CAGE - Centre for Arctic Gas Hydrate Environment and Climate Report Series, Volume 1 (2013)

To be cited as: Bünz, S. (2023). CAGE13-4 Cruise Report: Sub-seabed CO2 Storage: Impact on Marine Ecosystems (ECO2) (A 7th Framework Programme EU project) PART II. *CAGE - Centre for Arctic Gas Hydrate Environment and Climate Report Series, Volume 1.*

DOI: https://doi.org/10.7557/cage.6844

Additional info at: https://septentrio.uit.no/index.php/cage/database

ISSN: 2703-9625

Publisher: Septentrio Academic Publishing Tromsø Norway

FACULTY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF GEOLOGY

Date: August 31, 2013

UNIVERSITY OF TROMSØ cruise report

Tromsø – Longyearbyen 08-07-13 to 21-07-13

R/V Helmer Hanssen

PART II

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

Institutt for Geologi, Dramsveien 201
Universitetet i Tromsø

Stefan Bünz (chief scientist)

NO-9037 Tromsø • postmottak@uit.no • http://uit.no • Switchboard: (+47) 77 64 40 00 • Fax: (+47) 77 64 49 00
Department of Geology • Phone 77 64 44 09 • Fax 77 64 56 00

Table of Contents

PARTICIPANT LIST

Stefan Bünz (chief scientist)	University of Tromsø, Norway
Alexandros Tasianas	University of Tromsø, Norway
Sunil Vadakkepuliyambatta	University of Tromsø, Norway
Anoop Nair	University of Tromsø, Norway
Steinar Iversen	University of Tromsø, Norway
Andreia Plaza-Faverola	University of Tromsø, Norway
Sandra Hurter	University of Tromsø, Norway
Leif Tokle	University of Tromsø, Norway
Espen Valberg	University of Tromsø, Norway
Ola Eriksen	P-Cable AS, Oslo, Norway
Jens Greinert	Geomar, Germany
Manuel Bensi	OGS, Italy
Martina Kralj	OGS, Italy
Evgenia Martuganova	MSU, Moscow
Maria Ambrosimova	MSU, Moscow

INTRODUCTION AND OBJECTIVES

Cruise CAGE_07_HH13 is the first one of several cruises that will be carried out to collect cross-disciplinary data for addressing the objectives of the Norwegian Centre for Arctic Gas Hydrate, Environment and Climate, CAGE. CAGE is funded by the Norwegian Research Council for a period of 10 years to addressee main scientific questions about gas hydrate environments in Arctic regions.

Cruise CAGE_07_HH13 focused on the acquisition of acoustic data in two of the main target areas within CAGE, the deep (>1000 m water depth) seeping Vestnesa Ridge area and the shallower (< 400 m) highly active Prins-Karls Foreland (PKF) sites. Scientific problems that are to be addressed in these two key target areas include the periodicity of seepage (i.e. time scales of active, inactive and reactivated systems), quantification of gas and hydrates, the nature of gas sources, trigger mechanisms for seepage and the architecture of the fluid flow structures underlying seafloor seepage sites.

Specific objectives of cruise CAGE_07_HH13 were as follow:

- To repeat a P-cable survey covering the active seeps on the Vestnesa Ridge in order to develop time-lapse 4D seismic studies of gas leakage;
- To acquire a P-cable survey at the active seeping area offshore PKF for planning and re-evaluation of drilling sites during the upcoming MeBo cruise in 2014.
- To repeat hydro-acoustic surveying for monitoring of flares in PKF active area.

Figure 1: Location of the study area.

METHODS

Seismic methods

The CAGE part of the R/V Helmer Hanssen cruise is aimed to acquire P-Cable high-resolution 3D seismic data over pockmark fields, gas chimneys, shallow gas accumulations, and hydrate-bearing sediments on the Vestnesa Ridge and on the upper continental slope of W-Svalbard. We plan to repeat first baseline P-Cable 3D seismic cube shot over the active seeps in 2012.

The high-resolution P-Cable 3Dseismic system was used together with a Granzow high-pressure (210bar) compressor and one mini-GI gun (15/15 in^3). Onboard seismic processing and QC of P-Cable seismic data provided preliminary 3D cubes for quality assessment and geofluid interpretations.

During this cruise we used SIMRAD EM300 high-resolution multibeam seabed mapping see report C), P-Cable high-resolution seismic, SIMRAD EK 60 38 and 18 kHz echolot, and the Edgetech Discover penetration echolot. CTD stations are carried out to extract information about different (T, S) properties of water masses to calculate the speed of sound for calibrating the EM300.

The P-Cable 3D 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 and 3). 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.

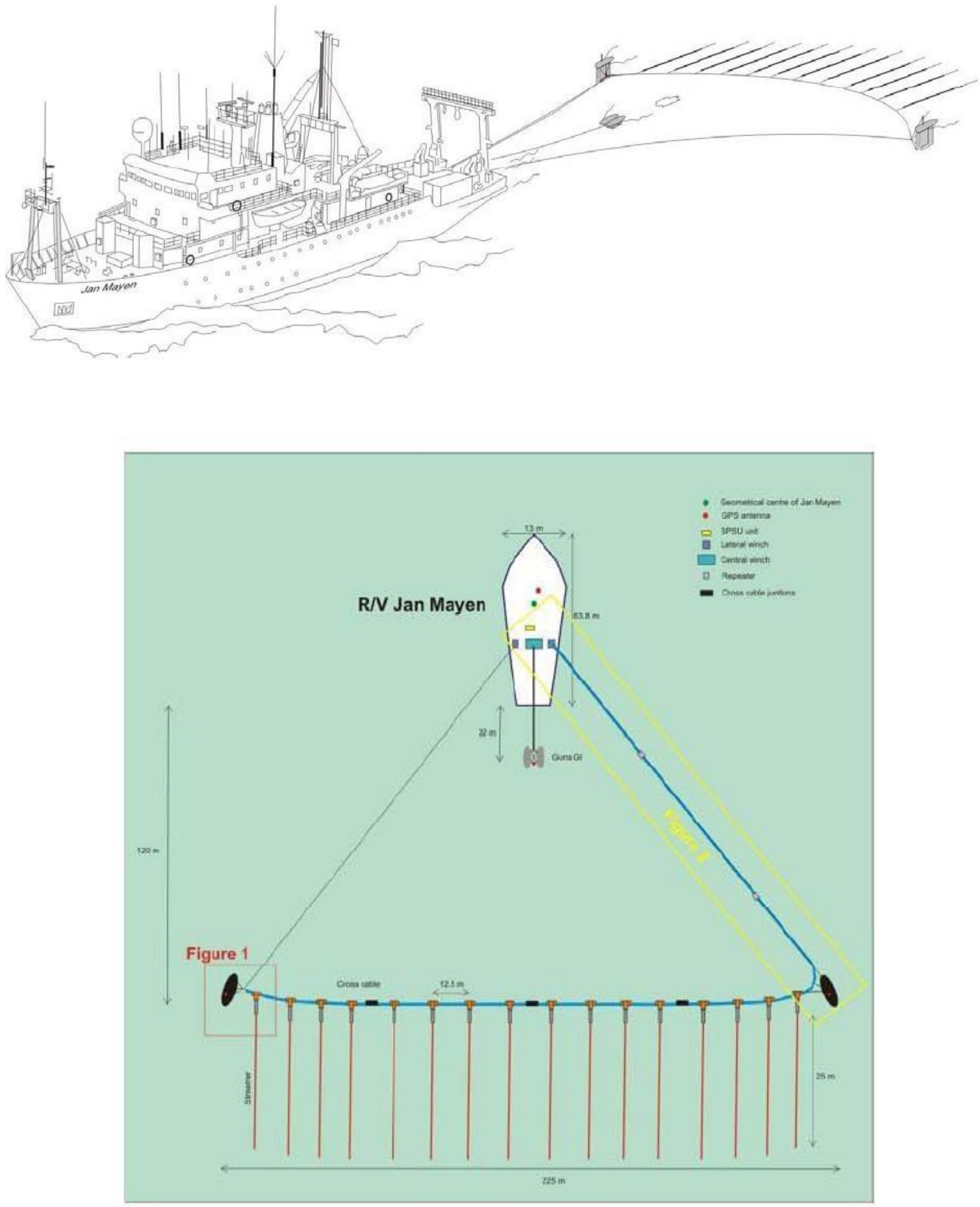


Figure 2: Schematic sketch (top) and technical drawing (bottom) of the P-Cable high-resolution 3D seismic system.

Figure 3: 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.

CTD

Conductivity-Temperature-Depth (CTD) is the oceanographer's standard tool for determining oceanic water masses. SeaBird's (SBE) 911plus CTD was used for oceanographic measurements (Figure 4). Apart from the standard temperature, conductivity and pressure (converted to depth), speed of sound, fluorescence and turbidity can also be measured. The temperature sensor is located at the base of the Rosette, thereby being the first sensor to measure the undisturbed water mass on the downcast. Furthermore, water is pumped through a conductivity tube, in which seawater conductivity is measured. Continuous pump operation is essential to prevent boundary layers forming on the tube's edges, and should data sets indicate fault malfunctions the data sets are flagged or deleted. CTD data was acquired and processed using SBE's in-house "SBE Data Processing".

Figure 4: CTD SBE911plus (on the left) used for measuring physical properties of the water column.

PRELIMINARY RESULTS

Acquired data was processed onboard for Quality control and preliminary interpretations. This included the multibeam and 3D seismic data.

Swath bathymetry onboard processing

Introduction

Swath bathymetry data were collected simultaneously with the 3D seismic and hydro-acoustic surveys. Mapping of the seafloor in the study areas were carried out with a hull-mounted, motion-compensated Kongsberg Simrad EM300 system. Both study areas (eastern part of Vestnesa Ridge and upper slope outcrop of hydrate stability field) cover an area of approximately 3 x 12 km (Figure 5). The water depth in study areas ranges from 1200-1300 m on the Vestnesa Ridge and from 240-420 m offshore PKF.

Processing of bathymetric data

Line statistics showed that the raw depth data had a good quality, only the outer beams had somewhat higher noise level. Kongsberg-Simrad Neptune software was used for processing of bathymetric data. The processing of bathymetric data consisted of statistical data cleaning, what was done block by block in BinStat. This function ensures an adaptive way of filtering and taking changes in the seabed terrain into account. Both areas were divided into several blocks. The basic role for blocks was putting a noise limit 2 and a STD limit 2. Noise limit 2 means that all depths with a distance from the plane larger than 2/100 * mean depth of the cell were rejected. Furthermore, STD limit is most common filtering parameter, and means that all depths with a distance from the plane larger than 2 * mean STD were rejected. In addition, raw data were also cleaned manually with the ping graphic editor to improve the accuracy on the depth data. After processing, the bathymetry data sets were exported from Neptune as a 3-column XYZ ASCII file (Easting, Northing, depth) with positive depth values based on a mean water datum. The XYZ bathymetry was gridded in the interactive visualization system Fledermaus. Aweighted-moving average gridding type was chosen with weight diameter set to 3 (Fledermaus- Reference manual 2007). The good density of measurement point allowed a grid cell size of 5 m x 5 m.

A bathymetric map of the Vestnesa study area is shown in Figure 6. It shows several relatively large (up to 800 m in diameter) pockmarks that are good indicators for seepage of gas from subsurface sediments. The 6 actively seeping pockmarks are shown in the inset Figure, which is adapted from Smith et al. (subm to G-cubed). During this cruise names were given to active seeps for an unique identification in future research and publications.

NO-9037 Tromsø • postmottak@uit.no • http://uit.no • Switchboard: (+47) 77 64 40 00 • Fax: (+47) 77 64 49 00
Department of Geology • Phone 77 64 44 09 • Fax 77 64 56 00

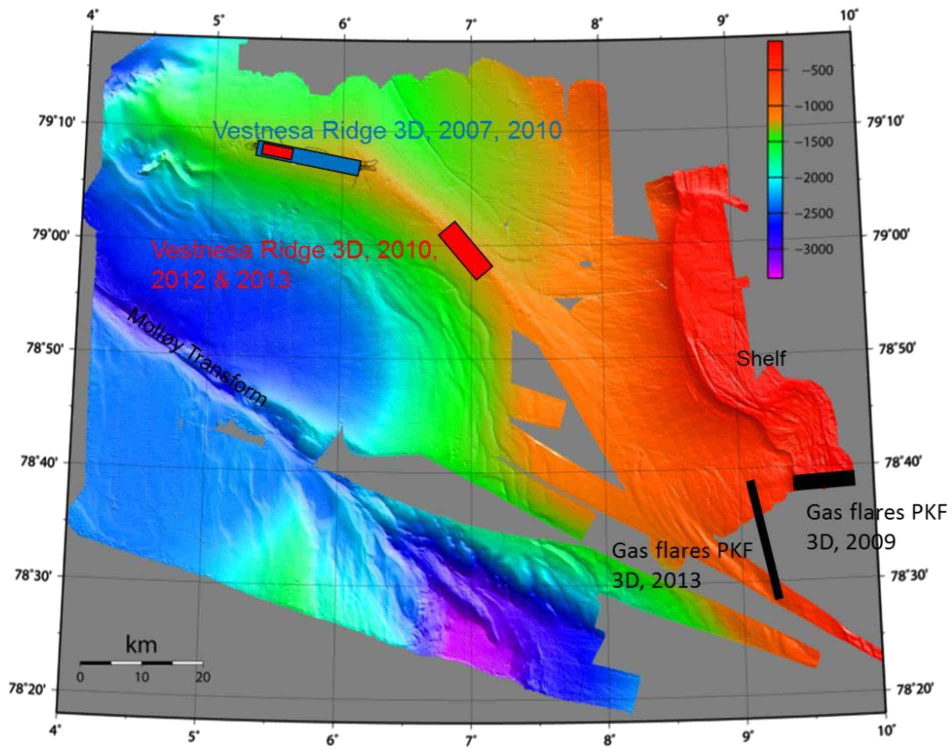


Figure 5: Study area offshore W-Svalbard. Two P-Cable surveys were acquired during this cruise, one located on the eastern half of the Vestnesa Ridge and the other at the outcrop of the hydrate stability zone on the upper continental slope.

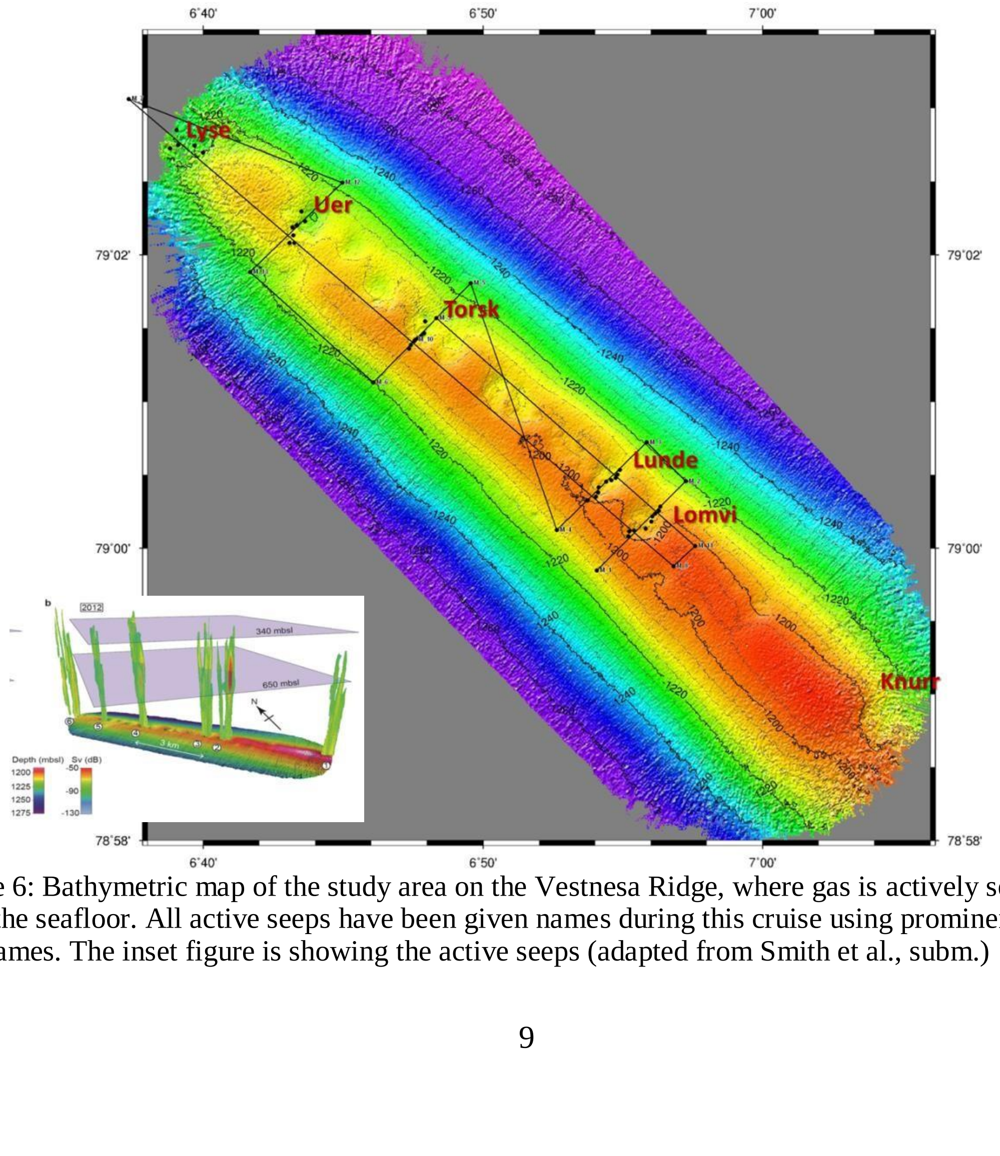


Figure 6: Bathymetric map of the study area on the Vestnesa Ridge, where gas is actively seeping from the seafloor. All active seeps have been given names during this cruise using prominent bird and fish names. The inset figure is showing the active seeps (adapted from Smith et al., subm.)

P-Cable 3D seismic onboard QC and processing

This report describes the on-board QC and processing of the 3D seismic data acquired with the P-Cable system on board the R/V Helmer Hanssen. A geographical map of the working area is shown in Figures 1 and 5. During this cruise data for two different 3D cubes were acquired and processed. Preliminary processing is done on board using the RadexPro software. Pre-processing includes navigation data preparation, geometry insertion in raw data, band pass filtering, spherical divergence correction, CDP binning, stacking, interpolation of data gaps and 3D Stolt migration.

Vestnesa Ridge Area 1 (active seeps): We accomplished 30 planned seismic lines. Projected spacing between lines was 60 m resulting in a block with a coverage of approximately 8 x 2 km (Figure 5). CDP binning was done at 6.25 m. The block was acquired following acquisition parameters and coverage of previous cruises in order to maximize similarity of this repeat survey for 4D time-lapse studies. The areas is characterized by pockmarks seemingly aligned at the crest of the ridge (Figure 6 and 7), and underlying vertical fluid migration structures (Figures 8).

Prince Karl Foreland (shelf flare are): Five seismic lines were acquired. Spacing between lines remained 60 m resulting in a narrow but large block with coverage of approximately 12.8 x 0.4 km (Figure 9). The block was acquired over an area at the shelf edge where flares have been monitored for many years. Seismic energy is highly attenuated at the upper 200 m of sediments and high amplitude reflections can be observed along a horizon at ~30 ms below the seafloor (Figure 10).

The CDP coverage for both areas is shown on Figures 11 and 12. A good coverage depends on ship navigation and line tracking. In few instances the ship was off the planned line by up to 20 m, which results in data gaps. However, these gaps mostly are only one bin size wide and thus, can be easily infilled during processing. A few large gap exists particularly in the Vestnesa area. The navigation file processing and checking as well as data input, geometry assignment and further data QC and processing are reported for both areas. The QC procedures and seismic data processing were performed in the RadExPro Plus software. Brute stack cubes were generated for both areas to assess the quality of the seismic data.

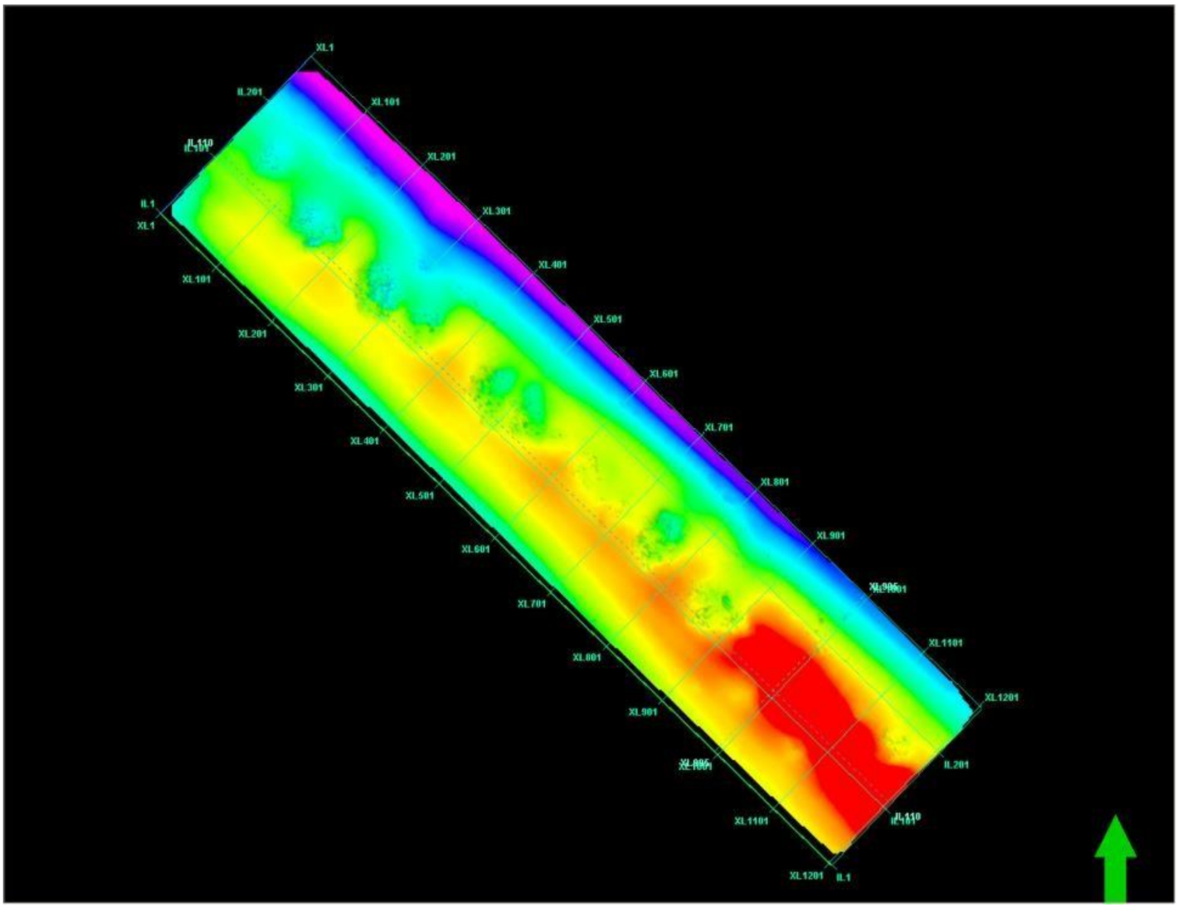


Figure 7: Seafloor map as picked from the Stolt-migrated 3D volume at area 1, Vestnesa Ridge active sites.

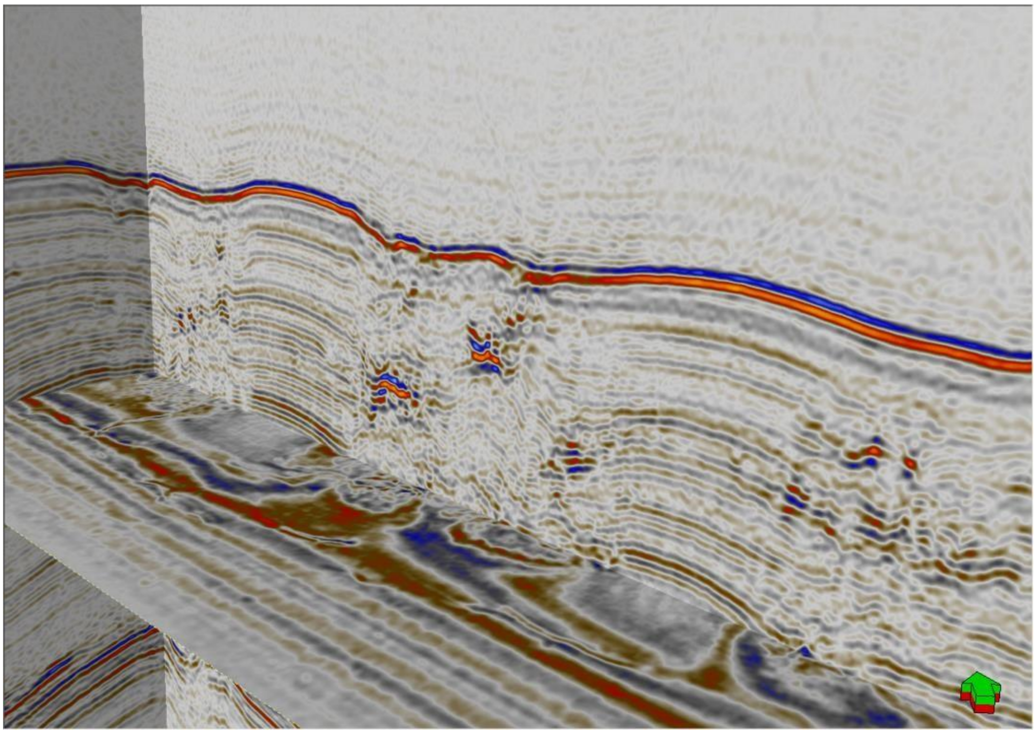


Figure 8: Subsurface fluid migration structures underlying pockmarks along the Vestnesa Ridge.

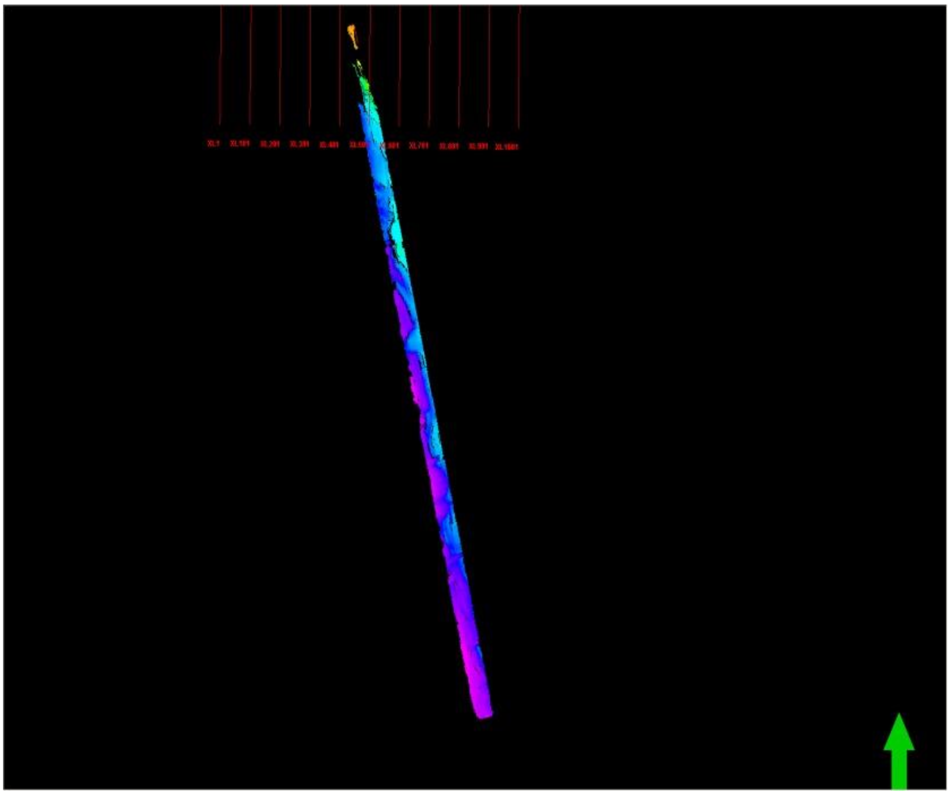


Figure 9: Seafloor map from the stack volume at PKF. It is 2.8x0.4 km.

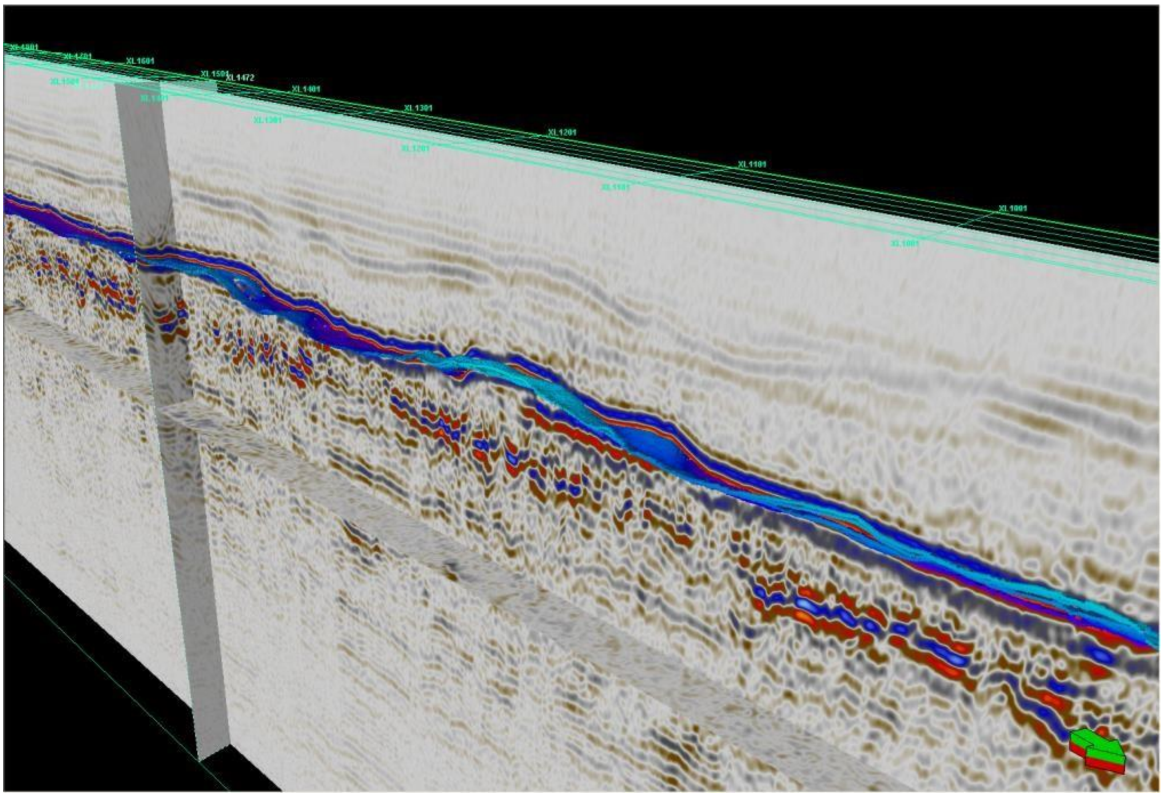


Figure 10: Subsurface image showing bright reflection below active seepage site at PKF.

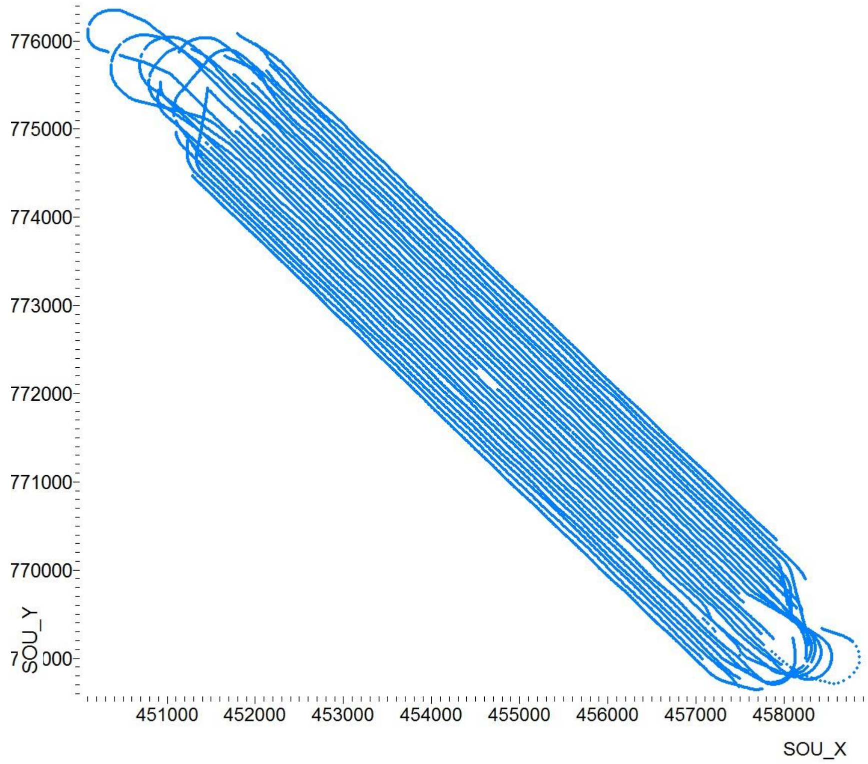


Figure 11: Coverage map of survey area 1.

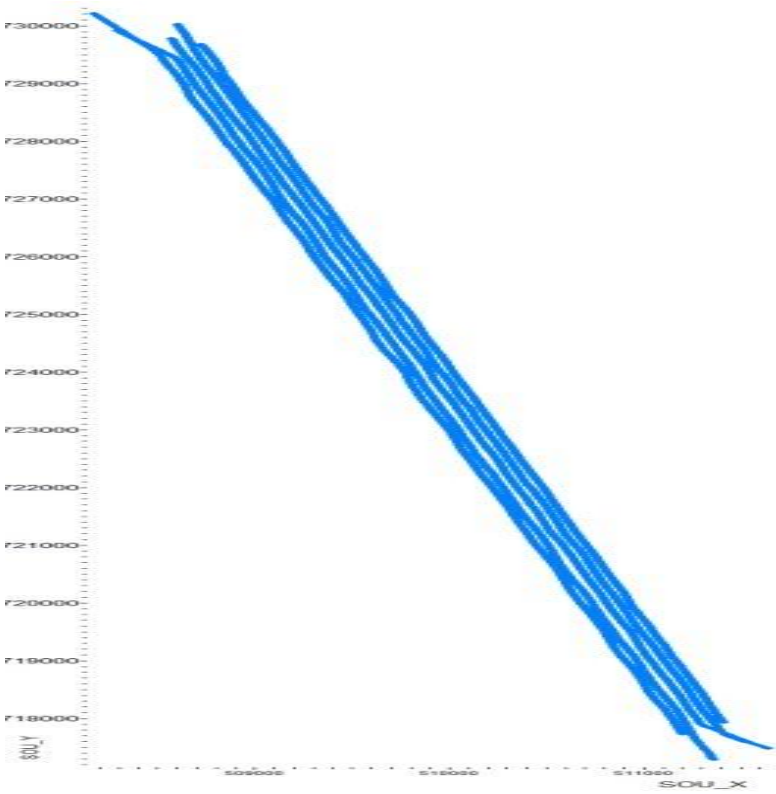


Figure 12: Coverage map of survey area 2.

Data Input

Seismic data were loaded from seg-d files and saved as RadExPro datasets within the RadExPro project database. In both areas, the lines were loaded separately directly after acquisition to be sure to correct for geometry input . Afterwards, the lines were loaded by blocks to one dataset.

Geometry Input

The geometry characteristics of the P-Cable system in this survey are described below. The P-Cable system was configured with 14 streamers that have 12.5 meters distance between streamers. Distance from Paravanes to the first and last streamers was 32.5 m and 26.25 m. Geometry was loaded with Geometry Input Module using the parameters listed before. Navigation files were prepared. Alpha trimmed averaging of raw navigation was involved in geometry input routine prior to geometry assignment. The geometry for every part was assigned in a similar way. There were no problems with navigation assignments and the geometry was used for all shots.

Geometry Check

After geometry input the assigned geometry was checked for consistence. Observed direct wave arrival time was compared with one calculated from the assigned geometry. To calculate this time, the velocity was assumed to be equal to 1.5 m/ms. Quality control was performed by visualizing every 10th common shot point gather. Figures 13 and 14 show some examples of such QC plots. On some shots the difference between calculated direct wave arrival time and observed one was about 3 ms, but on most shots the calculated time fitted the observed one well. Such difference can be caused by strong currents in the area and bad ship positioning.

Partial cubes, brute stacks and QC coverage

As data acquisition continued, partial brute stacks were calculated over the available subset of seismic lines to assess gaps in the coverage and seismic data quality. Coverage control is very important during data acquisition. Coverage of the data was controlled using QC plots generated in the RadExPro. Locations of CDP points were displayed in the 3D CDP Binning tool. At the end of each area coverage plots were made for all lines (Figures 11 and 12), and a brute stack cube for each area was generated. The seismic data quality is generally very good. However, several additional processing steps need to be run in the post-processing before the final version of the data is ready. These include, tide and residual statics corrections, amplitude corrections, filtering and migration.

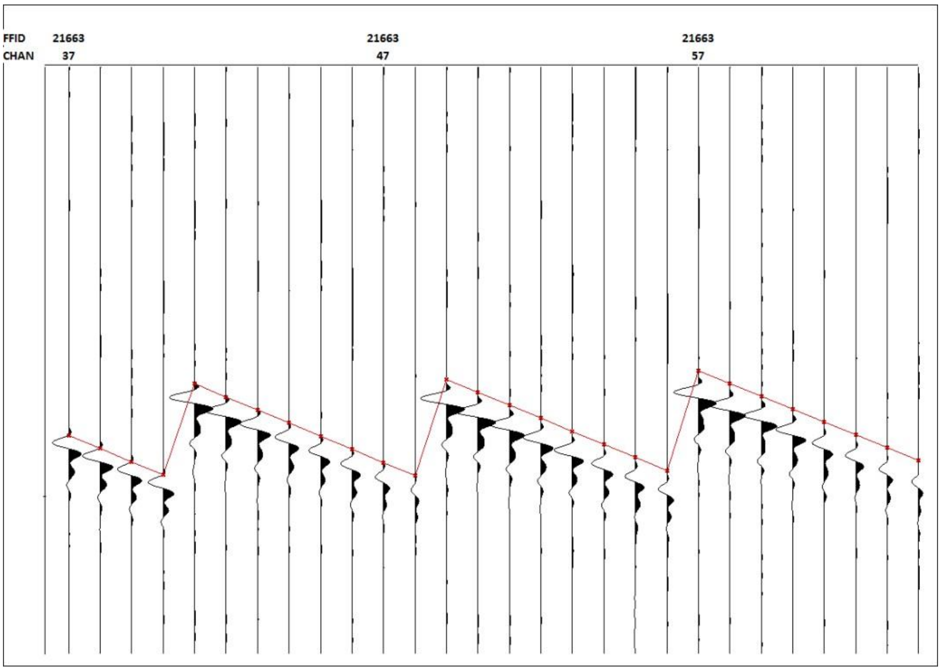


Figure 13: Geometry check plot with direct wave arrival and predicted theoretical arrival time (red line).

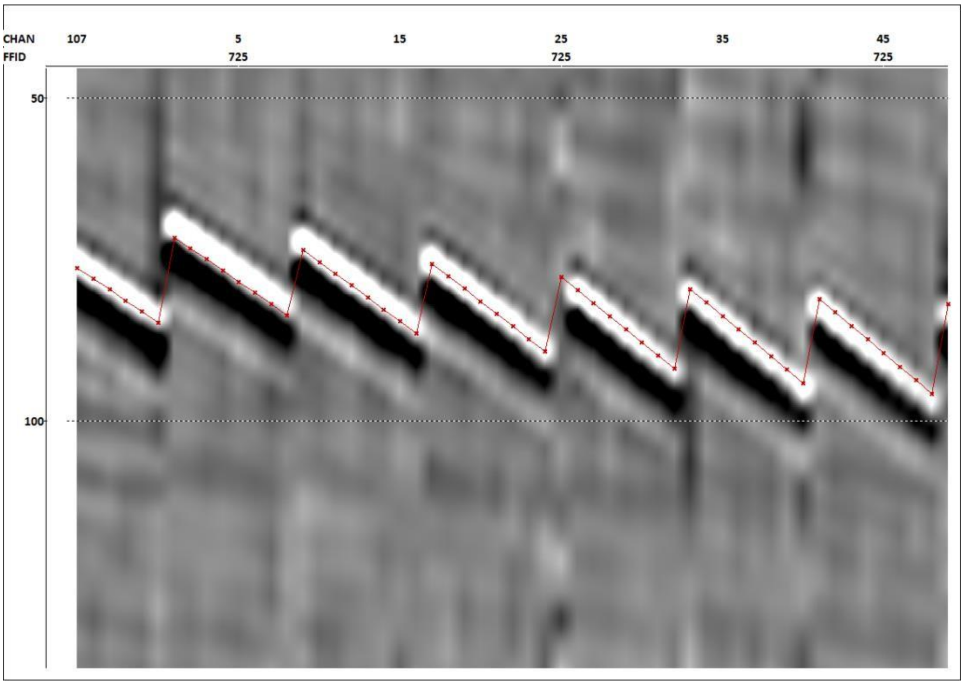


Figure 14: Geometry check plot with direct wave arrival and predicted theoretical arrival time (red line).

Chirp sub-bottom profiling

Chirp sub-bottom profiling data has been acquired simultaneously with the 3D seismic acquisition. Data were recorded for a Chirp frequency burst of 1-8 kHz. An example of a Chirp line crossing the active pockmarks on the Vestnesa Ridge is shown in Figure 15.

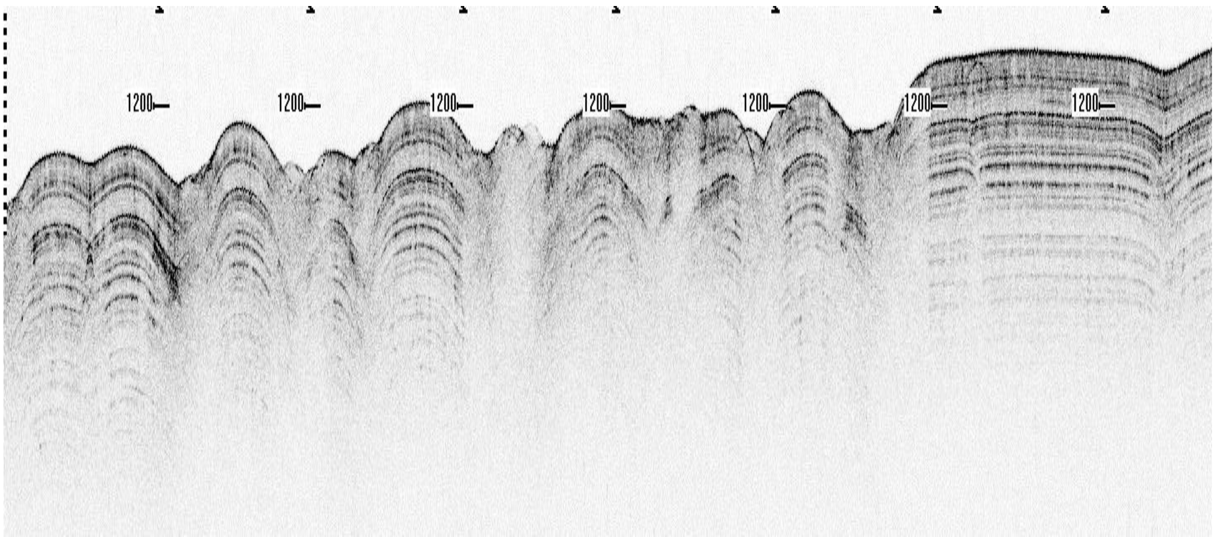


Figure 15: Example of Chirp sub-bottom profiling record of one of the 3D seismic lines. It shows several seafloor depression and vertical wipe-out zone beneath that are indicative of fluid seepage.

Single beam echosounder survey: „Flare Hunting"

By Jens Greinert; GEOMAR, Kiel Germany

During the cruise we used the EA60 scientific echosounder to detect bubbles being released from the seafloor at seep sites and are rising through the water column. The EA60 runs three frequencies, 18, 38 and 120 kHz at the same time. For our purposes we only used 18 and 38kHz as the high frequency didn't reach deep enough to detect bubbles. Recording was done with the standard acquisition software EA60. Post processing during the cruise was done with Fledermaus MidWater and EchoView to visualize echograms and plot them in 3D.

Three survey areas have been mapped in parallel to the 3D P-cable survey in the Snoevit and Vestnesa area and the shelf edge area offshore Prinz Karls Foreland. Special attention was given to adjust the echosounder settings during the survey at Vestnesa. The ping interval was chosen to be manual and has been adjusted to 3.15 sec to avoid the multiple from the seafloor to appear too close to the seafloor in the 18kHz signal, giving interfering signals within the range of the flares. With 3.15s ping interval the multiple appears in about 120m at 1200m water depth. With an average speed of 3 to 4 kn, the distance between pings is 4.8 to 6.5m ensuring that consecutive pings have a sufficient overlap with respect to the footprint [222 m for 18 kHz (10.6° beam angle); and 146m for 38kHz (7° beam angle) in 1200m deep water]. From multibeam line 100 onwards we triggered the multibeam pinging through the echosounder and could greatly reduce the noise artifacts from the multibeam in the echograms.

However, the simultaneously running Chirp still created some noise. The ER60 recording and control software also allows to adjust the power level, pulse duration, sample interval and band width; our settings were 2000W; 2048µs; 512µs (=0.375m depth resolution) and 1186Hz, respectively. The average sound velocity was set prior the survey to 1464m/s as derived from CTD Station #347. Some echogram examples are given from the Vestnesa in Figure 16. The map in Figure 17 shows the preliminary seep positions as picked from the echograms. Exact locations will be processed onshore. Figure 18 shows a 3-dimensional view of the Vestnesa study area where gas flare have been projected onto the bathymetry.

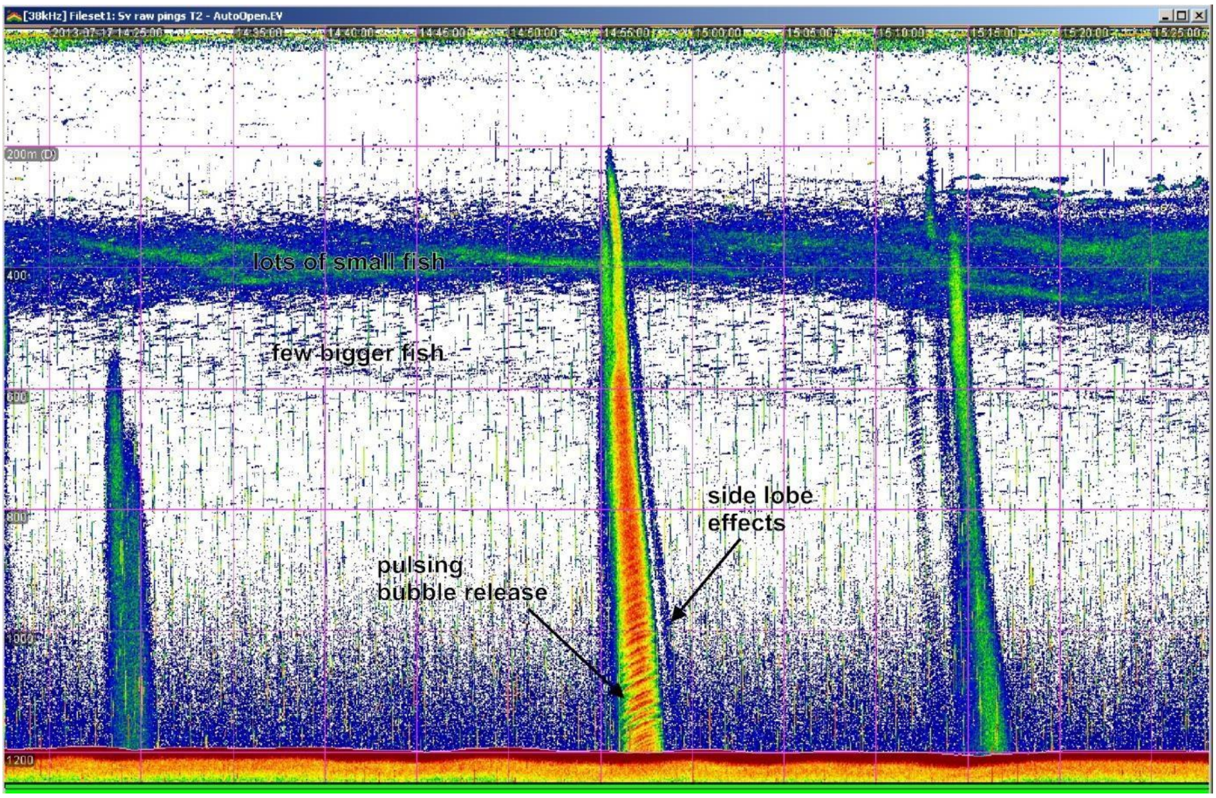


Figure 16: Echogram example from Vestnesa (38kHz), showing three different seep areas, all of them associated with pockmarks. The centre one shows pulsing bubble release. This could be confirmed by an adjacent survey line.

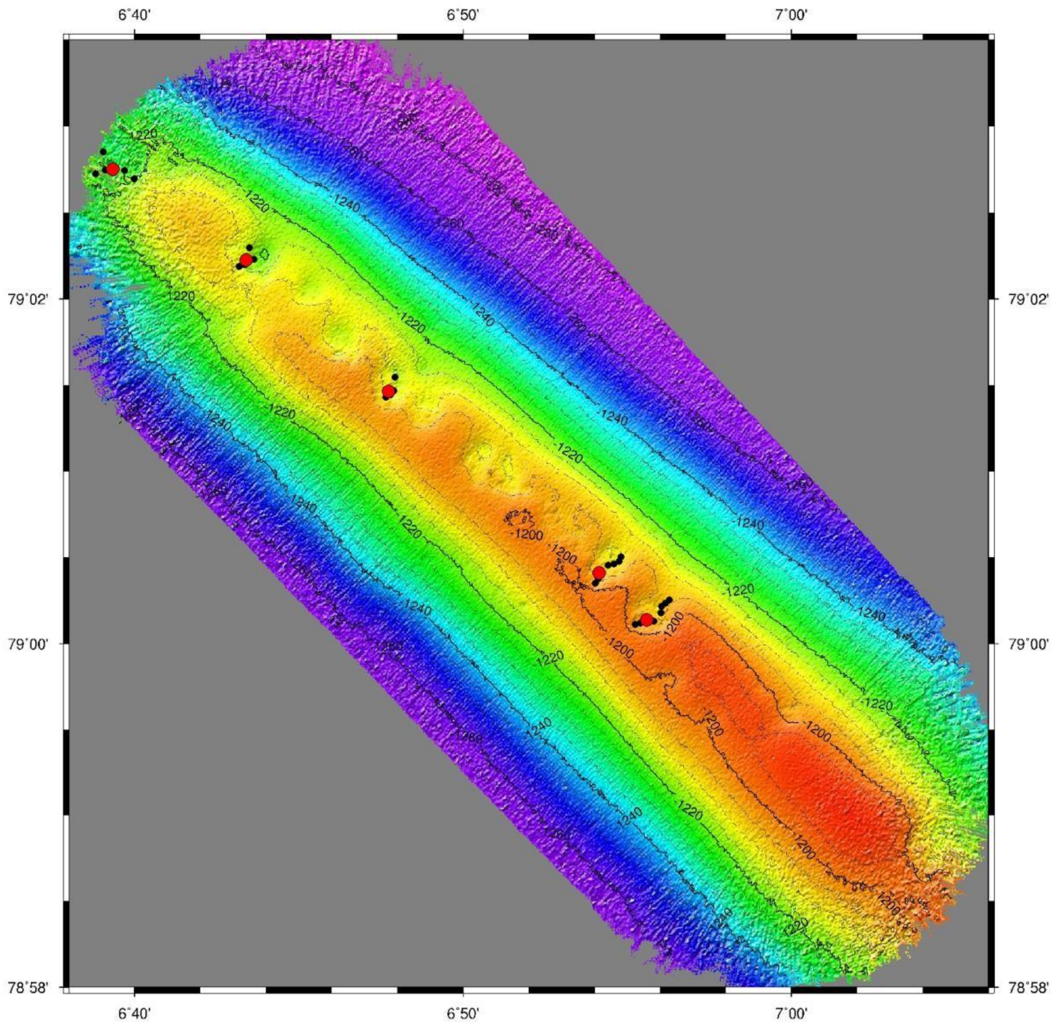


Figure 17: Map of the Vestnesa pockmark area. Black dots indicate the centers of rooted flares seen in the echosounder during the 3D seismic survey. Red dots indicate the most likely release site, which is always on the southern edge of the pockmarks and not in the centre.

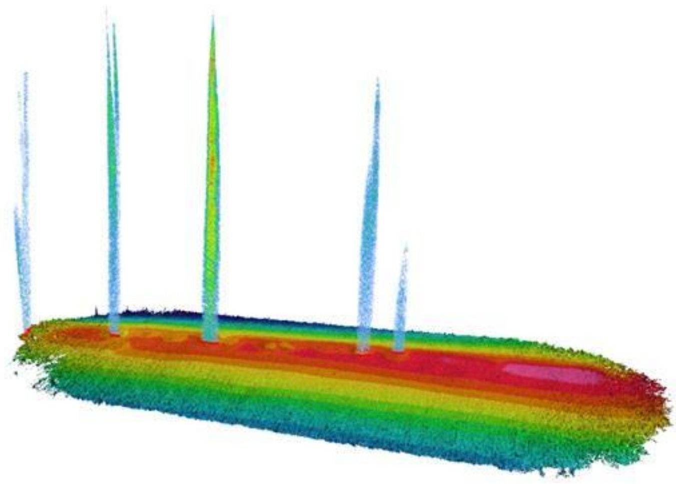


Figure 18: 3D view of the Vestnesa working areas with some flares projected on the 5 active seep sites found in 2013.

NARRATIVE OF THE CRUISE

Times in this report are given in local time (local time -2 hrs = UTC), 3D seismic data are logged in UTC time and ship logs are given in UTC time. Weather conditions at the start of the cruise were bad and did not allow us to leave the shelter of the fjords for two days. Afterwards, weather and sea state improved and were calm to slightly rough (Bft 3-5) with mostly grey skies. Air temperatures were between 5 °C and 12 °C. We started to prepare the cruise in Tromsø on July 8 with loading and assembling all seismic equipment. This cruise has two parts. This part covers the work related to the Centre of Excellence on Gas Hydrates, Environment and Climate (CAGE) at the University of Tromsø.

Monday, 08.07.
The scientific crew arrived during the afternoon hours. We started to load all equipment onboard the ship and began assembling the seismic equipment. Cables were spooled onto the winches. Electronics and computers for seismic data acquisition is set up in the laboratory. Loading and assembling lasted until into the evening hours. The last participants from Moscow State University arrived late at midnight. Missed baggage on the flight forced us to delay our departure. However, gale winds and high waves (4-5 m) in the SW Barents Sea wouldn't have us allowed to leave the shelter of the coastline anyhow.

Tuesday, 09.07.
ECO2 work.

Wednesday, 10.07.
ECO2 work.

Thursday, 11.07.
ECO2 work.

Friday, 12.07
ECO2 work.

Saturday, 13.07.
ECO2 work.

Sunday, 14.07.
ECO2 work finished. Steaming to the Vestnesa Ridge on the western Svalbard Margin.

Monday, 15.07.
Steaming to the Vestnesa Ridge on the western Svalbard Margin.

Tuesday, 16.07.
16:00 Arrival in the area west of Prins Karls Foreland, where we will recover a mooring with 100 thermistors deployed by partners from Geomar in summer 2012.
16:17 CTD station No. 346 in 458 m water depth. This station is necessary to calibrate and depth-fit the thermistor mooring.
16:50 Mooring is being released by acoustic release system.
16:53 Mooring at sea surface.
17:05 Start to recover the mooring. During recovery, each thermistor will be detached from the wire.

18:00 Recovery of mooring completed.
20:58 CTD station no. 347 in 1431 m water depth. This data is needed to calibrate sound velocity of the multibeam system, and for 4D seismic processing of the P-Cable 3D seismic data.
21:32 CTD station completed. We steam a little further in northwest direction and will deploy the P-Cable seismic towards the designated central line of the 3D survey.
22:30 Start of P-Cable deployment on the Vstnesa Ridge to acquire time-lapse seismic data in the area of the active Vestnesa vents.
23:30 The P-Cable has been fully deployed. However, the main power supply of the P-Cable shows leakage with significant variability. The likely cause is a bad contact along the cross cable. We run several test and try to communicate with the system via the Geoeel software in order to identify the location of the failure.

Wednesday, 17.07.
0:30 It is impossible to identify the failure location. We have to recover the system and start troubleshooting for the failure.
0:45 We recover the cross cable section by section and test in between by disconnecting the cross cable section and the streamer sections. Most often during recovery, there is no leakage. It only shows occasionally, probably during increased stress on the cable. We identify a possible leakage problem in section 10 or 11. But it's poorly repeatable and we continue to recover.
01:30 As we have recovered half the section, there is no sign of leakage whatsoever. We the therefore decide to put this half of the cross cable array back in the water but without streamers. That would tell us if the problem could be along this part of the cross cable, or is related to the disconnected streamers. We keep the deck cable connected and power switched on during deployment to see when leakage could be coming back.
01:45 Leakage is back already during deployment of sections 10-12. We are now somewhat sure that the problem must be related to one of these cross cable sections. With some bending and shaking of the cross cable we are able to reproduce the leakage at the junction box of streamer 10 and the connector to section 11.
02:30 After a break, visible inspections give no hint what could be wrong. There must be a loose contact somewhere. We go with the odds of our observations and replace section 11 assuming that it had problems in the connector to junction box 10.
03:30 Section 11 has been replaced and we decide to deploy the whole cable.
04:30 The P-Cable system is in the water and we have no leakage problems so far. All digitizers respond normally and also depth sensors work fine.
04:56 The mini-GI guns are deployed and we begin with pre-survey warm up and testing phase.
07:32 As we had slowly steamed northward during deployment and recovery operations, we actually start the survey by running line 1 in reverse direction. Data from this line will be useful to study acquisition effects on 4D time-lapse P-Cable seismic data. This reverse line has number 500.
08:32 Line 500 finished. We now start with the repetition of the 2012 P-Cable 3D seismic data from the SE part of the Vestnesa Ridge, an area of active gas leakage.
09:14 Start of Line 1. A detailed report of the acquisition is given in the 3D seismic line log in the appendix.
10:27 End of Line 1. Several (~50) error messages ("Incomplete File", …) occurred during this line. It seems that some digitizers (streamer 1 or 2 most often) send data late or there is a small time lag on the ethernet. The cause of these errors is yet unknown. Recording length is

reduced to 3 sec in order to reduce the amount of data being sent, but it does not help. Also ship speed is reduced to 3 to 3.5 kn in order to decrease the stress on the cables.
11:00 Start of line 2. The problem persist but is less frequent. One of the major implications of this failure is if it affects shot order, enumeration and shot timing, which could result in large gaps in the coverage which in turn, we would have to infill. Therefore our processing specialists from MSU start immediately to process and QC the data.
12:10 End of line 2. Several strong gas flares have been observed during the first two lines of the survey. Two in the northern part of the survey area are also particularly high reaching up to about 250 m water depth.
14:19 Start of line 4. Slightly delayed start of line 4 due to reboot of SPSU and trigger problems. Persistent problems with incomplete data files.
15:34 End of Line 4. After the end of the line we reduce sampling rate to 0.5 sec to reduce the amount of data being sent. That solved the problem. However, 0.5 sec is too low for the frequency bandwidth of the mini-GI gun data. The sampling interval is set back to 0.25 sec and the shot interval is increased to 7 sec to give more time to send data. Also this seems to allow the system to run fine without problems. Even at 6 sec shot interval there are no problems. So we decide to continue with this interval. At a slightly lower ship's speed it shouldn't make a big difference in the coverage.
16:08 Start of Line 5.
23:55 Close to midnight, we complete line 9. Only very few (<10) incomplete data errors occur on each line. Several interesting gas flare observations have been made. Amongst others, echosounder data indicate some form of episodic gas release.

Thursday, 18.07.
23:59 We completed line 24, which is the 14th line finished during this day. Error messages are a bit more frequent but would not cause problems for processing. Also, some depth sensors are not updating depth any longer.

Friday, 19.07.
00:11 Start of line 25
10:07 End of line 30 and completion of the P-Cable survey at Vestnesa. Error messages had been even more frequent during the last lines. We will inspect the system during transit.
11:15 The P-Cable system has been successfully recovered.
11:20 We start a short hydro-acoustic survey of the gas flares at Vestnesa. Survey lines are acquired with only the echosounder system running to minimize interference from other systems.
15:30 At the end of the survey we slowly drift across two of the flares. That will allow determining the bubble rise speed.
17:00 Departure from Vestnesa and return to the Prins Karls Foreland gas flare area.
21:00 arrival at the shelf edge offshore Prins Karls Foreland. Here we start a short hydro-acoustic survey.
23:30 End of hydro-acoustic survey.
Saturday, 20.07.
00:00 Start of deployment of P-Cable in the PKF area acquiring high-res 3D data along the upper outcrop of the gas-hydrate stability zone.
01:00 P-Cable successfully deployed. Warm up of the system.
01:43 Beginning of survey, line 1.
15:09 end of survey. Five lines were acquired in total. Beginning of recovery of the P-cable system.
16:00 P-Cable system recovered. Transit back to Lonyearbyen.

Sunday, 21.07.
06:00: Arrival in Longyearbyen. End of cruise.

ACKNOWLEDGEMENT

We thank the captain and his crew of R/V Helmer Hanssen of the University of Tromsø for their excellent support during the 3D and multicomponent seismic survey. 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.

APPENDIX

CTD stations

Date	Time	Station Nr	Latitude	Longitude	Depth [m]
16.07.2013	14:17	346	78 36.693100 N	009 17.114773 E	459
16.07.2013	18:58	347	78 48.319201 N	007 01.153451 E	1431

3D seismic line log Vestnesa 2014

Expedition: Helmer Hanssen July 2013 Survey: Vestnesa4D 17.07. – 19.07. Sheet #: 1 - 4

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.)
					Pre-survey warm up.
0	17.07.	02:56 -	1 -		After several hours of troubleshooting we found the bad contact in section 11 (Switch 6023). Approx 10 nm off the start of the line, heading south to start the survey. Will start the survey with shooting line 1 in reverse direction (line number 500). Line 1 in reversed direction
500	17.07	05:32 – 06:32	1 - 818	46 -787	4.4 kn, wind 5.8 m/s Error messages coming often: cycle time decreased Around sp ~474, 537, … Speed decreased to ~3.7 kn.to test for solutions to errors Trigger disconnected and connected for testing Disarmed and armed… Example of error messages “serial string not detected-file 679: Incomplete data on file missing sections 2-14” Trace length changed to 3 s to test if solve problem but it doesn't seem to be the case.

1	17.07	07:14-08:27	819-1889	903-1856	3.7 kn, wind 6.9 m/s Error messages as above persist and occurs every 2-3 shots. Other type of error message: “Alrm: trigger 1325 time threshold exceed” Message “Overdriven channel” Stable periods without errors for about 10-20 shots from sp 1513-1568
2	17:07	9:00-10:10	1890-2847	1951-2806	Ship speed 3.9 kn, wind 7.16 m/s Beginning of the line errors persist but less frequent. Pressure of the gun1 low. System stable, no error messages from ~2704-2760
3	17:07	10:39-11:53	2850-3832	2908-3811	Ship speed 3.6 kn, wind 7 m/s Error persists with similar frequency than line 2. Stable period between sp 3000- 3036
4		12:19- 13:34	3833- 50	3834- 4735	Slightly delayed start of line 4 due to reboot of SPSU and trigger problems. Persistent problems with “incomplete data on file. Missing sections”. Most often section 1 is missing, but also section 2 or 3 are delayed. Trigger time in SEG-D header likely wrong. Check in processing. Some serial strings missing, likely connected to above problem. After end of line, sampling rate is reduced to .500 ms from shot number 4751. This solved the problem but 0.5 ms in on the limit of being to low sampling rate. Continuous ping is disabled with no effect. Sampling back to 0.250 ms and shot interval up from 5s to 7s. 7s shot interval seem to work much better.

5	17.07	14:08 – 15:17	5026 - 5532	5080 – a5366	Ship speed 3.6 kn, wind 6.5 m/s Shot interval is now 6 s, sampling rate 0.250 ms Massing data on 5125 and 5126 Software crash at shot: 5384 Long gap between 5384 and a5026. Duplicated shot numbers after restart of software. Numbers after restart start with a. Missing data at file a5152 Missing data a5206, a5239, 5384, 5398, 5400, 5423 Continue the line after end of line to cover a flare, End the line and start turning at shot 5467
6	17.07	16:00 – 17:09	6000 - 7134	6263 - 6948	Ship speed 3.6 kn, wind 4.5 m/s Starting at shot number 6000 Missing data: 6087, 6088, 6346, 7090
7	17.07	17:36 - 18:55	7135 - 8010	7209 - 7831	Ship speed 4.0 kn, wind 3.5 m/s Missing data: 7168, 7170, 7216, 7219, 7322, 7323, 7395, 7419,7584,7585,7738,7739,7787,7788,79840,7841,7843,7845
8	17.07	18:56-20:27	8011-8927	8143-8818	Ship speed 4.0 kn, wind 2.8 m/s Missing data:8308,8309,8371,8373,8534,8536
9	17.07	20:28-21:55	8928-9804	9020-9671	Ship speed 3.7 kn, wind 1.8 m/s Missing data:9011,9012,9033,9034,9287,9288,9464,9465,9466,9467
10	17.07	21:55-23:22	9805-10686	9946-10576	Ship speed 3.8 kn, wind 1.8 m/s Missing data:9811,9812,10055,1056,10057,10058,10059, 10060,10061,10069,10291,10292,10430,10431,10444,10445
11	17.07-	23:23-	10687- 11586	10772-	Ship speed 3.7 kn, wind 3.6 m/s Missing data:10728,10766,10777,10926, 11094, 11253, 11268, 11383, 11476, 11551, 11556, 11560, 11575,
12	18.07	01:01 – 02:05	11587 - 12501	11679 - 12333	Ship speed 4.1 kn, wind 1.7 m/s Missing data: 11607, 11631, 11721,11722,11741,11742, 11796, 11803, 11829, 11878, 12005, 12062, 12142, 12269, 12322, 12388, 12487,

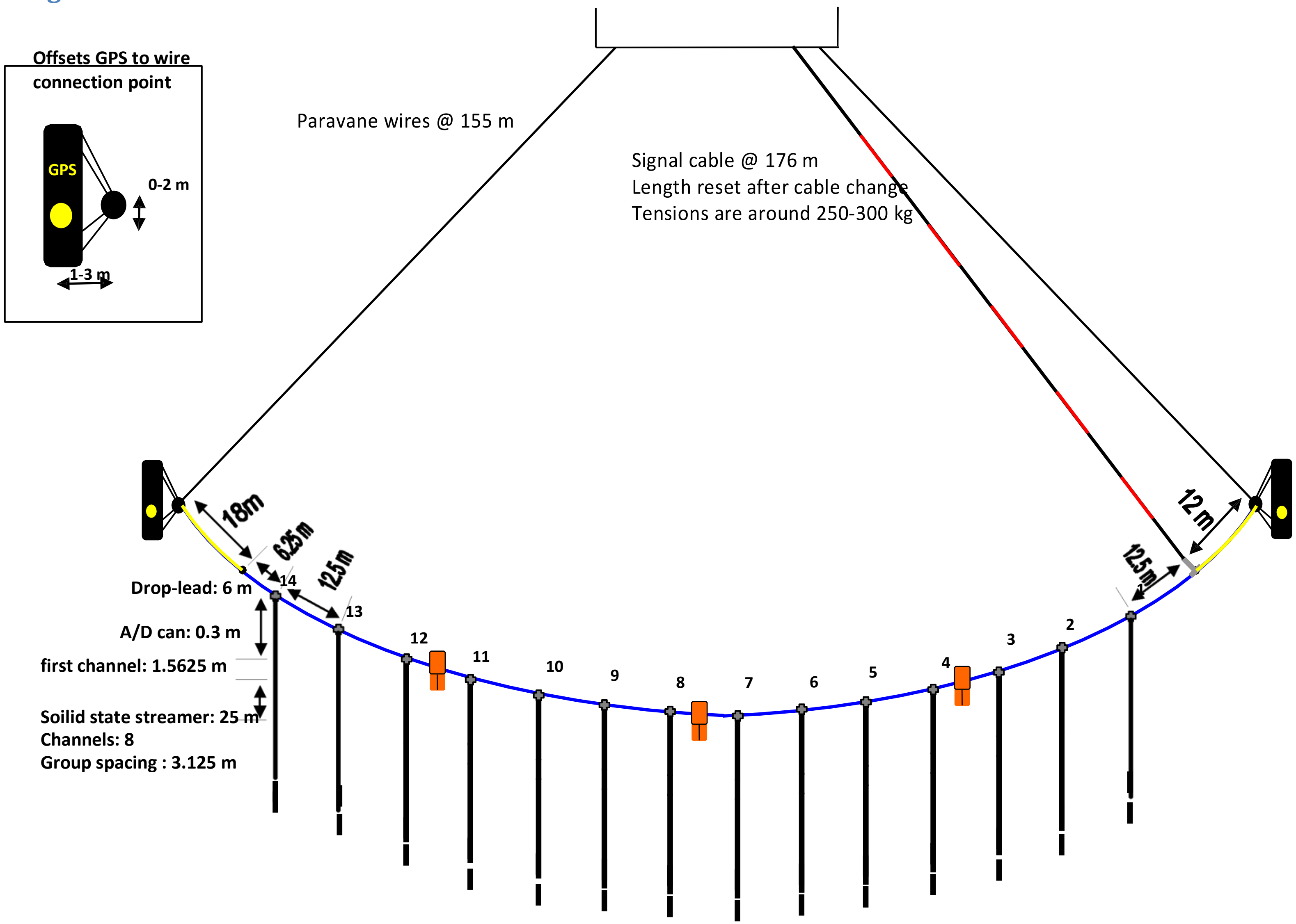
13	18.07	02:31 – 03:34	12502 - 13358	12592 - 13242	Ship speed 3.7 kn, wind 3.3 m/s Missing data: 12549, 12584, 12642, 12662, 12695, 12705, 12742, 12752, 12758, 12771, 12813, 12877, 12900, 12907, 12961, 13033, 13074, 13090, 13180, 13315, 13331, 13348,
14	18.07	03:59 – 05:03	13359 - 14174	13406 - 14060	Ship speed 3.7 kn, wind 2.7 m/s Missing data: 13441, 13672, 13689, 13699, 13720, 13758, 13782,
15	18.07	05:40 – 06:43	14175 - 14943	14317 - 14912	Ship speed 3.7 kn, wind 2.7 m/s Missing data:14416, 14644-46, 14673, 14674, 14763-64, 14792-14795, Missed start of line.
16	18.07	07:05-08:28	14949-15796	14973-15728	Ship speed 3.4 kn, wind 2 m/s Missing data: 15132-33, 15180-81, 15253-54, 15300-01, 15352-53, 15383-84, 15396-97, 15523-24, 15607-10, 15656-7, 15683, 15685, Depth sensors not updating.(3,4,6,9,10,11,12)
17	18.07	08:36-10:14	15797-16796	15915-16660	Ship speed 3.4 kn, wind 2.8 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data:15849,15851,16006,16007,16012,16211,16222,16223, 16234,16235,16269,16286,16287,16298,16299,16303,16304, 16408-09, 16641-42
18	18.07	10:24-11:54	16797-17713	16875-17643	Ship speed 3.4 kn, wind 2.5 m/s Depth sensors not updating.(3,4,6,9,10,11,12)
					Missing data: 16992,16994,17091,17092,17128,17129,17130,17132, 17133,17134,17148,17149,17230,17231,17312,17313, 17366,17367,17392,17393,17423,17425,17450,17451, 17520,17522,17593,17594,17612,17613,17634,17635 Changed the multibeam maximum coverage from line 100 (in multibeam) onwards to 2 km
19	18.07	12:06-13:27	17714- 18588	17777- 18530	Ship speed 3.2 kn, wind 5.5 m/s Depth sensors not updating.(3,4,6,9,10,11,12)
					Missing data:17769, 17778, 17779, 17912-13, 18044, 18045,

					18417, 18418, 18468, 18469, 18543, 18544
20	18.07	13:57 – 15:09	18589 - 19626	18821 - 19550	Ship speed 3.5 kn, wind 2.2 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data: 18629, 18630, 1863, 18744, 18745, 18775, 18776, 18994, 18995, 19097, 19098, 19199, 19200, 19293, 19294, 19456, 19457, 19500, 19501, 19536, 19537, 19551, 19552, 19603, 19605.
21	18.07	15:36 – 16:49	19627 - 20609	19825 - 20552	Ship speed 3.3 kn, wind 3.5 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data: 19704, 19705, 19760, 19761, 19811, 19812, 20039, 20041, 20103, 20104, 20269, 20270, 20315, 20316, 20607, 20608
22	18.07	17:16 – 18:39	20610 - 21660	20827 - 21582	Ship speed 3.3 kn, wind 2.5 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data: 20627, 20628, 20680, 20681, 20736, 20737, 20820, 20821, 20824, 20825,21142,21143,21400,21401, 21515,21516
23	18.07	18:51-20:18	21661-22548	21721-22480	Ship speed 3.5 kn, wind 2.8 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data: 21680,21682,21757-60,21810,21846,21847, 21883,21885,21949,21950,22026,22027,22059,22060,22084, 22085,22098,22099,22212,22214,22355,22356,22403,22497, 22498
24	18.07	20:35-21:59	22549-23397	22579-23310	Ship speed 3.8 kn, wind 1.41 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data:22652,22653,22666,22667,22687,22688,22706,22707, 22732,22733,22802,22804,22897,22898,22937,22938, 23099,23100,23173,23175,23257,23258,
25	18.07	22:11 - 23:43	23398-24335	23463-24221	Ship speed 3.8 kn, wind 2.6 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data:23403,23459,23460,23595,23616,23617,23657-59,23683-86,23698,23699,23718,23719,23817,23818,23862,

					23863,23966,23967,24005,24006,24051,24052,24067,24068, 24077,24078,24104,24105,24112,24113,24165,24166,24192, 24193,24239,24241
26	18.07-19.07	23:54 - 01:01	24336 - 25237	24362 - 25113	Ship speed 3.3 kn, wind 2 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data:24377,24378,24412,24437,24438,24441-44, 24495,24497,24519,24521,24553,24554,24556,24557,24577, 24578,24631-33,24635,24705,24706,24717,24718,24725-27, 24729,24735,24736,24863,24865,24895,24896,24940,24941, 24984, 24995, 25011, 25021, 25203, 25221
27	19.07 19.07	01:39 – 02:51 03:16 – 04:34	25238 - 26046 26047 - 26931	25259 - 26005 26100 - 26913	Ship speed 3.6 kn, wind 3 m/s Depth sensors not updating.(3,4,6,9,10,11,12) Missing data:25252, 25258, 25298, 25348, 25372, 25387, 25396, 25423, 25460, 25465, 25485, 25521, 25539, 25589, 25644, 25693, 25705, 25722, 25790, 25837, 25860, 25894, 25910, 25925, 25938, 25944, 25972, 26005 Ship speed 3.6 kn, wind 3 m/s
28 29	19.07	05:02 – 6:26	26932 - 57902	27038 - 27882	Depth sensors not updating.(3,4,6,9,10,11,12) Missing data: 26051, 26093, 26136,26137, 26195, 26282, 26294, 26339, 26381, 26407, 26434, 26443, 26447, 26508, 26517, 26529, 26567, 26570, 26611, 26641, 26664, 26669, 26680, 26715, 26789, 26815, 26824, 26857, 26867, 26877, 26884, 26905, Ship speed 3.0 kn, wind 3.5 m/s
30	19.07	06:45 – 08:07	27903 - 28748	28010 - 28741	Depth sensors not updating.(3,4,6,9,10,11,12) Missing data: 27005, 27007, 27015, 27061, 27122 ,27140, 27203, 27244, 27264, 27281, 27328, 27329, 27351, 27371, 27425, 27427, 27561, 27563, 27576, 27577, 27604, 27605, 27606, 27608, 27651, 27652, 27677, 27678, 27784, 27785, 27809, 27810, 27823, 27824, 27825, 27827, 27892, 27894, Ship speed 3.3 kn, wind 2.5 m/s
					Depth sensors not updating.(3,4,6,9,10,11,12) Missing data: 27914 (overdriven channel 08:48), 17963-64, 27976-77, 28023-24, 28051-52, 28055-56, 28120-21, 28146

					(overdriven channel 09:10), 28180, 28182, 28193-94, 28208-09, 28216-17, 28228-29, 28298 (overdriven channel 09:28), 28299-300, 28309-10, 28323-24, 28390-91, 28398, 28400, 28402, 28404, 28453-54, 28499-501, 28503, 28510-11, 28591-92, 28617-18, 28626, 28628, 28712, 28714,

Survey configuration



Observed spread of paravanes: 166 -170 m
Observed distance between gun and paravanes: 96 – 106 m, deviations between distances to both paravanes up to 5 m

Ship's speed: 3.5 - 4 kn
Gun system: mini-GI (15/15 in^3)
Shooting pressure: ~170 bar
Shooting interval: 5 sec, 6 sec from line 5 onward
Recording window: 3 sec
Recording delay: 0 sec

Switch table :

Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7	Pos 8	Pos 9	Pos 10	Pos 11	Pos 12	Pos 13	Pos 14
6027	6032	6021	6024	6010	6029	6011	6030	6033	6034	6025	6026	6022	6019
0,47	0,34	0,68	0,23	0,57	0,99	0,59	0,26	0,17	-0,41	0,32	0,46	0,19	3,89

3rd line is offset measured after recovery (19.07.2013, 11:30)

3D seismic line log PKF 2013

Expedition: Helmer Hanssen July 2013 Survey: PKF 2013 gas hydrate outcrop zone 20.07. – 20.07
Sheet #: 1 - 4

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.)
0	20.07.	01:00 -	1 -		Pre-survey warm up. Still some incomplete data files after replacing one cross cable subsection. Channel 25 looks bad. A lot of incomplete data files, almost no good shots, restart SPSU. Slow and variable response time on ping. Varies between 1 and 600 ms Ship speed: 4.1 kn, wind 6.1 m/s Ch. 25 bad
1	20.07	01:43 – 03:27	722 - 1775	746 - 1733	Missing data: 751, 790 – 794, 931, 968, 1070, 1078, 1100, 1122, 1130, 1170, 1173, 1178, 1196, 1211, 1269, 1320-25, 1458 - 1465, 1490, 1584, 1746, Ship speed: 3.9 kn, wind 7.1 m/s Ch. 25 bad
2	20.07	03:55 – 05:33	1776 – 2864	1814 - 2818	Missing data: 1834, 1856, 1893, 1922, 2004, 2057, 2094, 2111, 2149, 2164, 2187, 2207, 2221, 2248, 2292, 2352, 2416, 2435, 2466, 2569, 2577, 2677, 2765, 2830, 2841, Ship speed: 4 kn, wind 7 m/s Ch. 25 bad
3	20.07	05:57-07:50	2865 - 4036	2903-3984	Missing data:2904-05, 2949, 2950, 2951, 2953, 295, 2987-90, 3012-13, 3047-50, 3083, 3084, 3086, 3087, 3090, 3091, 3107-09, 3119-22, 3140-42,

					3153-54, 3198-99,3206-07,3227-30,3250-51,3316-17,3483-84,3525-28,3559-60,3587-88,3695-96,3820-21,3844-45,3989-90
4	20.07	08:11-09:58	4037-5113	4042-5028	Ship speed: 4 kn, wind 7 m/s Ch. 25 bad Missing data:4092-93,4134-35,4503-04,4515-16, 4677-78,4760-61,4838-39,4940-41, **Gun position not available from 09:38UTC**
5	20.07	10:08-13:09	5114- 5336-6395	5198- 5385-6391	Ship speed: 3.6 kn, wind 3.5 m/s Ch. 25 bad Missing data:5131-32, from 5230 all shots were incomplete for section 7. We disarm and arm again. Started again at **5262**. At around 5285 error on gun, low pressure on gun 1. Several errors: no fire gun 1 Shooting stopped at 5335 to check the gun. Gun taken onboard. Gun hydrophone found to be hanging loose. Redoing the line again after repairing. **Line 5 shot no. starting from 5336** Missing data:5355-56,5363,5365,5386-87,5437-38, 5450-51,5557-58,5571-72,5628-29,5635-36,5644-45, 5845-46, 5923-24, 5936-37, 5976-77, 5979-80, 6024, 6025, 6039-42, 6083-84, 6104-05,

Observed spread of paravanes: 166 -170 m

Observed distance between gun and paravanes: 96 – 106 m, deviations between distances to both paravanes up to 5 m

Ship's speed: 3.5 - 4 kn
Gun system: 2 x mini-GI (15/15 in^3 and 30/30 in^3)
Shooting pressure: ~170 bar
Shooting interval: 6 sec
Recording window: 1.5 sec
Recording delay: 0 sec

Switch table :

Pos 1	Pos 2	Pos 3	Pos 4	Pos 5	Pos 6	Pos 7	Pos 8	Pos 9	Pos 10	Pos 11	Pos 12	Pos 13	Pos 14
6027	6032	6021	6024	6010	6029	6011	6030	6023	6034	6025	6026	6022	6019
0,47	0,34	0,68	0,23	0,57	0,99	0,59	0,26		-0,41	0,32	0,46	0,19	3,89

3rd line is offset measured after recovery (19.07.2013, 11:30)