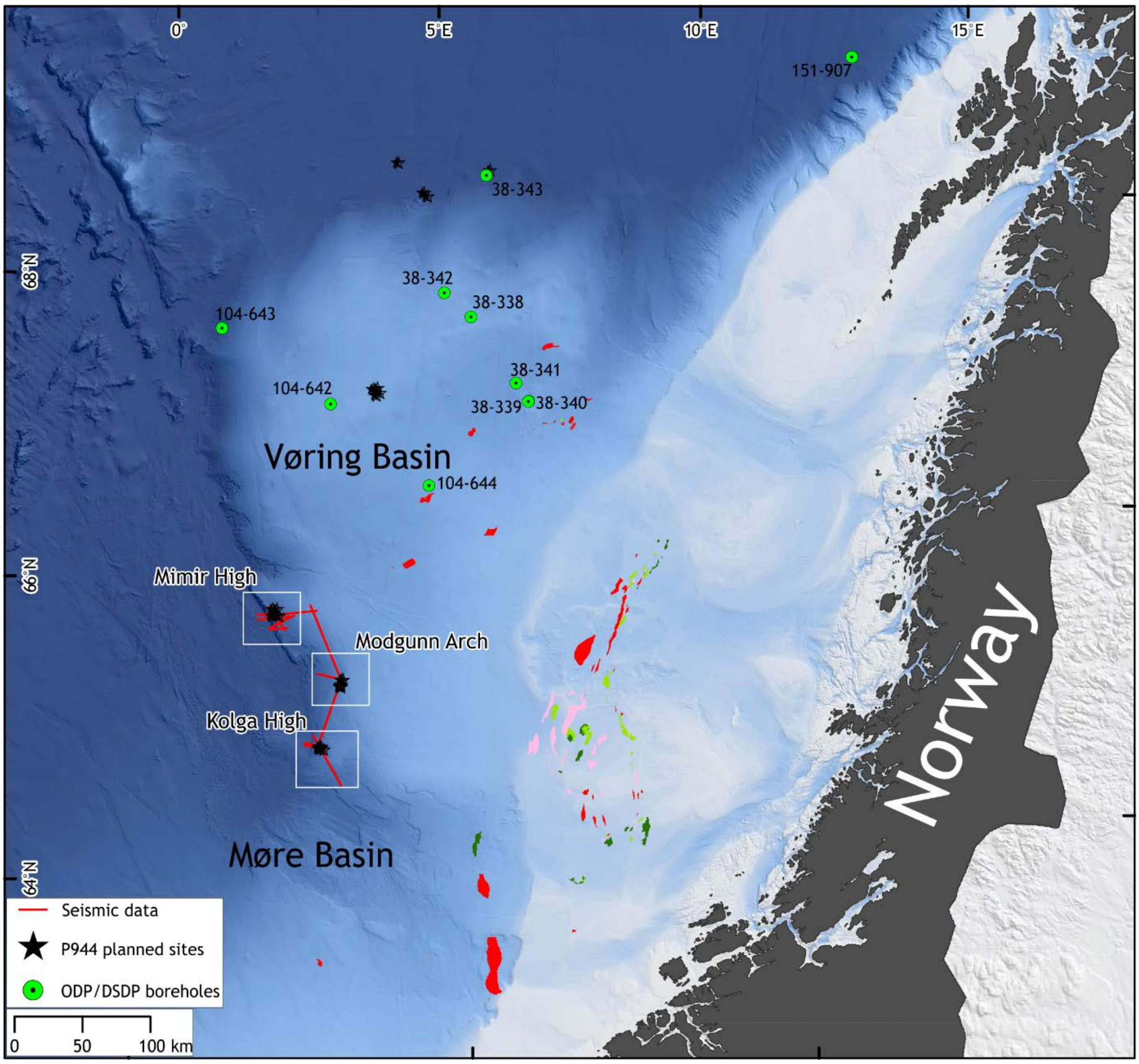


*Figure 1:* Location of the study areas on the outer margins of the Møre and Vøring Basins. IODP proposal 944-Full sites are indicated by black stars. This expedition focused on the three southern sites of the drilling proposal at Kolga High, Modgunn Arch and Mimir High.

# METHODS

## Seismic methods

The high-resolution P-Cable 3D seismic system was used together with a Granzow high-pressure (210bar) compressor and mini-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 preliminary interpretations.

During this cruise we used the Kongsberg 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.

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 acoustic systems.

## 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 2). 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. 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 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. 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 10-12 streamer sections for a 250-300 m long active hydrophone cable with 80-96 channels at a receiver spacing of 3,25 m. The lead-in cable to the active streamer had a length of 70 m behind the ship. The depth of the streamer cable was controlled by two ION Digicourse II birds and set to 2.5 m, and to 3 m when weather conditions were worse and wave height above 2 m.

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

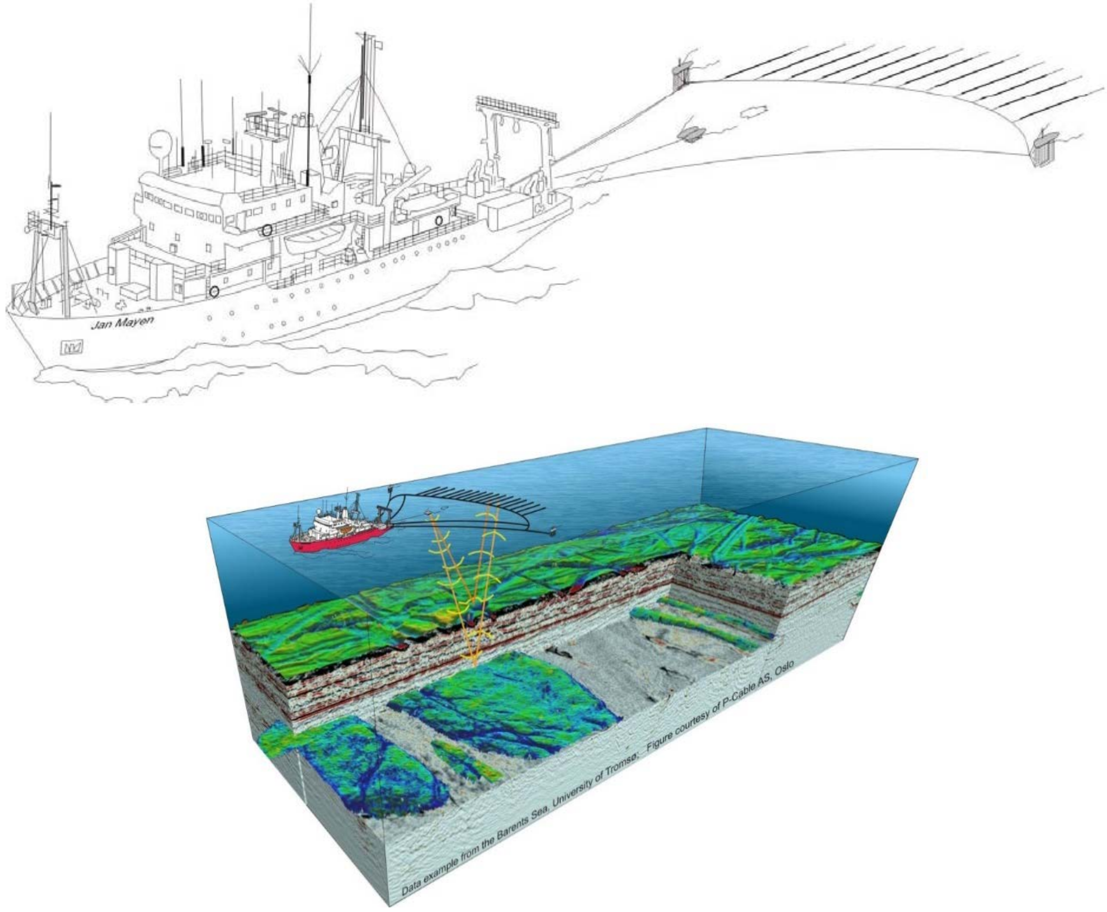


*Figure 2: Schematic sketch an acquisition principle of the P-Cable high-resolution 3D seismic system.*

## 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 was poor in the beginning of the cruise with wave heights up to 2 m but still allowed 2D seismic acquisition. During the middle part of the cruise, weather was much improved with waves of 1 m or less and allowed almost 4.5 days of 3D seismic acquisition in two areas. Weather conditions towards the end of the cruise deteriorated significantly with waves between 3-5 m. Air temperatures were between 10-13°C. The cruise was mobilized in Tromsø on the 4th August with assembly of the equipment. More details and notes on the seismic data acquisition can be found in the seismic line logs at the end of this document.

**Tuesday, 04.08.2020**

Mobilization of equipment. All participants onboard. Departure from Tromsø at 21:00.

**Wednesday, 05.08.2020**

Transit to the working area on the SW Vøring margin is estimated to take 2 days.

**Thursday, 06.08.2020**

Arrival at southern Kolga High at 17:00. Conduct CTD station to obtain acoustic velocity for water in order to calibrate acoustic systems. Deployed seismic streamer and airguns at 18:15 but could not start acquisition due to gun air leakage and problems with streamer bird communication.

**Friday, 07.08.2020**

Redeployed streamer and airguns after fixing problems. Start of 2D seismic line at 00:30 heading N from NPD well 6402/3 towards IODP sites on the Kolga High. Recovered airguns after line due to problems with injector chamber. Redeployed 06:15 for Line 2, but had to recover airguns again due to problems with its hydrophone. Deployed again for line 3 at 09:45. Acquired three more lines at Kolga High and at 16:15 started a transit line towards IODP proposal sites on the Modgunn Arch. Airgun caused further problems, few shots are lost. Line is stopped and one gun is replaced. Started new line connecting with previous line and continue transit towards Modgunn Arch.

**Saturday, 08.08.2020**

00:45 at Modgunn Arch add a cross line over two alternate drilling proposal sites. Line finished at 03:16 and as weather has worsened and is straining the seismic equipment, we stop acquisition. However, weather still permits gravity coring through the small moon pool of Helmer Hanssen. Between 04:00 and 14:00 we take 5 gravity cores (4 cores of 4+ meters, one empty) at and around primary IODP drill sites that target hydrothermal vents at shallow burial. Continued with 2D seismic transit line (line 10) northbound between IODP proposal drill sites on Modgunn Arch and Mimir High. The transit is split into a N-S segment and an E-W segments to avoid acquisition through deeper parts of the margin that are affected by mass transport deposits. N-S segment finished at 21:30. Unfortunately, weather had deteriorated with wave heights above 2 m and we had to stop seismic acquisition. We transit westward towards Mimir High during the remainder of the night and await better weather conditions.

**Sunday, 09.08.2020**

We restart 2D seismic acquisition at 09:30 as weather is calming. Three lines are acquired at Mimir High that provide constraints for the planned 3D P-Cable seismic acquisition. Weather had further calmed and the weather outlook for the next 4-5 days is very good providing us with a good time window for the planned 3D seismic work. Seismic equipment was recovered at 15:00 and we reconfigured from 2D to 3D seismic. At 18:30 we started to deploy the P-Cable 3D seismic system for a survey at Mimir High. The system was in the water and working at 19:45 and we started pre-survey checks and configuration. Line 1 of the 3D seismic survey started at 20:36.

**Monday, 10.08.2020**

20 acquisition lines are shot for this 3D seismic survey. More details can be found in the appendix.

**Tuesday, 11.08.2020**

Line 20 ended shortly after midnight and we had recovered the 3D seismic system by 01:15. We headed back to the survey area at Modgunn Arch where we intend to acquire a larger 3D seismic data sets over hydrothermal vent structures and sill complexes at shallow burial. At 08:30 we started to deploy the P-Cable system and at 09:55 the system and airguns were in water and working properly. After a short pre-survey check, we started Line 1 at 10:45. By the end of the day, 8 acquisition lines had been completed.

**Wednesday, 12.08.2020**

Acquisition lines 9 – 24 completed. Problems with one gun during Line 11, but fixed after one hour.

**Thursday, 13.08.2020**

Immediately after midnight, problems with airgun during line 25 due to punctured air hose. Fixed after one hour and back to survey. Completed line 37 by the end of the day including a repeat of line 25. Weather was getting worse with high winds, though waves have yet to pick up so we continued as long as possible.

**Friday, 14.08.2020**

We managed to get 3 more acquisition lines before deteriorated weather force us to stop. At 06:00 equipment is back on deck. Weather forecasts are bad for the next days, particularly this Friday and early Saturday with wave heights of above 3 m forcing us to lay down.

**Saturday, 15.08.2020**

Weather started to improve in late morning with winds slowly calming down to 10 m/s but wave heights were still 2,5 m on average with some single waves certainly up to 5 m. In the afternoon, winds had further calmed. Wave heights were still around 2 m and were not expected to decrease as the huge low pressure front in the northern north Atlantic a few degrees north of us was causing significant swell over long distances. The weather situation also dictated that we would not be able to acquire any seismic data on the Vøring Plateau or further north on the outer margin. Needing to stay behind the bad weather additional seismic surveys were only possible at our working sites in the south. As some planned 2D seismic lines at Mimir High were cancelled earlier during the cruise due to bad weather downtime, we decided to return to that area. At 15:00 we deployed the 2D seismic equipment, shooting a line (no. 14) in the direction of winds and waves as this would put considerably less stress and tension on the equipment in the water.

Line 15 started at 19:00 heading in opposite direction but with reduced ship speed the line was successfully acquired. However, both lines were affected by significant noise of 50 and 60 Hz. We paused the acquisition and troubleshooted the cause of the noise which was subsequently attributed to streamer section no 2.

**Sunday, 16.08.2020**

2D seismic line 16 started at 01:45. 5 more seismic lines were acquired at Mimir High until 14:00 when we had to stop our survey and make our way back to Tromsø.

**Monday, 17.08.2020**

On transit back to Tromsø.

**Tuesday, 18.08.2020**

Arrival in Tromsø at 09:00. Demobilization.

## 2D and 3D seismic acquisition

During this expedition on RV Helmer Hanssen, our primary target areas for high-resolution seismic acquisition are located on the outer margins of the Møre and Vøring Basins and included the three southern IODP proposal 944 drill sites at Kolga High, Modgunn Arch and Mimir High. A total of 20 2D seismic lines and two 3D seismic cubes were acquired in these three areas (Figure 3). Multibeam bathymetry and sub-bottom profiler data were acquired simultaneously with the seismic data. The locations of most of the 2D seismic lines were carefully planned prior to the cruise based on existing conventional industry seismic data. Parameters for the 2D seismic and 3D seismic acquisition are given in Tables 1 and 2, respectively. A principle sketch of the 2D seismic acquisition geometry is shown in Figure 4 and for the 3D seismic geometry in Figure 2. The configuration of the streamer varied slightly during the survey as section had to be maintained or removed due to noise problems. Chirp sub-bottom profiling data was acquired along every 2D seismic line.

The seismic acquisition started with a line tying NPD well 6402/3 with the southernmost planned drill site at Kolga High (Figure 5). Five 2D seismic lines cover both primary and alternate drill sites at Kolga High. Another tie line connects to the planned drill sites at Modgunn Arch (Figure 3). A relatively large P-Cable 3D seismic cube (8,2 x 2,6 km) was acquired at Modgunn Arch that aims to investigate hydrothermal vent complexes and sill intrusions at shallow burial in unprecedented detail (Figure 6). Chirp sub-bottom profiling data was also acquired on every acquisition line of the 3D seismic survey sub-meter resolution for the uppermost few 10s of meters. Two seismic lines (CAGE20-4-HH-010-2D northward and CAGE20-4-HH-020-2D westward) provide a tie to the planned drill sites at Mimir High (Figure 3). This line layout avoids steep escarpments and mass transport deposits on a direct line between the sites. At Mimir High, several 2D seismic lines have been acquired across the escarpment to image the outcropping strata, including the Paleocene-Eocene boundary, in much greater detail than on existing very low resolution 2D seismic. In addition, a 3D seismic cube (8,0 x 1,2 km) was shot covering the primary and 2 of the alternate proposed drill sites.

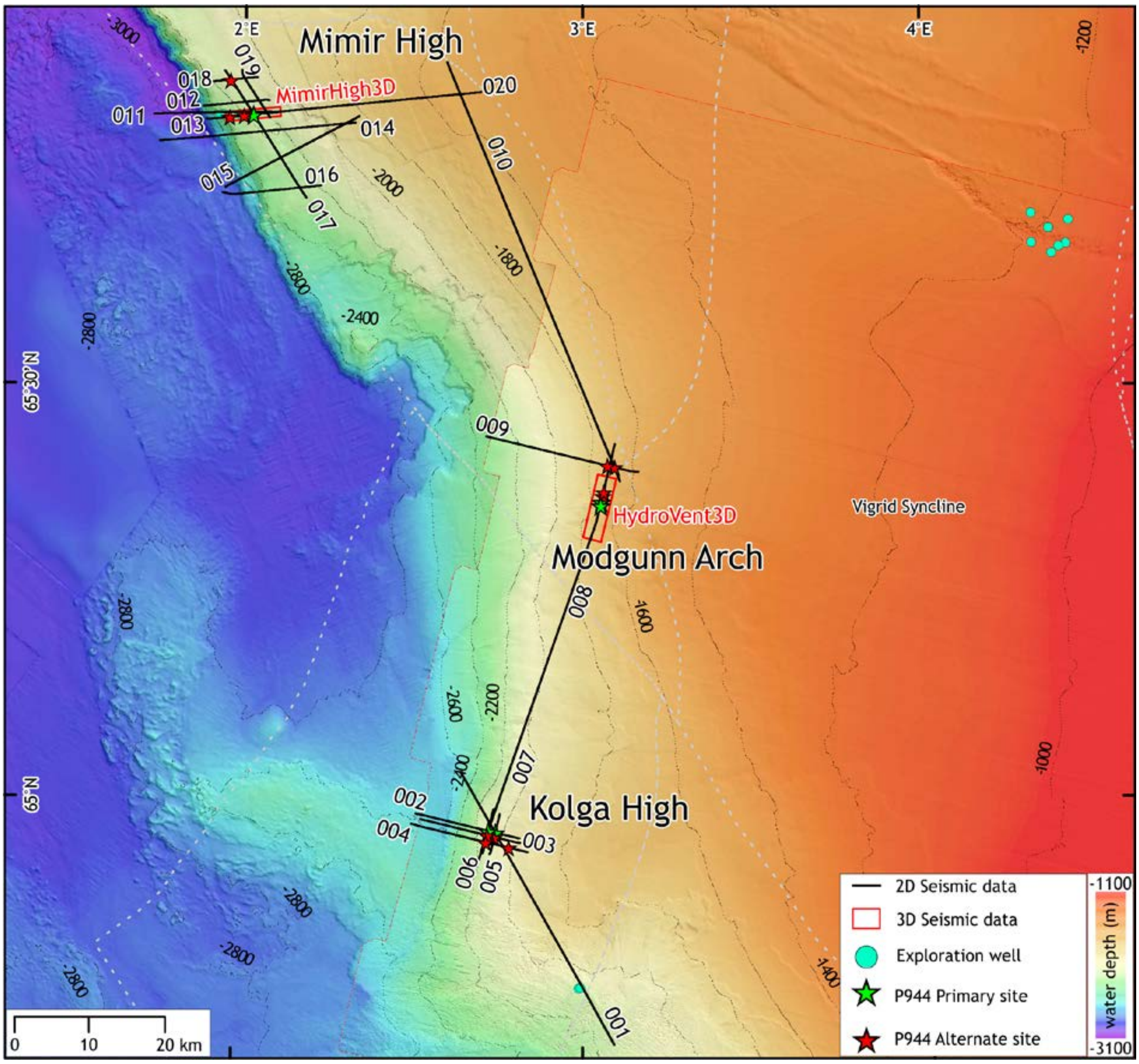


*Figure 3: Overview of 2D and 3D seismic data acquired during this expedition with RV Helmer Hanssen at the three southern drill sites at Kolga High, Modgunn Arch and Mimir High.*

Table 1: The detailed survey parameters for the 2D seismic survey.

| **Survey parameters** | |
|---|---|
| Deployment / recovery | 0,5 h |
| Survey speed | 5 kt |
| Source | 1 mini GI 30/30 $in^3$ & 1 mini GI 15/15 $in^3$ |
| Shooting rate | 6 s |
| Shooting pressure | 170 bar |

| | |
|---|---|
| Source towing depth | 2 m |
| Dominant frequency (bandwidth) | 140-180 Hz (20-400 Hz) |
| Positioning | GPS transponder on gun raft |
| Streamer length | 320 m, 370 m, 345 m (see below) |
| Active section | 250 m (Lines 1-13), 300 m (Lines 14-15), 275 m (Lines 16-20) |
| Across track position relative to gun | 10 m to port |
| Number of channels | 80, 96, 88 (see above) |
| Receiver group spacing | 3.125 m |
| Streamer towing depth, 2 ION DigiCourse II Depth birds | 2.5 m, 3 m on some lines in bad weather (see line log in appendix) |
| Sampling rate / interval | 4000 Hz / 0.25 ms or 2000 Hz / 0.5 ms |
| Recording length | 4-5 s |

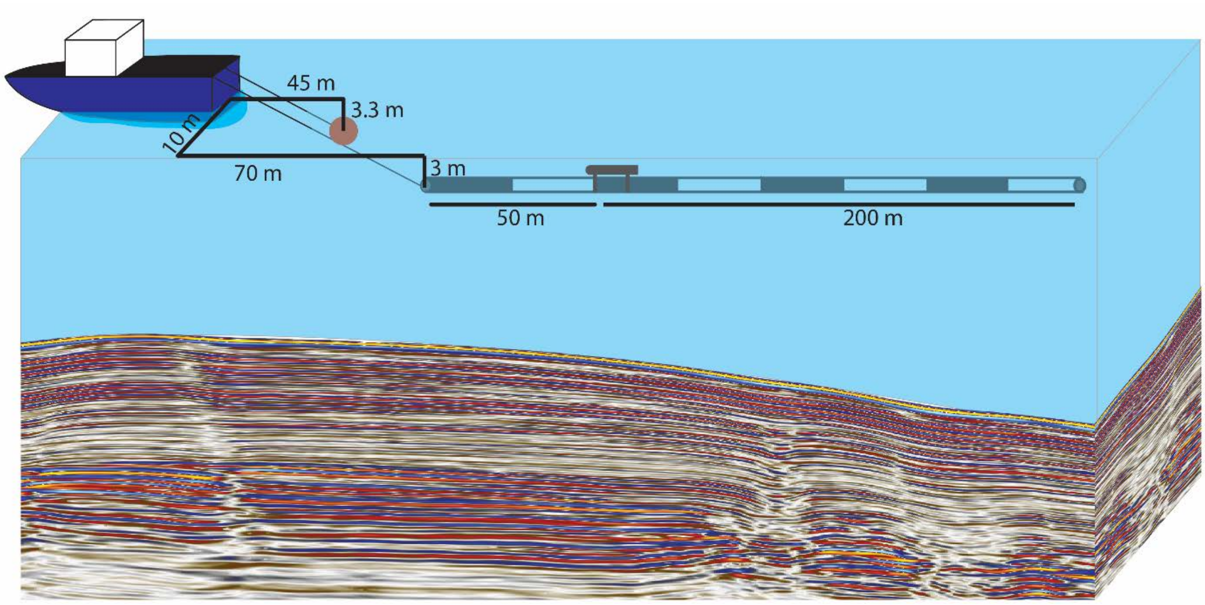


*Figure 4: Acquisition geometry of the 2D multi-channel seismic streamer. Notice that in this cruise we used 10, 12 and 11 streamer sections. Hence, the active section was 250 m, 300 m and 275 m instead of 200 m.*

Table 2: The detailed survey parameters for the P-Cable 3D seismic survey.

| **Survey parameters** | |
|---|---|
| Deployment / recovery | 1 h |
| Survey speed | 4 kt |
| Turn time | ~0.5-0.7 h |
| Source | 1 mini GI 30/30 $in^3$ & 1 mini GI 15/15 $in^3$ |
| Shooting rate | 6 s |
| Shooting pressure | 170 bar |
| Source towing depth | 2 m |
| Dominant frequency (bandwidth) | 140-180 Hz (20-400 Hz) |
| Positioning | GPS transponder on gun raft and the two paravans |
| | |
| Seismic streamer | 14 25-m-long active sections towed parallel with streamer spacing of 12,5 m |
| Active section | 8 channels per streamer section with 3,125 receiver group spacing |
| Streamer towing depth | 1,5 m |
| Sampling rate / interval | 4000 Hz / 0.25 ms |
| Recording length | 4 sec |
| | |

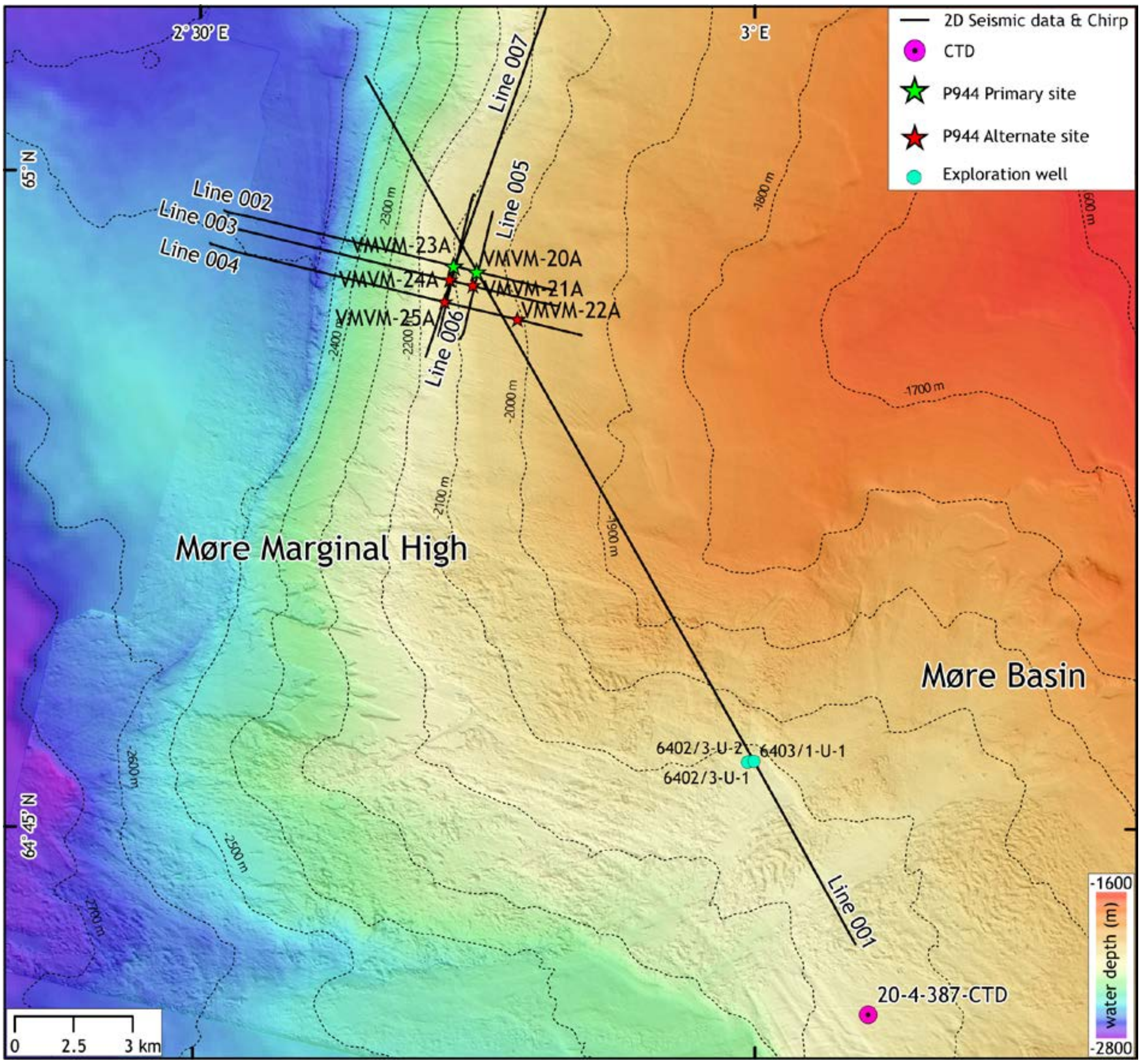


*Figure 5: Seismic data acquisition at Kolga High.*

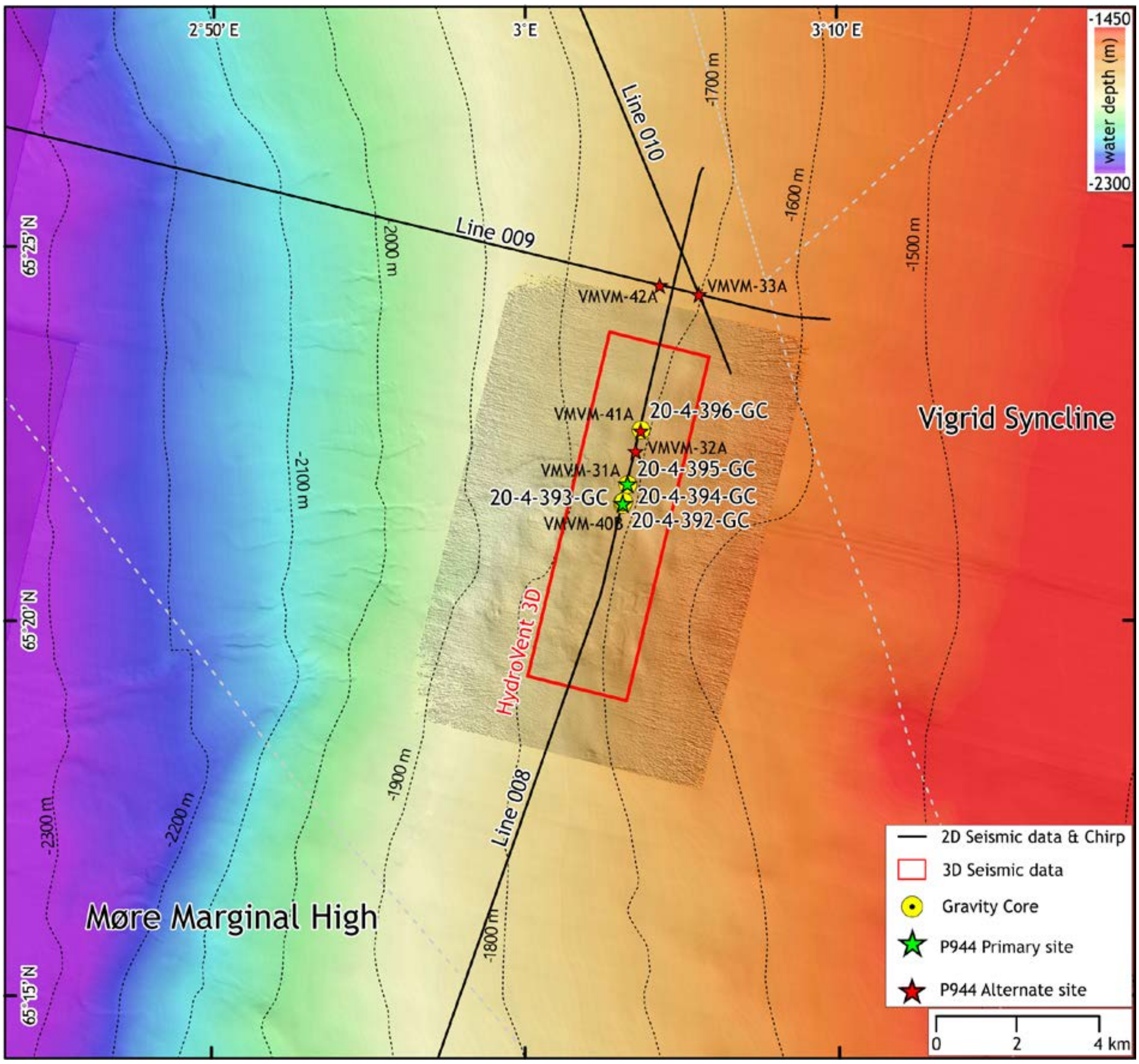


*Figure 6: Overview of data acquired at Modgunn Arch including 2D and 3D high-resolution seismic data (8,2 x 2,6 km), sub-bottom profiler data and 4 gravity cores.*

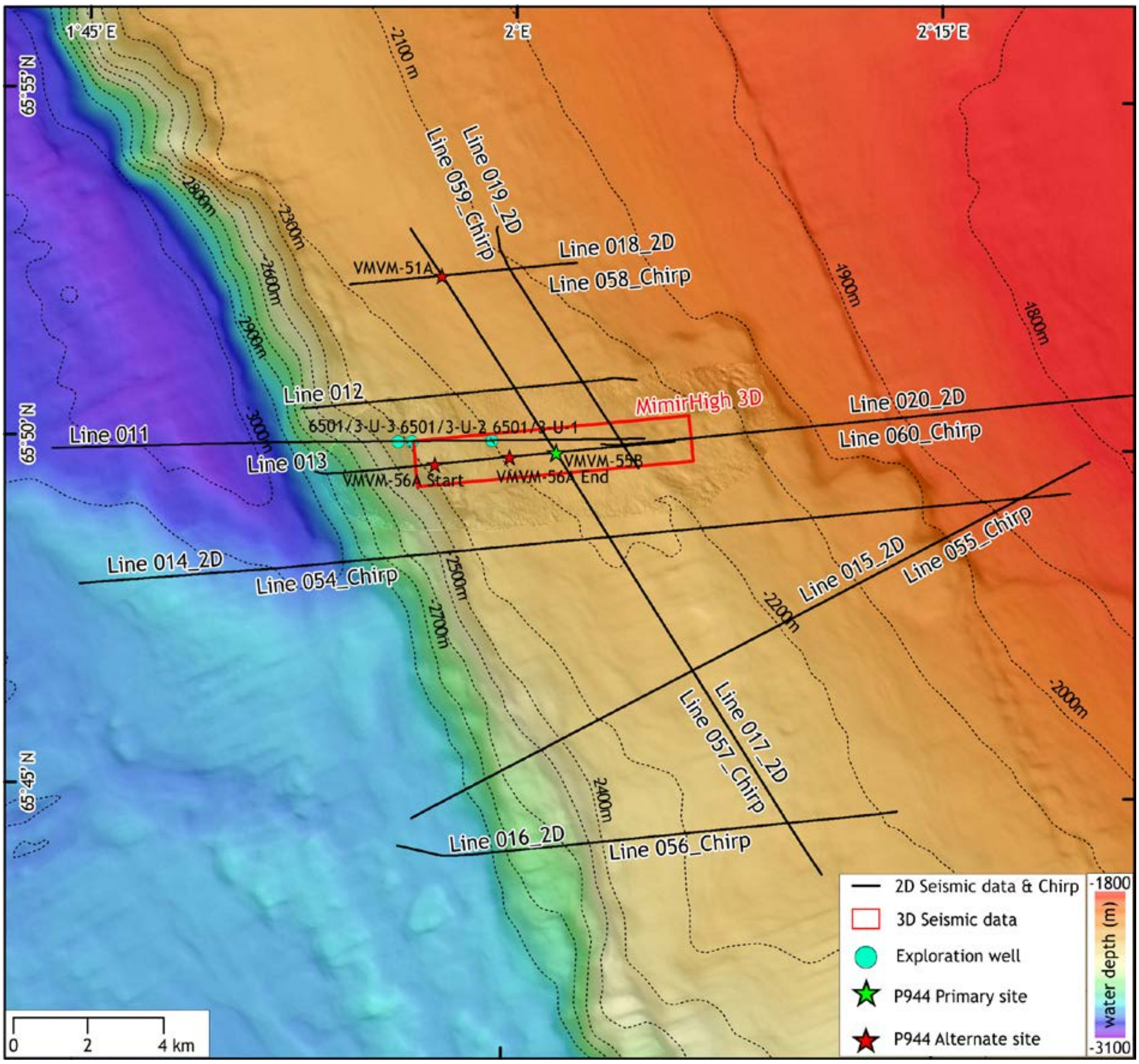


*Figure 7: Seismic data acquisition at Mimir High including nine 2D seismic lines and a 3D seismic cube (8,0 x 1,2 km).*

## 2D seismic processing

We processed 2D seismic data on board in RadExPro 2020.1 software, following a standard processing routine consisting of SEG-D import, geometry assignment and CDP binning, denoising, stacking, deghosting, migration and post-migration cleaning (Table 3).

The geometry parameters for this survey are outlined in Table 1 and Figure 4. Denoising of the 2D lines was largely dependent on the source of noise; some sources of noise were not consistent across the entire 10 day survey period. A simple bandpass filter was applied to all lines, parameterized to 20-30-800-1000 Hz, although for some later lines the high pass and cut were reduced to 500/600-800 Hz. As is typical in CAGE/UiT processing routines, we had to apply a despiking/burst noise removal algorithm to the lines. Various additional noise filters were applied on a line-by-line basis including F-K filtering to remove coherent noise and F-X predictive filtering. To note, denoising flows were designed for shot gathers. Amplitude corrections (normalization, spherical divergence) were also applied.

In order to account for the destructive interference of the short time lag multiple, or ghost, we applied a deghosting routine to some of the lines. This targeted the source ghost, with a time delay of between 1.9-2.3 ms – although this was not implemented across all lines. In general the migration algorithm used was the Stolt F-K migration with a constant velocity of 1500 m/s. Without having velocity information, this was the most consistent migration across all lines although a Kirchhoff migration appeared to have good results when a constant velocity was adequate for the geologic setting. Data examples for lines 10 and 20 are shown in Figure 8 and Figure 9, respectively.

The data will be post-processed and quality-controlled at UiT, including testing alternative migration algorithm and post-migration denoising using Geoteric.

Table 3: Processing parameters for the 2D seismic survey.

| **Seismic processing flow** | |
|---|---|
| SEG-D import and geometry assignment | Input of SEG-D files<br>Geometry assignment and offset calculation |
| Filtering in the shot gathers | Removal of bad channels<br>Bandpass filter of 20-30-800-1000 Hz or 20-30-600-800 Hz<br>Burst noise removal<br>F-X filtering /F-K filtering |
| Deghosting in channel gathers<br>(*not applied to lines 40-46) | TopMute (mute above seafloor)<br>Resample to 0.05 ms<br>SharpSeis Deghosting<br>Resample back to 0.5 ms |
| NMO and stacking | NMO (1500 m/s)<br>Ensemble Stack |
| Migration | Stolt F-K (1500 m/s, maximum frequency 500 Hz, slope 50 Hz assuming maximum dip of 45) |
| SEG-Y output | IBM floating point<br>CDP_X,4R,IBM,181/ CDP_Y,4R,IBM, 185<br>Coordinate system: ED50-UTM31N |

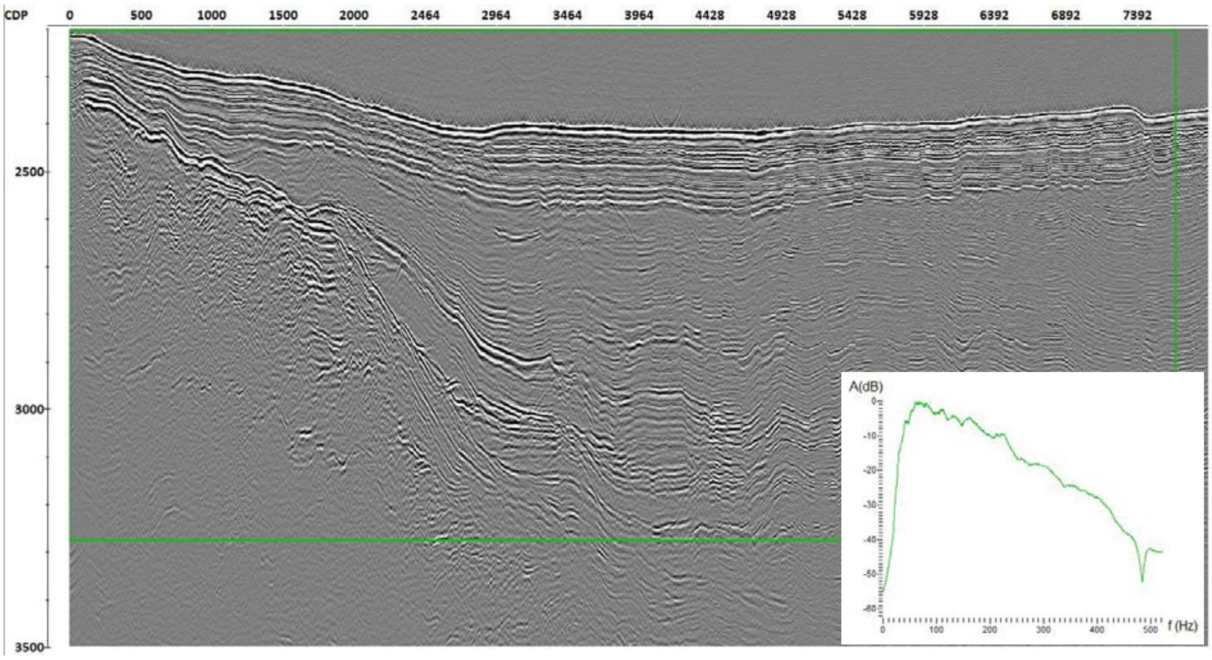


*Figure 8: Example of Line 10 heading northwest from the Modgunn Arch after processing seismic data on board (see Figure 3 for location). Inset image shows frequency spectrum calculated from the data outlined by the green rectangle.*

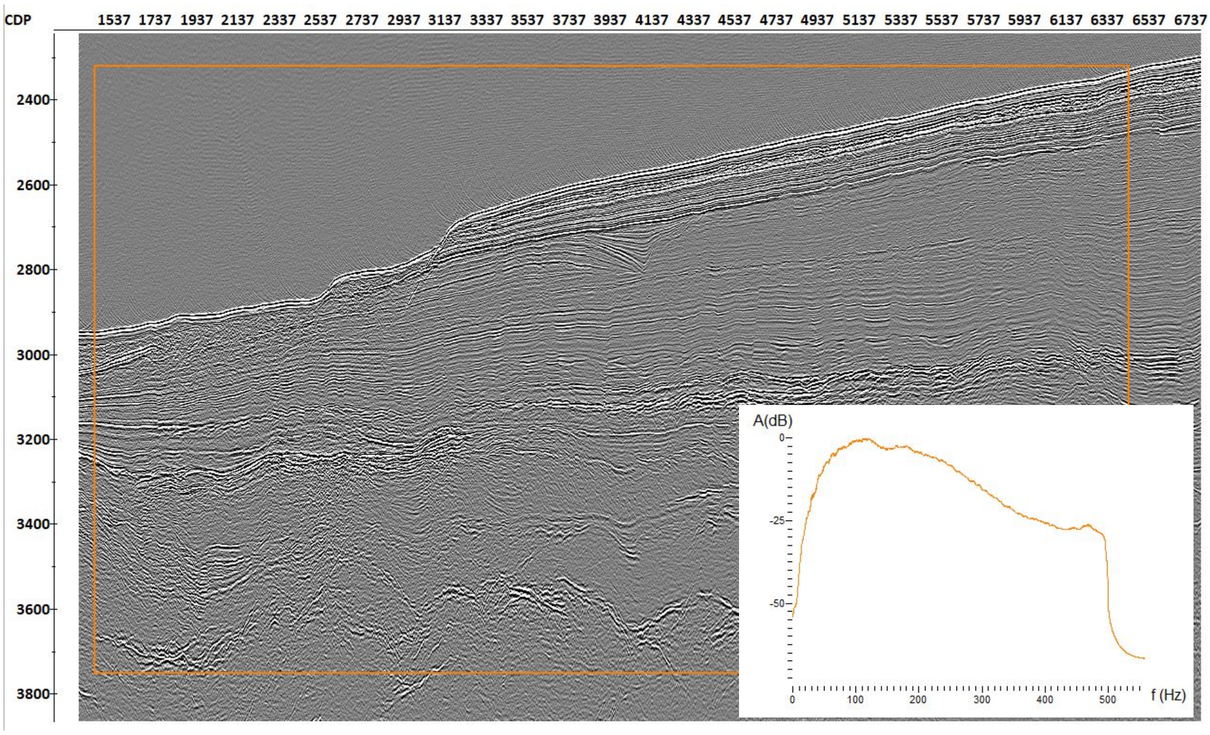


*Figure 9: Example of Line 20 at Mimir High after on board processing (see Figure 3 for location). Inset image shows frequency spectrum calculated from the data outlined by the brown rectangle.*

## 3D seismic processing

We processed 3D seismic data on board in RadExPro 2020.1 software, following a standard processing routine consisting of SEG-D import, geometry assignment and refining, denoising, deghosting, merging sailing lines, CDP binning, NMO and stacking, interpolation and finally migration (Table 4).

After importing SEG-D shot files into RadExPro, geometry is first assigned and then refined. Assigning receiver positions within RadExPro is based upon the GPS positions of the paravanes, the gun and the aft of the ship, assuming the streamer approximates a catenary curve. Points along the catenary should thus be the position of the T-junctions, and then receivers are positioned an appropriate distance back. However, this presumes that the streamer is a catenary; i.e. symmetrical in particular – weather and water current activity often preclude such symmetry, and therefore we refine geometry by using least-squares approximation of the cross-cable curve, constrained by the length of the cross-cable, GPS coordinates of paravanes and known distances of receivers along the streamers.

Noise in the data was reduced by using a simple bandpass filter set to 20-30-1000-1500 Hz, despiking the data set and implementing an F-X filter. The bandpass filter kept a lot of high frequencies, however later testing showed that we could have narrowed this to ~20-30-600-800 Hz without reducing data quality and potentially improving the dataset prior to deghosting. F-X filtering gives best results when applied to shot gathers and improves results of later processing flows significantly. Burst noise removal must be applied to both 3D seismic datasets in order to remove what is presumably electrical burst noise from the dataset.

Deghosting was the only wavelet processing method we implemented. We used the module SharpSeis Deghosting - primarily focused on the source ghost as the receiver ghost corresponds to a frequency above the ‘usable’ frequency range. The minimum and maximum ghost time delays were 2.3 and 3.7 ms respectively.

3D processing follows a standard routine; merge, CDP bin to 6.25 x 6.25 m, NMO correction and Stack, interpolation followed by migration. CDP binning to 6.25 x 6.25 m results in an average trace fold of 5 traces per CDP bin (Figure 10). NMO correction and stacking assumes a constant velocity of 1500 m/s. Here, we used a simple Stolt 3D Post Stack migration with a constant velocity of 1500 m/s with the intention of improving the migration after the expedition. A data example of the 3D seismic data from Mimir High is shown in Figure 11).

The data will be post-processed and quality-controlled at UiT, including testing alternative migration algorithm and post-migration denoising using Geoteric.

Table 4: Processing parameters for the 3D seismic survey.

| **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 20-30-1000-1500 Hz |
| | Amplitude correction / Trace equalization |
| | Burst noise removal |

| | |
|---|---|
| | F-X Predictive filtering |
| Deghosting in channel gathers | TopMute (mute above seafloor)<br>Resample to 0.05 ms<br>SharpSeis Deghosting of the source ghost<br>Resample back to 0.25 ms<br>TopMute |
| NMO and stacking | NMO (constant velocity, 1500 m/s)<br>Ensemble Stack using mean stack mode |
| Interpolation | Empty bins filled in by interpolation |
| Migration | Migration using a stolt migration (constant velocity 1500 m/s) |
| SEG-Y output | IBM floating point, big-endian<br>ILINE_NO,4I,,189/XLINE_NO,4I,,193/CDP_X,4R,IBM,181/ CDP_Y,4R,IBM,185<br>ED50-UTM31 N |

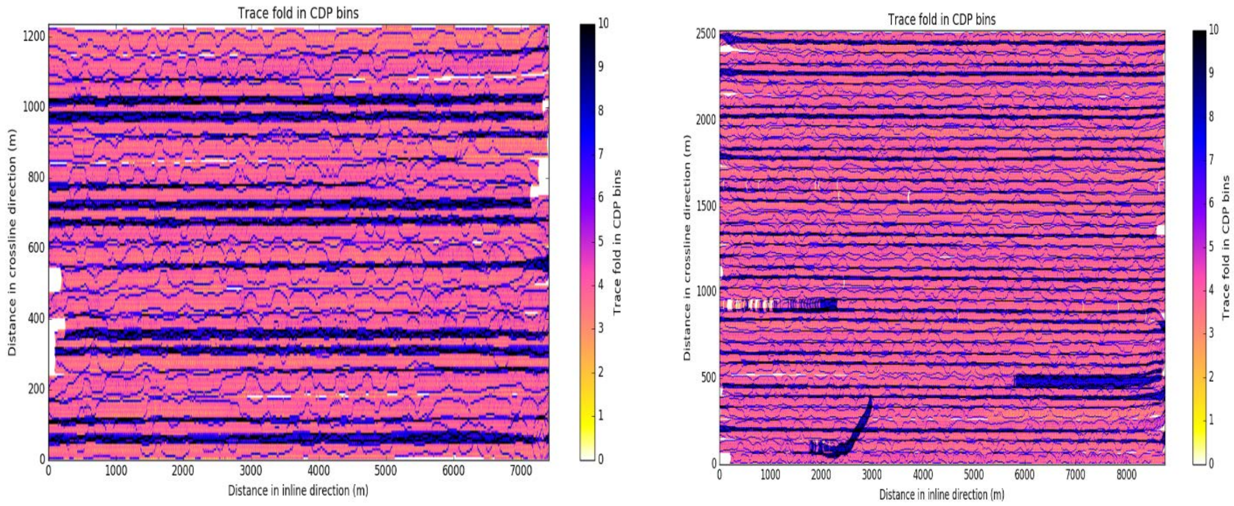


*Figure 10: Fold map Mimir High 3D survey (left) and HydroVent 3D survey (right).*

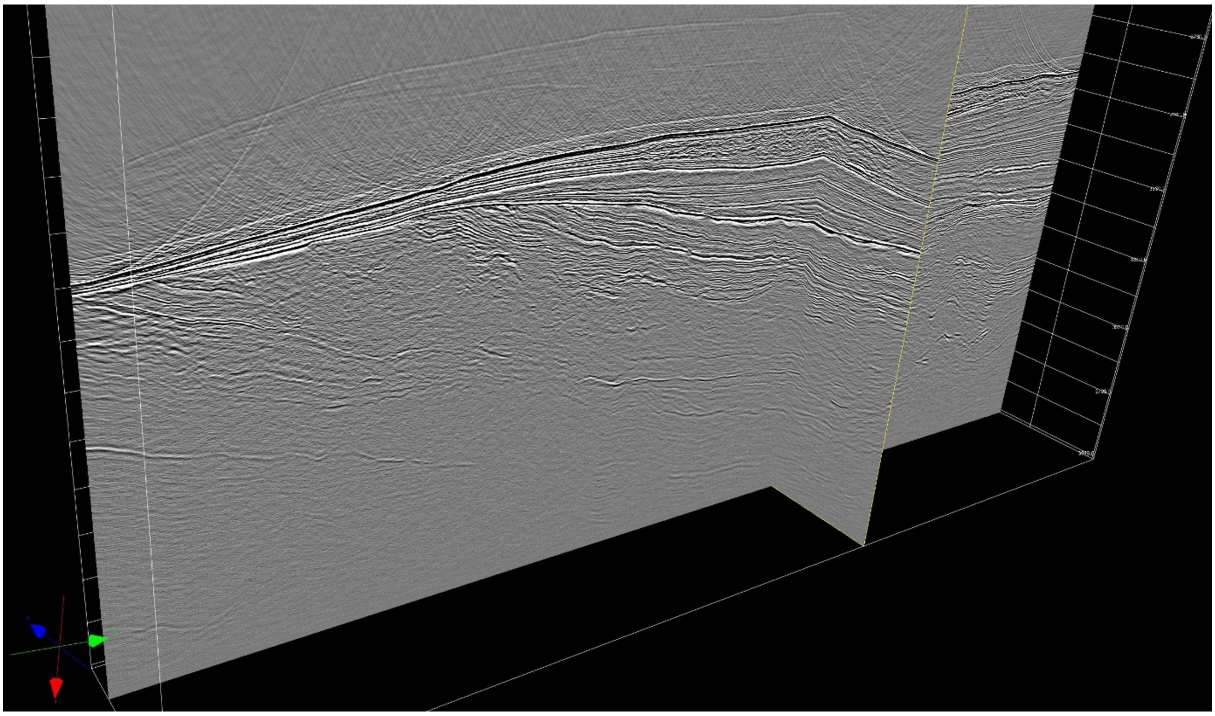

*Figure 11: 3D view of an example of the high-resolution P-Cable 3D seismic data acquired at Mimir High.*

## Gravity Coring

We collected four gravity cores in the Modgunn Arch area, which is characterized by a vent complex consisting of several hundreds of individual vents. The goal of the coring is to study the activity of the vent complex and to characterize the sediments of the uppermost stratigraphy. The cores, collected along a seismic transect in water depths from 1687 to 1706 m, showed a penetration varying from 441 to 487 cm. Existing high-quality 3D seismic data combined with the acquisition of new high-resolution 3D and chirp data during the cruise were used to define the best suited coring sites (Figure 12). Two gravity cores are directly located above a vent characterized by seismic blanking in the shallow subsurface (HH-392-GC and HH-394-GC). The other two gravity cores penetrate continuously stratified sediments, and will be used as reference cores (HH-395-GC and HH-396-GC).

All four cores have been sampled for geochemical and geobiological fluid analysis directly after core recovery. The sampled sediments were taken from the base of the gravity core and fill two thirds of the provided aluminum cans. All cores have been sampled twice to allow different analyzing techniques at a later stage. The cans were subsequently put in the freezer of Helmer Hanssen, with the cap of the can lying at the bottom. Throughout the sampling process, we strictly avoided any contact to plastic substances to avoid contamination of the sediments.

The gravity cores were cut into five sections of approximately one meter, and stored at the cooling room of the vessel. Each section was labeled twice on the liner and on both caps. The sediments collected within the core catcher are preserved as separate samples.

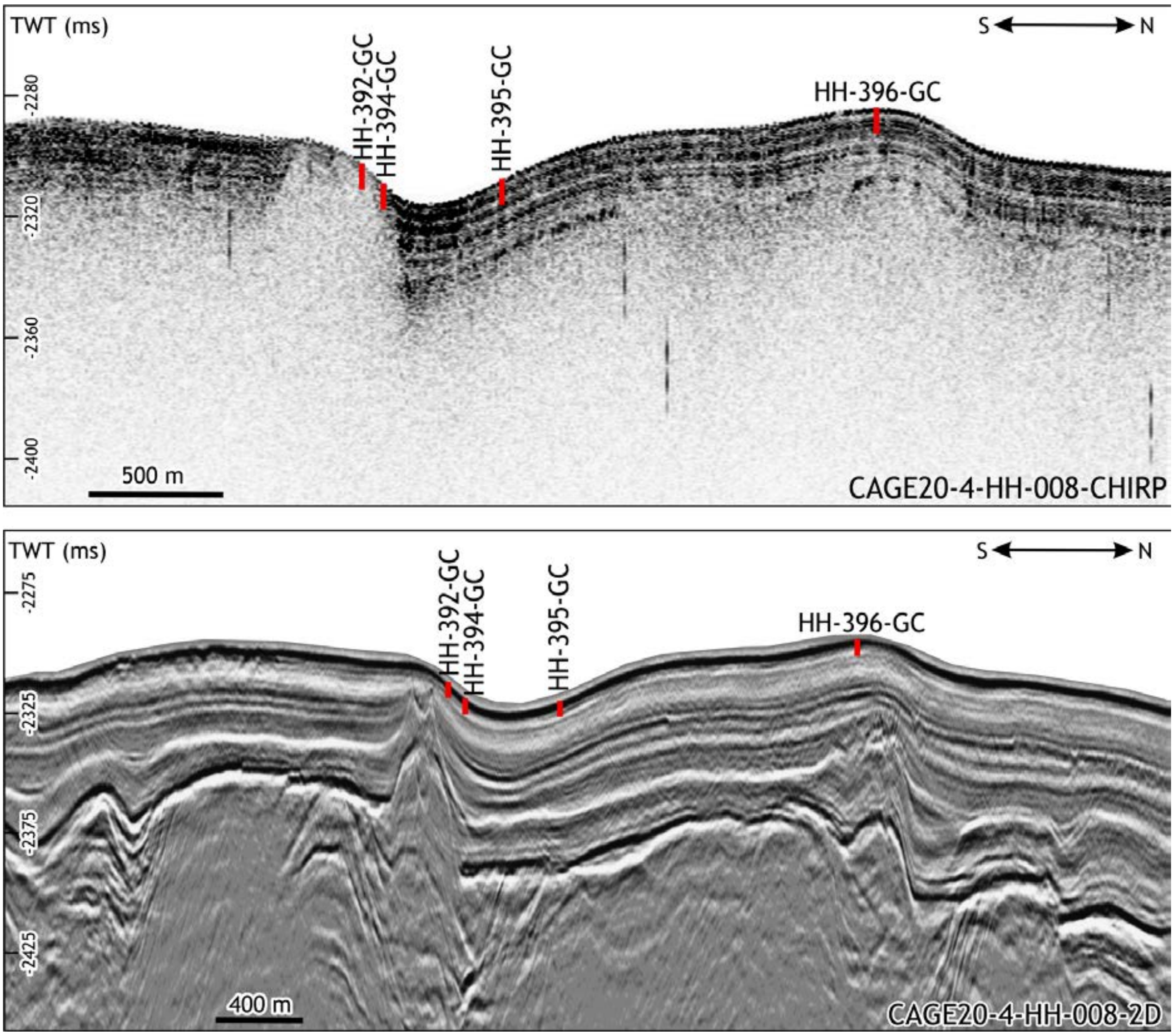


*Figure 12:* Seismic profile across the coring transect. Four gravity cores have been collected in the Modgunn Arch area (red bars). Upper panel: Chirp data. Lower panel: High-resolution 2D seismic data.

## References

Berndt, C., Planke, S., Teagle, D., Huismans, R., Torsvik, T., Frieling, J., Jones, M.T., Jerram, D.A., Tegner, C., Inge Faleide, J. and Coxall, H., 2019. Northeast Atlantic breakup volcanism and consequences for Paleogene climate change-MagellanPlus Workshop report. Scientific Drilling, 26, pp.69-85.

Huismans, R., Berndt, C., Planke, S., Jones, M.T., Tegner, C., Faleide, J.I., Gernigon, L., Frieling, J., Torsvik, T., Teagle, D., Jolley, D., Breivik, A., Svensen, H.H., Jerram, D.A., Myklebust, R., Abdelmalak, M.M., Augland, L.E., Buiter, S., Millett, J., and Bünz, S., 2019. The Nature, Cause and Climate Implications of Excess Magmatism During the Northeast Atlantic Continental Breakup. IODP Application P944-Full2, 44pp.

Lebedeva-Ivanova, N., Polteau, S., Bellwald, B., Planke, S., Berndt, C. and Stokke, H.H., 2018. Toward one-meter resolution in 3D seismic. The Leading Edge, 37(11), pp.818-828.

# APPENDIX

Shortened tables of station and line logs are included in this report. More extensive information in spreadsheets is available on request.

## Station log CAGE20-4

| Location | Station Id | Date | Time (UTC) | Lat. [N] Long. [E] | Recovery [cm] | Water Depth [m] | Notes |
|---|---|---|---|---|---|---|---|
| Kolga High | CAGE20-4-HH-387-CTD | 06.08 | 15:16 | 64°40.782' 03°06.056' | | 2151 | No water samples |
| Modgunn Arch | CAGE20-4-HH-392-GC | 08.08 | 04:02 | 65°21.561' 03°03.098' | 487 | 1700 | |
| Modgunn Arch | CAGE20-4-HH-393-GC | 08.08 | 05:49 | 65°21.600' 03°03.099' | 0 | 1704 | Empty core |
| Modgunn Arch | CAGE20-4-HH-394-GC | 08.08 | 07:25 | 65°21.603' 00°33.131' | 441 | 1703 | |
| Modgunn Arch | CAGE20-4-HH-395-GC | 08.08 | 09:07 | 65°21.831' 03°03.263' | 475 | 1706 | |
| Modgunn Arch | CAGE20-4-HH-396-GC | 08.08 | 10:51 | 65°22.559' 03°03.690' | 460 | 1687 | |

## Line log CAGE20-4

| Location | Line ID | Date | Time (UTC) START | Lat. [N] Long. [E] START | Time (UTC) STOP | Lat. [N] Long. [E] STOP | Source/ Pulse mode | Shot Interval [sec] | Ship Speed (kn) |
|---|---|---|---|---|---|---|---|---|---|
| Kolga High | CAGE20-4-HH-001-2D | 06.08 | 22:31 | 64°42.050' 03°05.780' | 03:47 | 65°02.196' 02°38.960' | 2 mini GI (30/30 & 15/15) | 6 | 4 (until shot 1565) 4.5(after 1565) |
| Kolga High | CAGE20-4-HH-001-CHIRP | 06.08 | 22:17 | 64°51.390' 03°06.530' | 03:47 | 65°02.196' 02°38.960' | Chirp | 4 | 4.7 |
| Kolga High | CAGE20-4-HH-002-2D | 07.08 | 05:47 | 64°59.030' 02°32.304' | 07:19 | 64°57.327' 02°49.310' | 2 mini GI (30/30 & 15/15) | 6 | 4.5 |
| Kolga High | CAGE20-4-HH-002-CHIRP | 07.08 | 05:49 | 64°59.030' 02°32.304' | 08:19 | 64°57.327' 02°49.310' | Chirp | 4 | 4.5 |
| Kolga High | CAGE20-4-HH-003-2D | 07.08 | 07:45 | 64°57.030' 02°49.007' | 09:18 | 64°58.739' 02°31.925' | 2 mini GI (30/30 & 15/15) | 6 | 5.1 |
| Kolga High | CAGE20-4-HH-003-CHIRP | 07.08 | 07:38 | 64°56.984' 02°50.375' | 09:18 | 64°58.739' 02°31.925' | Chirp | 4 | 5.1 |
| Kolga High | CAGE20-4-HH-004-2D | 07.08 | 09:41 | 64°58.207' 02°31.905' | 11:23 | 64°56.360' 02°50.350' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Kolga High | CAGE20-4-HH-004-CHIRP | 07.08 | 09:38 | 64°58.283' 02°31.424' | 11:27 | 64°56.158' 02°50.596' | Chirp | 4 | 5 |
| Kolga High | CAGE20-4-HH-005-2D | 07.08 | 12:08 | 64°56.340' 02°44.210' | 12.46.00 | 64°59.230' 02°45.839' | 2 mini GI (30/30 & 15/15) | 6 | 4.8 |
| Kolga High | CAGE20-4-HH-005-CHIRP | 07.08 | 12:08 | 64°56.340' 02°44.210' | 12.48.41 | 64°59.420' 02°45.918' | Chirp | 4 | 4.8 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Kolga High | CAGE20-4-HH-006-2D | 07.08 | 13.01.09 | 64°59.256'<br>02°44.520' | 13.43.52 | 64°56.151'<br>02°42.743' | 2 mini GI (30/30 & 15/15) | 6 | 4.5 |
| Kolga High | CAGE20-4-HH-006-CHIRP | 07.08 | 12.59.09 | 64°59.454'<br>02°44.653' | 13.46.15 | 64°56.023'<br>02°42.557' | Chirp | 4 | 4.5 |
| Kolga High | CAGE20-4-HH-007-2D | 07.08 | 14.13.38 | 64°55.969'<br>02°42.338' | 16:57 | 65°08.186'<br>02°52.237' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Kolga High | CAGE20-4-HH-007-CHIRP | 07.08 | 14.13.38 | 64°55.969'<br>02°42.338' | 17:01 | 65°07.959'<br>02°51.979' | Chirp | 4 | 5 |
| Modgunn Arch | CAGE20-4-HH-008-2D | 07.08 | 17:51 | 65°08.171'<br>02°52.228' | 21:52 | 65°26.050'<br>03°05.740' | 2 mini GI (30/30 & 15/15) | 6 | |
| Modgunn Arch | CAGE20-4-HH-008-CHIRP | 07.08 | 17:53 | 65°08.355'<br>02°52.381' | 21:54 | 65°26.060'<br>03°06.000' | Chirp | 4 | |
| Modgunn Arch | CAGE20-4-HH-009-2D | 07.08 | 22:46 | 65°24.039'<br>03°09.315' | 01:16 | 65°26.643'<br>02°42.733' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Modgunn Arch | CAGE20-4-HH-009-CHIRP | 07.08 | 22:44 | 65°24.033'<br>03°09.565' | 01:18 | 65°26.653'<br>02°42.560' | Chirp | 4 | |
| Modgunn Arch | CAGE20-4-HH-010-2D | 08.08 | 12:11 | 65°22.980'<br>03°07.411' | 19:25 | 65°53.913'<br>02°35.881' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Modgunn Arch | CAGE20-4-HH-010-CHIRP | 08.08 | 12:13 | 65°23.057'<br>03°07.192' | 19:29 | 65°54.278'<br>02°35.926' | Chirp | 4 | |
| Mimir High | CAGE20-4-HH-011-2D | 09.08 | 07:29 | 65°49.875'<br>01°47.353' | 09:01 | 65°50.091'<br>02°04.860' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-011-CHIRP | 09.08 | 07:36 | 65°49.897'<br>01°48.676' | 09:03 | 65°50.048'<br>00°25.293' | Chirp | 4 | |
| Mimir High | CAGE20-4-HH-012-2D | 09.08 | 09:33 | 65°50.951'<br>02°04.079' | 10:33 | 65°50.437'<br>01°52.286' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-012-CHIRP | 09.08 | 09:29 | 65°50.898'<br>02°04.807' | 10:36 | 65°50.433'<br>01°52.182' | Chirp | 4 | |
| Mimir High | CAGE20-4-HH-013-2D | 09.08 | 11:25 | 65°49.521'<br>01°53.555' | 12:29 | 65°50.069'<br>02°06.071' | 2 mini GI (30/30 & 15/15) | 6 | 5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mimir High | CAGE20-4-HH-013-CHIRP | 09.08 | 11:18 | 65°49.560'<br>01°52.555' | 12:30 | 65°50.079'<br>02°06.286' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-014-CHIRP | 11.08 | 08:39 | 65°24.638'<br>03°04.809' | 10:07 | 65°18.936'<br>03°01.664' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-015-CHIRP | 11.08 | 10:34 | 65°19.150'<br>03°01.613' | 11:45 | 65°24.020'<br>03°04.027' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-016-CHIRP | 11.08 | 12:09 | 65°23.590'<br>00°34.350' | 13:29 | 65°18.934'<br>03°01.850' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-017-CHIRP | 11.08 | 13:45 | 35°18.900'<br>03°01.390' | 14:58 | 65°23.703'<br>03°04.176' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-018-CHIRP | 11.08 | 15:22 | 65°23.959'<br>03°04.625' | 16:37 | 65°19.089'<br>03°01.817' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-019-CHIRP | 11.08 | 16:57 | 65°18.990'<br>03°01.355' | 18:11 | 65°23.770'<br>03°04.125' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-020-CHIRP | 11.08 | 18.35.00 | 65°23.780'<br>03°04.611' | 19:50 | 65°18.888'<br>03°01.992' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-021-CHIRP | 11.08 | 20:06 | 65°18.930'<br>03°01.188' | 21:19 | 65°23.957'<br>03°03.931' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-022-CHIRP | 11.08 | 21.38.00 | 65°23.973'<br>03°04.746' | 22:55 | 65°18.975'<br>03°01.913' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-023-CHIRP | 11.08 | 23:05 | 65°19.091'<br>03°01.197' | 00:15 | 65°23.804'<br>03°03.889' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-024-CHIRP | 12.08 | 00:23 | 65°23.793'<br>03°04.809' | 01:38 | 65°18.869'<br>03°01.932' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-025-CHIRP | 12.08 | 02:57 | 65°16.215'<br>02°59.543' | 04:57 | 65°23.896'<br>03°03.999' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-026-CHIRP | 12.08 | 05:06 | 65°23.683'<br>03°04.919' | 06:18 | 65°19.001'<br>03°02.097' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-027-CHIRP | 12.08 | 06:32 | 65°19.087'<br>03°01.059' | 07:41 | 65°23.843'<br>00°33.825' | Chirp | 4 | 4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Modgunn Arch | CAGE20-4-HH-028-CHIRP | 12.08 | 07:54 | 65°23.752'<br>00°34.940' | 09:03 | 65°18.983'<br>03°02.160' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-029-CHIRP | 12.08 | 09:16 | 65°19.070'<br>03°00.894' | 10:28 | 65°23.881'<br>03°03.783' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-030-CHIRP | 12.08 | 10.40.43 | 65°23.751'<br>03°04.962' | 11:54 | 65°18.875'<br>03°03.141' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-031-CHIRP | 12.08 | 12:06 | 65°18.925'<br>03°00.890' | 13:25 | 65°23.974'<br>03°03.915' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-032-CHIRP | 12.08 | 13:34 | 65°23.735'<br>03°04.977' | 14:49 | 65°18.980'<br>03°02.325' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-033-CHIRP | 12.08 | 15:02 | 65°19.181'<br>03°00.854' | 16:12 | 65°23.717'<br>03°03.512' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-034-CHIRP | 12.08 | 16:29 | 65°23.642'<br>03°05.105' | 17:39 | 65°19.060'<br>03°02.461' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-035-CHIRP | 12.08 | 17:55 | 65°19.128'<br>00°30.763' | 19:03 | 65°23.942'<br>03°03.613' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-036-CHIRP | 12.08 | 19:18 | 65°23.602'<br>03°05.139' | 20:28 | 65°18.861'<br>03°02.394' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-037-CHIRP | 12.08 | 20:40 | 65°19.069'<br>03°00.751' | 21:55 | 65°23.963'<br>03°03.609' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-038-CHIRP | 12.08 | 22:10 | 65°23.751'<br>03°05.184' | 23.22.00 | 65°18.993'<br>03°02.578' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-039-CHIRP | 13.08 | 00:31 | 65°17.452'<br>02°59.969' | 02:12 | 65°23.952'<br>03°03.477' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-040-CHIRP | 13.08 | 03:56 | 65°19.043'<br>03°00.593' | 05:11 | 65°23.933'<br>03°03.304' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-041-CHIRP | 13.08 | 05:28 | 65°23.703'<br>03°05.270' | 06:40 | 65°19.093'<br>03°02.727' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-042-CHIRP | 13.08 | 06:58 | 65°19.096'<br>03°00.461' | 08:07 | 65°23.724'<br>03°03.102' | Chirp | 4 | 4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Modgunn Arch | CAGE20-4-HH-043-CHIRP | 13.08 | 08:27 | 65°23.663'<br>03°05.403' | 09:42 | 65°18.885'<br>03°02.698' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-044-CHIRP | 13.08 | 09:59 | 65°19.102'<br>03°00.363' | 00:00 | 65°23.884'<br>03°03.117' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-045-CHIRP | 13.08 | 11:29 | 65°23.734'<br>03°05.436' | 12.42.00 | 65°18.773'<br>03°02.579' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-046-CHIRP | 13.08 | 13:00 | 65°19.256'<br>03°00.362' | 14:14 | 65°23.978'<br>03°03.165' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-047-CHIRP | 13.08 | 14:35 | 65°23.565'<br>03°05.517' | 15:46 | 65°19.028'<br>03°02.954' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-048-CHIRP | 13.08 | 16:11 | 65°19.085'<br>03°00.107' | 17:22 | 65°23.747'<br>03°02.861' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-049-CHIRP | 13.08 | 17:44 | 65°23.694'<br>03°05.658' | 18:58 | 65°18.854'<br>03°02.864' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-050-CHIRP | 13.08 | 19:16 | 65°19.062'<br>03°00.026' | 20:28 | 65°23.996'<br>03°02.940' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-051-CHIRP | 13.08 | 20:48 | 65°23.650'<br>03°05.710' | 22:05 | 65°18.777'<br>03°02.950' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-052-CHIRP | 14.08 | 00.18.26 | 65°19.129'<br>03°00.108' | 01.31.36 | 65°23.945'<br>03°02.835' | Chirp | 4 | 4 |
| Modgunn Arch | CAGE20-4-HH-053-CHIRP | 14.08 | 01.52.28 | 65°23.776'<br>03°05.821' | 03:06 | 65°19.092'<br>03°03.225' | Chirp | 4 | 4 |
| Mimir High | CAGE20-4-HH-014-2D | 15.08 | 13:29 | 65°47.887'<br>01°45.314' | 16:31 | 65°49.385'<br>02°19.713' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-054-CHIRP | 15.08 | 13:29 | 65°47.888'<br>01°45.375' | 16:30 | 64°49.385'<br>02°19.713' | Chirp | 4 | 5 |
| Mimir High | CAGE20-4-HH-015-2D | 15.08 | 17:06 | 65°49.772'<br>02°20.037' | 09:48 | 65°44.559'<br>01°56.600' | 2 mini GI (30/30 & 15/15) | 6 | 4 |
| Mimir High | CAGE20-4-HH-055-CHIRP | 15.08 | 17:03 | 64°49.875'<br>02°20.491' | 19:42 | 65°44.694'<br>01°57.167' | Chirp | 4 | 4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mimir High | CAGE20-4-HH-016-2D | 15.08 | 23:49 | 65°44.175' 01°56.433' | 01.26.53 | 65°44.794' 02°14.030' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-056-CHIRP | 15.08 | 22:26 | 65°44.076' 01°53.263' | 01.24.52 | 65°44.767' 02°13.557' | Chirp | 4 | 5 |
| Mimir High | CAGE20-4-HH-017-2D | 16.08 | 02.29.25 | 65°43.995' 02°10.879' | 04:58 | 65°53.106' 01°56.284' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-057-CHIRP | 16.08 | 02.18.52 | 65°43.494' 02°11.742' | 04:54 | 65°52.865' 01°56.697' | Chirp | 4 | 5 |
| Mimir High | CAGE20-4-HH-018-2D | 16.08 | 05:23 | 65°52.258' 01°54.619' | 06:06 | 65°52.630' 02°02.477' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-058-CHIRP | 16.08 | 05:21 | 65°52.246' 01°54.292' | 06:01 | 65°52.579' 02°01.513' | Chirp | 4 | 5 |
| Mimir High | CAGE20-4-HH-019-2D | 16.08 | 06:41 | 65°52.994' 01°59.430' | 07:38.11 | 65°49.602' 02°04.715' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-059-CHIRP | 16.08 | 06:38 | 65°53.172' 01°59.430' | 07:34 | 65°49.821' 02°04.249' | Chirp | 4 | 5 |
| Mimir High | CAGE20-4-HH-020-2D | 16.08 | 08:11 | 65°50.001' 02°03.525' | 11.58.30 | 65°51.676' 02°42.118' | 2 mini GI (30/30 & 15/15) | 6 | 5 |
| Mimir High | CAGE20-4-HH-060-CHIRP | 16.08 | 08:10 | 65°50.001' 02°03.279' | 11.57.08 | 65°51.668' 02°42.009' | Chirp | 4 | 5 |

# 3D seismic line log

Expedition: Helmer Hanssen CAGE20-4, August 2020 Survey: MimirHigh3D 09.08 – 10.08. Sheet #: 1 - 6

3D seismic at Mimir High, Vøring Margin

Survey configuration: see end of this log Times are UTC

| **3D line number:** | **Date:**<br><br>**Start - end** | **Time (UTC):**<br><br>**Start - end** | **Shot point number**<br><br>**First - last** | **Shot point number when crossing planned start and end of line** | **Comments**<br>**(sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)** |
|---|---|---|---|---|---|
| 00 | 09.08-09.08 | 17:47 – | 1- 416 | N/A | Pre-survey warm-up and test. Changed from internal to external trigger at SP227. Re-armed twice, a few SPs might be missing.<br>Disabled channels:<br>Noisy channels: 7, 9, 20 (S), 33, |
| 01 | 09.08-09.08 | 18:36-19:37 | 417-1017 | 443-973 | Line 1 towards west, wind 5m/s, air temp 12.2,<br>Noisy channels: 7,30,54,80,97,104 |
| 02 | 09.08-09.08 | 20:24-21:36 | 1018-1736 | 1151-1688 | 6.6 m/s windspeed airtemp: 12.5, seatemp: 12.78<br>Channel 9,33,41,49,57,65,73,89,97 and 105 noisy. |
| 03 | 09.08-09.08 | 22:01-23:01 | 1737-2338 | 1792-2322 | 12.76 seatemp 12.4 C air temp 5.8 m/s windspeed 188 wind direction around 1m wave height Noisy channels: 7,9,30,32,41,49,57,65,73,80,81,97,104 |

| | | | | | |
|---|---|---|---|---|---|
| 04 | 09.08-10.08 | 23:20-00:22 | 2339-2957 | 2408-2916 | 12.75C seatemp 12.6C airtemp 6.5m/s Windspeed 205 wind direction. Noisy channels: 7,9,16,30,32,41,49,57,65,73,80,81,97,104 |
| 05 | 10.08-10.08 | 00:47-1:50 | 2958-3591 | 3021-3555 | 12.9C seatemp, 12.3C airtemp, 6.3 m/s windspeed, 218 degrees wind direction. Relatively more random burst noises in the specially first half (shots) of the line in different channels. |
| 06 | 10.08-10.08 | 02:19-03:19 | 3592-4201 | 3627-4161 | 12.79 degrees celcius seatemp, 12.2 degrees C air temp. 5.8 m/s windspeed, from 214 degrees. Noisy chans same as prior lines. |
| 07 | 10.08-10.08 | 03:42-04:41 | 4202-4794 | 4231-4775 | 12.84 degrees celcius seatemp, 12.2 degrees C air temp. 6.2 m/s windspeed, from 209 degrees. Noisy chans same as prior lines. Slightly more wavy this line? |
| 08 | 10.08-10.08 | 05:06-06:10 | 4795-5427 | 4849-5396 | 12.76 degrees celcius seatemp, 12.3 degrees C air temp. 6.4 m/s windspeed, from 192 degrees. Noisy chans same as prior lines |
| 09 | 10.8-10.08 | 06:28-07:26 | 5428-6004 | 5466-5979 | 12.82 degrees celcius seatemp, 12.4 degrees C air temp. 6.0 m/s windspeed, from 192 degrees. Noisy chans same as prior lines |
| 10 | 10.8-10.08 | 07:49-08:51 | 6005-6625 | 6072-6590 | Ship speed 4 kn, 12.75 degrees celcius seatemp, 12.5 degrees C air temp. 5.3 m/s windspeed, from 201 degrees. Noisy chans same as prior lines |
| 11 | 10.8-10.08 | 09:07-10:06 | 6626-7215 | 6673-7190 | Ship speed 4.2 kn, 13.02 degrees celcius seatemp, 12.7 degrees C air temp. 5.9 m/s windspeed, from 197 degrees. Noisy chans same as prior lines |

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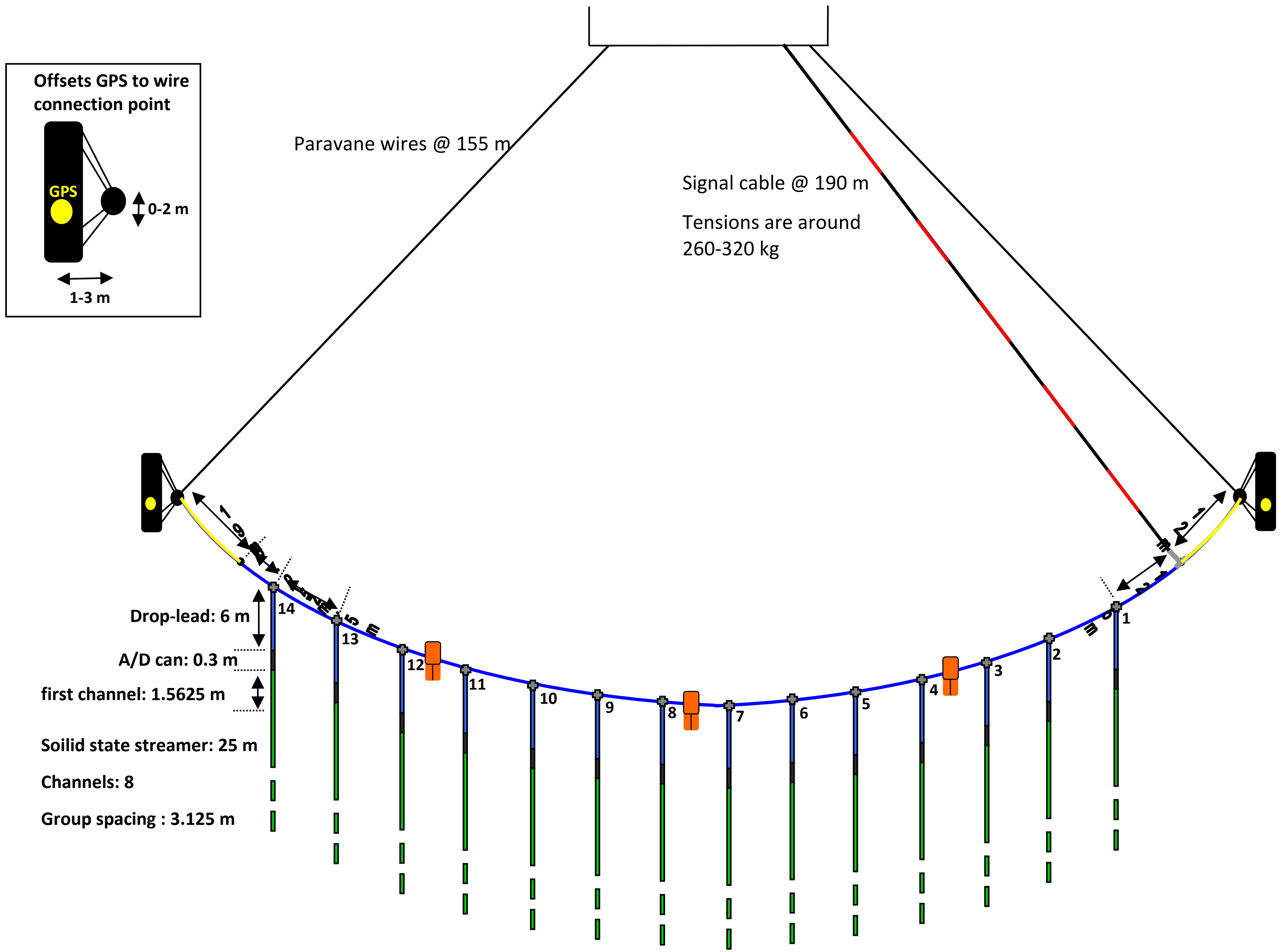
|---|---|---|---|---|---|
| 12 | 10.8-10.08 | 10:24-11:27 | 7216-7846 | 7297-7806 | 12.9C seatemp 12.6C airtemp 7.2 m/s wind speed 190 degree direction. Noisy chans same as prior lines |
| 13 | 10.8-10.08 | 11:42-12:53 | 7847-8550 | 7934-8488 | 13C sea temperature, 13.4 air temperature 7.5 m/s windspeed (from 180 direction). Noisy chans same as prior lines |
| 14 | 10.8-10.08 | 13:05-14:08 | 8551-9179 | 8608-9146 | 12.8 C sea temperature, 12.8 C air temperature 7.1m/s wind speed (from 192 direction). Noisy chans same as prior lines |
| 15 | 10.8-10.08 | 14:23-15:28 | 9180-9825 | 9235-9776 | 13.1 C sea temperature, 13.4 C air temperature 5.6 m/s wind speed (from 193.6direction). Noisy chans same as prior lines |
| 16 | 10.8-10.08 | 15:43-16:51 | 9826-10499 | 9912-10452 | 12.97 C sea temperature, 12.9 C air temperature 5.5 m/s wind speed (from 194 direction). Noisy chans same as prior lines |
| 17 | 10.8-10.08 | 17:04-18:09 | 10500-11151 | 10538-11082 | 13.06 C sea temperature, 13.2 C air temperature 4.5 m/s wind speed (from 201.7 direction). Noisy chans same as prior lines |
| 18 | 10.8-10.08 | 18:22-19:37 | 11152-11891 | 11287-11840 | 13.02 C sea temperature 12.6 C air temperature 2.6 m/s windspeed 188 degree wind direction. Noisy channels same as before. Wave height around 0.5m. |
| 19 | 10.8-10.08 | 19:48-20:50 | 11892-12513 | 11950-12468 | 13.1 C sea temperature 12.5 C air temperature 1.9 m/s wind speed 162 degree wind direction. Ship deviated from line in the first 50 shots. Noisy channels same as before. |
| 20 | 10.8-10.08 | 21:06-22:10 | 12514-13148 | 12624-13115 | 13.0 C sea temperature 12.6 C air temperature 2.7 m/s wind speed 150 degree wind direction. Noisy channels same as before. |

## Survey configuration:



Observed spread of paravanes:  160 -165 m
Observed distance between gun and paravanes: 98 – 118 m, deviations between distances to both paravanes up to 10 m, particular differences depending on direction of acquisition lines

Ship's speed: 4 kn ± 0,3 kn
Gun system:  Two mini-GI  (30/30 $in^3$ and 15/15 $in^3$ )
Gun towing depth: 2 m
Shooting pressure: ~170 bar
Shooting interval: 6 sec
Recording window: 4 sec
Recording delay: 0 sec
Sampling interval: 0.25ms
Streamer depth: 1.5m

# 3D seismic line log

Expedition: Helmer Hanssen CAGE20-4 August 2020 Survey: HydroVent3D 11.08 – 14.08. Sheet #: 1 - 6

3D seismic over Hydrothermal Vents at Modgunn Arch, Vøring Margin

Survey configuration: see end of document Times are UTC

| **3D line number:** | **Date:**<br><br>**Start - end** | **Time (UTC):**<br><br>**Start - end** | **Shot point number**<br><br>**First - last** | **Shot point number when crossing planned start and end of line** | **Comments**<br>**(sailing direction, ship speed, depth sensor, wind speed, air temperature downtime, etc.)** |
|---|---|---|---|---|---|
| 00 | 11.08-11.08 | 07:55 – 08:47 | 1- 443 | N/A | Pre-survey warm-up and test. |
| 01 | 11.08-11.08 | 08:48-10:07 | 444-1232 | 530-1190 | 13.2 C sea temperature, 13.1 C air temperature 0.6 m/s wind speed (from 200 direction). Noisy chans same as prior lines |
| 02 | 11.08-11.08 | 10:32-11:44 | 1233-1944 | 1280-1858 | 13.2 C sea temperature, 13.4 C air temperature 1.6 m/s wind speed (from 130 direction). Data quality very good with very few bursts. Noisy chans: 7,9,24,66,71,77,79,80,103,104. |
| 03 | 11.08-11.08 | 12:09-13:28 | 1945-2730 | 2034-2695 | 13.3 C sea temperature, 13.4 C air temperature 1.9 m/s wind speed (from 230 direction). Noisy chans: 7,9,24,66,71,77,79,80,103,104. |

| | | | | | |
|---|---|---|---|---|---|
| 04 | 11.08-11.08 | 13:44-14:58 | 2731-3472 | 2810-3440 | 13.3 C sea temperature, 13.4 C air temperature 2.3 m/s wind speed (from 160 direction). Noisy chans: 7,9,24,66,71,77,79,80,103,104. |
| 05 | 11.08-11.08 | 15:23-16:38 | 3473-4219 | 3536-4188 | 13.4 C sea temperature, 14.1 C air temperature 2.4 m/s wind speed (from 204 direction). Noisy chans: 7,9,66,71,77,79,80,103,104. |
| 06 | 11.08-11.08 | 16:58-18:12 | 4220-4957 | 4268-4914 | 13.44 C sea temperature, 13.6 C air temperature 4 m/s wind speed (from 158 direction). Noisy chans: 7,9,66,71,77,79,80,103,104. |
| 07 | 11.08-11.08 | 18:36-19:49 | 4958-5682 | 5000-5655 | 13.5 C sea temperature, 13.3 C air temperature, 3.3 m/s wind speed (from 250 direction). Noisy chans: 7,9,24,49,54,66,77,97,104 |
| 08 | 11.08-11.08 | 20:09-21:18 | 5699-6383 | 5730-6344 | 13.5 C sea temperature, 13.0 C air temperature, 2.6 m/s wind speed (from 275 direction). Noisy chans: 7,9,16,24,49,54,66,77,97,104 |
| 09 | 11.08-11.08 | 21:40-22:56 | 6383-7139 | 6441-7094 | 13.6 C sea temperature, 13.0 C air temperature, 2.8 m/s wind speed (from 277 direction). Noisy chans: 7,9,24,49,54,66,77,97,104 |
| 10 | 11.08-12.08 | 23:05-00:17 | 7146-7847 | 7184-7806 | 7351 lost shot 81<br>13.6 C sea temperature, 13.0 C air temperature, 1.3 m/s wind speed (from 192 direction). Noisy chans: 7,9,29,66,77,80,97,103,104 |
| 11 | 12.08-12.08 | 00:26-01:38 | 7848-8439 | 7889-8430 | 13.58C seatemp 12.7C Airtemp 1.9 m/s True windspeed (156 degree direction). |

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| | | | | | Gun 2 stopped firing every second shot around shot number 8408. Guns taken in at the end of the line. |
| 12 | 12.08-12.08 | 03:38-04:56 | 8826-9600 | 8899-9558 | Fixed Gun2 and redeployed at 02:50 UTC.<br>Shots 8440-8825 are way before the start of the line. These may be used for wide-swath 2D (?)<br>Start of line 12 of 3D at shot number 8826<br>13.48C seatemp 13.1C Airtemp 4.3 m/s True windspeed (145 degree direction).<br>Geoeel missing triggers often |
| 13 | 12.08-12.08 | 05:07-06:19 | 9601-10319 | 9630-10271 | 13.63C seatemp 13.4C Airtemp 5.8 m/s True windspeed (153 degree direction).<br>Some dropped shots along the line, not as many as line 12 |
| 14 | 12.08-12.08 | 06:32-07:42 | 10320-11025 | 10365-10979 | 13.44C seatemp 13.3C Airtemp 5.6 m/s True windspeed (150 degree direction). |
| 15 | 12.08-12.08 | 07:54-09:05 | 11026-11731 | 11071-11686 | 13.58C seatemp 13.5C Airtemp 6.2 m/s True windspeed (150 degree direction). |
| 16 | 12.08-12.08 | 09:16-10:29 | 11732-12461 | 11767-12414 | 13.49C seatemp 13.3C Airtemp 8.1 m/s True windspeed (137 degree direction). |

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|---|---|---|---|---|---|
| 17 | 12.08-12.08 | 10:42-11:56 | 12462-13197 | 12503-13144 | 13.7 C sea temperature, 13.6 C air temperature, 8.6 m/s wind speed (from 138 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 18 | 12.08-12.08 | 12:08-13:24 | 13198-13962 | 13260-13910 | 13.5 C sea temperature, 13.6 C air temperature, 9.1 m/s wind speed (from 148 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 19 | 12.08-12.08 | 13:36-14:49 | 13963-14692 | 14005-14654 | 13.6 C sea temperature, 13.6 C air temperature, 10.1 m/s wind speed (from 140 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 20 | 12.08-12.08 | 15:02-16:15 | 14693-15412 | 14721-15373 | 13.47 C sea temperature, 13.4 C air temperature, 8.7 m/s wind speed (from 141 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 21 | 12.08-12.08 | 16:29-17:41 | 15413-16142 | 15459-16099 | 13.51C sea temperature, 13.5 C air temperature, 10 m/s wind speed (from 150 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 22 | 12.08-12.08 | 17:55-19:03 | 16143-16815 | 16176-16773 | 13.45C sea temperature, 13.5 C air temperature, 10 m/s wind speed (from 153 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 23 | 12.08-12.08 | 19:18-20:29 | 16816-17523 | 16842-17468 | 13.42C sea temperature, 13.6 C air temperature, 8.4 m/s wind speed (from 166 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 24 | 12.08-12.08 | 20:41-21:55 | 17524-18260 | 17565-18210 | 13.42C sea temperature, 13.3 C air temperature, 9.2 m/s wind speed (from 173 direction). Noisy chans: 7,9,30,49,66,77,97,104 |
| 25 | 12.08-12.08 | 22:12-23:20 | 18261-18514 | 18305-18514 | 13.43C sea temperature, 13.7 C air temperature, 9.5 m/s wind speed (from 175 direction). Noisy chans: 7,9,24,30,49,66,77,97,104 |

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| | | | | | 18498 leakage (close to end of line, we finished the line)<br>Guns have been taken in, tested and deployed from 23:25-00:30<br>Gun air cable broken at two places, causing air leakage. One of the chain connecting the gun frame to floatation was broken, which may have broken the cable. The cable was fixed on deck.<br>Potentially no data recorded from 22:37-23:20<br>Shot 18514 might have happened at 22:37 instead of 23:20. |
| 26 | 13.08-13.08 | 00:40-02:12 | 18515-19437 | 18748-19399 | Extended line. 13.38C sea temperature, 13.7 C air temperature, 6.7 m/s wind speed (from 190 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 25a | 13.08-13.08 | 02:27-03:40 | 19438-20174 | 19485-20134 | Redoing Line 25 as it had only few shots saved.<br>Serial string not detected 03:03:28, shot 19800<br>13.36C sea temperature, 13.8 C air temperature, 8.5 m/s wind speed (from 277 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 28 | 13.08-13.08 | 03:56-05:12 | 20175-20928 | 20229-20877 | 13.35C sea temperature, 12.9 C air temperature, 7.6 m/s wind speed (from 283 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |

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|---|---|---|---|---|---|
| 27 | 13.08-13.08 | 05:29-06:42 | 20929-21659 | 20977-21627 | 13.4C sea temperature, 12 C air temperature, 8.5 m/s wind speed (from 300 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 30 | 13.08-13.08 | 06:58-08:10 | 21660-22377 | 21705-22330 | 13.35C sea temperature, 12.2 C air temperature, 7.9 m/s wind speed (from 315 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 29 | 13.08-13.08 | 08:28-09:42 | 22378-23119 | 22418-23074 | 13.4C sea temperature, 11.8 C air temperature, 7.0 m/s wind speed (from 306 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 32 | 13.08-13.08 | 10:00-11:11 | 23120-23822 | 23164-23787 | 13.34C sea temperature, 11.9 C air temperature, 6.6 m/s wind speed (from 313 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 31 | 13.08-13.08 | 11:31-12:41 | 23823-24520 | 23860-24490 | 13.4C sea temperature, 11.6 C air temperature, 5.9 m/s wind speed (from 310 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 34 | 13.08-13.08 | 13:00-14:15 | 24521-25273 | 24556-25208 | 13.46C sea temperature, 12.2 C air temperature, 6.5 m/s wind speed (from 262 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 33 | 13.08-13.08 | 14:33-15:49 | 25274-26027 | 25330-25997 | 13.45C sea temperature, 11.4 C air temperature, 8 m/s wind speed (from 267 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |

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| 36 | 13.08-13.08 | 16:12-17:25 | 26028 - 26752 | 26063-26718 | 13.46C sea temperature, 11.4 C air temperature, 6.5 m/s wind speed (from 284 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 35 | 13.08-13.08 | 17:45-19:00 | 26753-27493 | 26793-27438 | 13.43C sea temperature, 11.4 C air temperature, 7.6 m/s wind speed (from 250 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 38 | 13.08-13.08 | 19:16-20:28 | 27494-28210 | 27550-28162 | Ship off-track for initial few shots. 13.44C sea temperature, 11.1 C air temperature, 7.1 m/s wind speed (from 233 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104 |
| 37 | 13.08-13.08 | 20:50-21:48 | 28211-28762 | 28253-28762 | 13.40C sea temperature, 10.7 C air temperature, 9.1 m/s wind speed (from 241 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104.<br><br>We started missing shots around 28737. No data saved from shots after 21:48. Guns were taken out and problem fixed. |
| 11r(remaining) | 13.08-13.08 | 22:43-23:14 | 28263-29016 | 28875-28989 | We shot small section of line again to cover missing shots in the initially covered line. Line is shot from reverse direction (reverse to original sail direction).<br><br>13.34C sea temperature, 10.9 C air temperature, 9.4 m/s wind speed (from 240 direction). Noisy chans: 7,9,24,30,49,54,66,77,97,104. |

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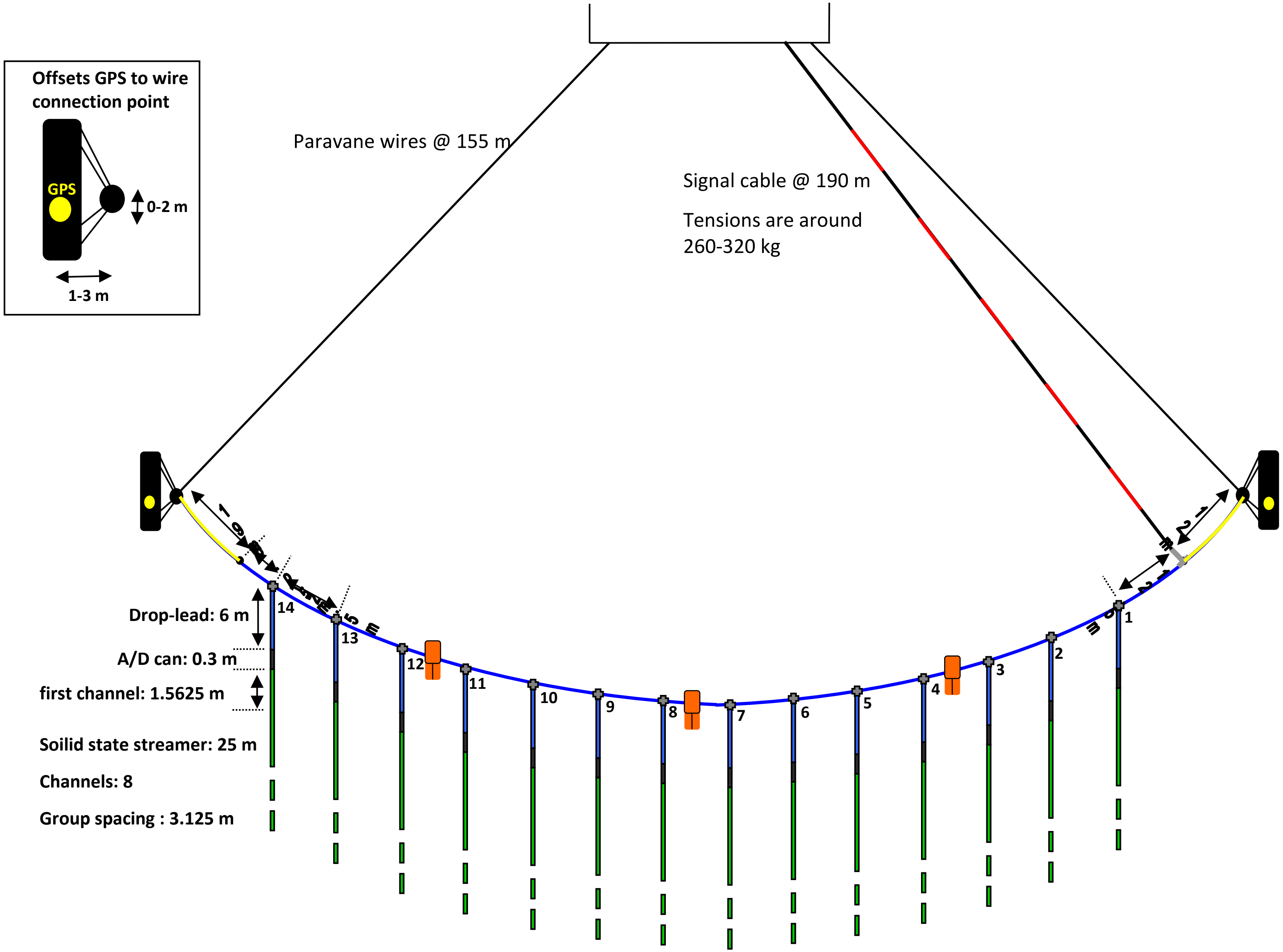
| | | | | | Triggers missing in this line also. |
| 37r | 13.08-14.08 | 23:31-00:00 | 29017-29290 | 29070-29245 | Doing data acquisition again on this line for missing shots. Sail direction same as in original line.<br><br>13.37C sea temperature, 11.2 C air temperature, 10.4 m/s wind speed (from 238 direction). |
| 40 | 14.08-14.08 | 00:20-01:32 | 29291-30012 | 29322-29967 | 13.35C sea temperature, 11.9 C air temperature, 10.5 m/s wind speed (from 225 direction). Noisy chans: 7,9,24,30,49,54,66,70,77,80, 97,104. |
| 39 | 14.08-14.08 | 01:54-03:08 | 30013-30755 | 30070-30715 | 13.33C sea temperature, 12.1 C air temperature, 12.2 m/s wind speed (from 233 direction). Noisy chans: 7,9,24,30,49,54,66,70,77,80, 97,104. |

**Comment:**

## Survey configuration:



Observed spread of paravanes: 170-175 m
Observed distance between gun and paravanes: 100 – 117 m, deviations between distances to both paravanes up to 10 m, particularly large difference between northward or southward acquisition lines.

Ship's speed: 4 kn ± 0,3 kn
Gun system: Two mini-GI (30/30 $in^3$ and 15/15 $in^3$)
Gun towing depth: 2 m
Shooting pressure: ~170 bar
Shooting interval: 6 sec
Recording window: 4 sec
Recording delay: 0 sec
Sampling interval: 0.25ms
Streamer depth: 1.5m