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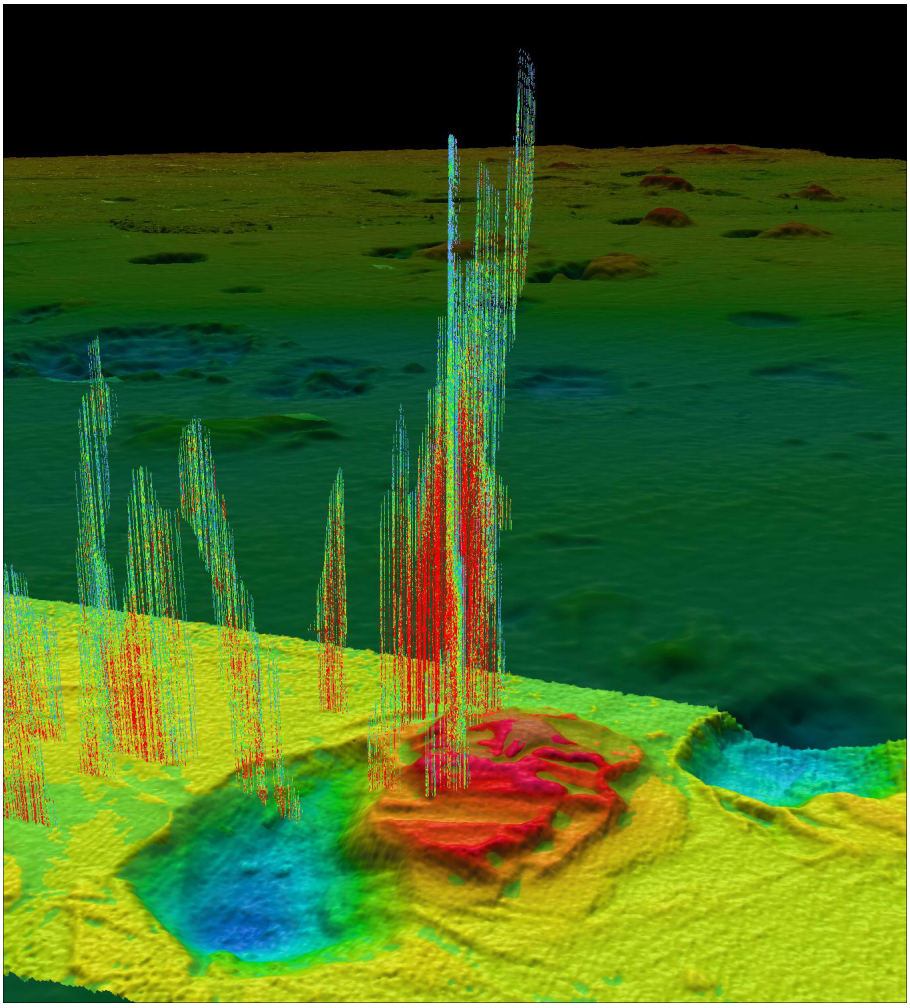
CRUISE REPORT

Marine Geological Cruise to the Maud Basin and Crater Area, Bjørnøyrenna

R/V Helmer Hanssen 15th April – 22nd April, 2016



Gas flares above a pingo and crater in central Bjørnøyrenna

Centre for Gas Hydrate, Environment and Climate (CAGE)
Department of Geology
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N-9037 Tromsø, Norway

1. Introduction and scientific objectives

The cruise was a part of the Centre of Excellence for Gas Hydrate, Environment and Climate (CAGE) at UiT - The Arctic University of Norway.

The aim of the cruise was to visit two study areas: the first a new study site called Maud Basin in southern Bjørnøyrenna – an area where industry data has shown promising evidence for gas leakage associated with pingo/crater formation and an underlying hydrocarbon reservoir. The second site is the Crater Area previously visited by CAGE in 2015 (15-5).

More specific objectives of the cruise were to:

- Obtain multibeam and seismic lines over pingos and a crater in Maud Basin, southern Bjørnøyrenna, already identified on industry seismic data
- Re-examine the high density flares areas of the Crater Area previously surveyed in 2015 for any changes
- Survey new areas in the surrounding region of the Crater Area
- Obtain plankton net data from gas leaking sites for analyses of biomass

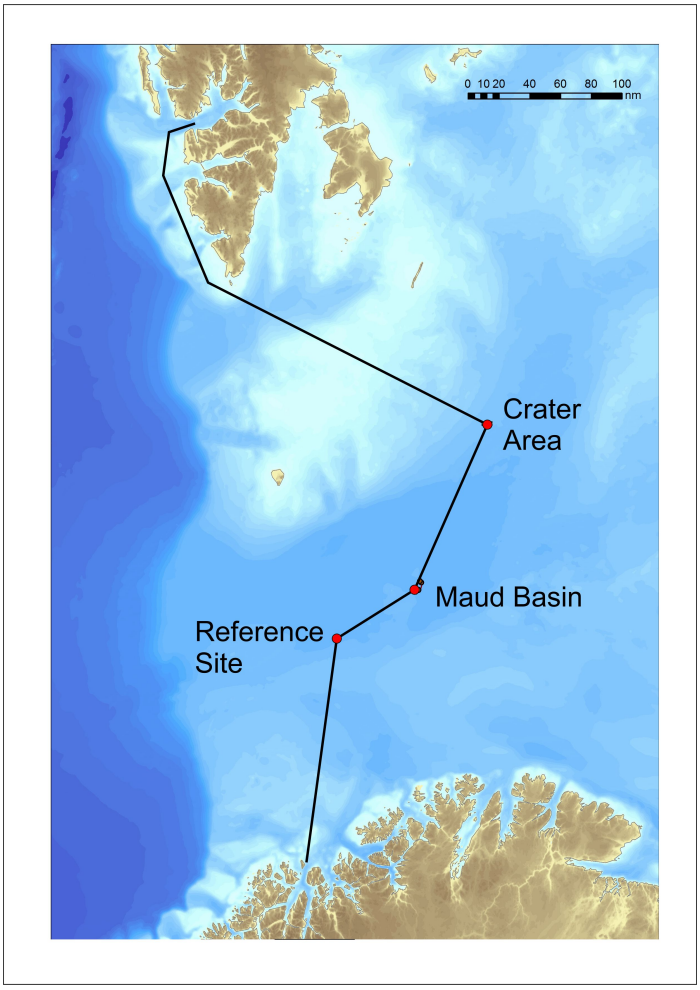

Figure 1. Map of the two study areas and reference site (red circles) for cruise CAGE 16-2: Maud Basin and the Crater Area.

2. Cruise participants

Name	Shift	Cabin
Karin Andreassen (Cruise leader)	1	505
Bjørn Runar Olsen	Open	404
Henry Patton	1	322
Sunil Vadakkepuliyambatta	1	209
Eythor Gudlaugsson	2	323
Pavel Serov	1	211
Pär Jansson	2	210
Siri Ofstad	2	213
Julie Meilland	1	411

Shift 1: 08:00-14:00; 20:00-02:00. Shift 2: 14:00-20:00; 02:00-08:00.
Breakfast: 07:30-08:30. Lunch: 13:30-14:30. Dinner: 19:30-20:30
Cruise shifts: started April 16th, 8pm; stopped April 20th, 8pm.

3. Equipment

3.1 Subbottom Profiler (Chirp)

A X-STAR Full Spectrum Sonar is a versatile wideband FM sub-bottom profiler that generates cross-sectional images of the seabed and collects digital normal incidence reflection data over many frequency ranges. X-STAR transmits an FM pulse that is linearly swept over a full spectrum frequency range (also called “chirp pulse”).

The chirp system comprises of a hull-mounted 4 x 4 transducer array operated at an energy level of 4 kW and at a shot rate of 1 s. The signal lasts 40 ms, starts at 1.5 kHz and end at 9 kHz. The system can operate in up to 8000 m of water. The penetration depth depends on the sediment type/thickness, it can be up to 80 m in soft clay.

During this cruise, we imaged the morphology of the ocean floor and its shallow sub-bottom sedimentary layers and structures using the subbottom profiler along all lines. This could then be used for deciding the locations of where to extract gravity cores.

3.2 Multibeam Echosounder

In the hull of R/V Helmer Hansen a Kongsberg Simrad EM 300 multi-beam echo sounder has been installed. The multi-beam system measures the two-way travel time that a sound wave initiated by a transmitter needs to reach the sea floor and come back. These waves have a frequency of 30 kHz, which is too high to penetrate the seafloor sediments, but gives a high resolution for a bathymetric map.

Once data have been acquired, programs such as, Neptune, Fledermaus and ArcGIS were used to visualize, clean, filter and process them. Multibeam data collected from the Maud Basin area suffered from the poor weather conditions, with the lines collected being relatively noisy. At the Crater Area, a higher-density multibeam survey (60-100 m spaced lines; swath 30°) of 12 lines was carried out over one of the larger pingo sites that had been previously observed to have high flare activity. The resulting data from these lines was gridded at a 2.5 m resolution. During periods of rough weather when coring/water sampling was not possible, multibeam surveying was extended to the northwest of the Crater Area (Figure 9). These data were collected using a broader 60° swath with line spacing of c. 1 km.

3.3 CTD

CTD (Conductivity, Temperature, Depth) sensors measure the physical properties of seawater. In addition to measuring the conductivity, temperature and pressure (from which depth is calculated), the CTD sensors measure or calculate salinity of seawater, density, sound velocity, turbidity, fluorescence/chlorophyll, and oxygen content. Furthermore, the CTD deck unit can trigger closing of Niskin bottles at discrete depths. Water samples may be taken from the Niskin bottles for further analysis.

R/V Helmer Hanssen uses SBE 911plus CTD for producing vertical profiles of seawater properties. A winch is used to lower the CTD system into the water. The SBE 911plus CTD can measure physical properties of the seawater from up to eight auxiliary sensors, in marine or fresh-water environments at depths up to 6000 meters. However, the winch wire length limits CTD measurements to approximately 3200 meters. The CTD sensors record data at a rate of 24 samples per second. The 911plus system uses the modular SBE 3plus temperature sensor, SBE 4C conductivity sensor, SBE 5T submersible pump, and TC duct. The submersible pump pumps water along the sensor to measure the conductivity. The TC duct makes sure that temperature and conductivity are measured on the same parcel of water. If required, 12 water bottles can be attached to the CTD instrument set up to collect the water samples from any depth. A single conductor cable supplies the power to the system and transmits data from and to the CTD system real time.

During our cruise, we used the sound velocity profiles from different CTD stations to calibrate depth calculations in the swath bathymetry data.

A CTD station was collected from our Reference Site in southern Bjørnøyrenna. Poor weather conditions in Maud Basin meant sample stations were not carried out. We acquired 9 CTD profiles in the Crater Area. A first look at the CTD data shows homogenous profiles of temperature and salinity, - indicating that Atlantic water dominates the area during the survey (see Figure 2). We

collected water samples for methane concentration, pH, DIC and nutrients at 8 stations, with varying depth resolution for the different parameters.

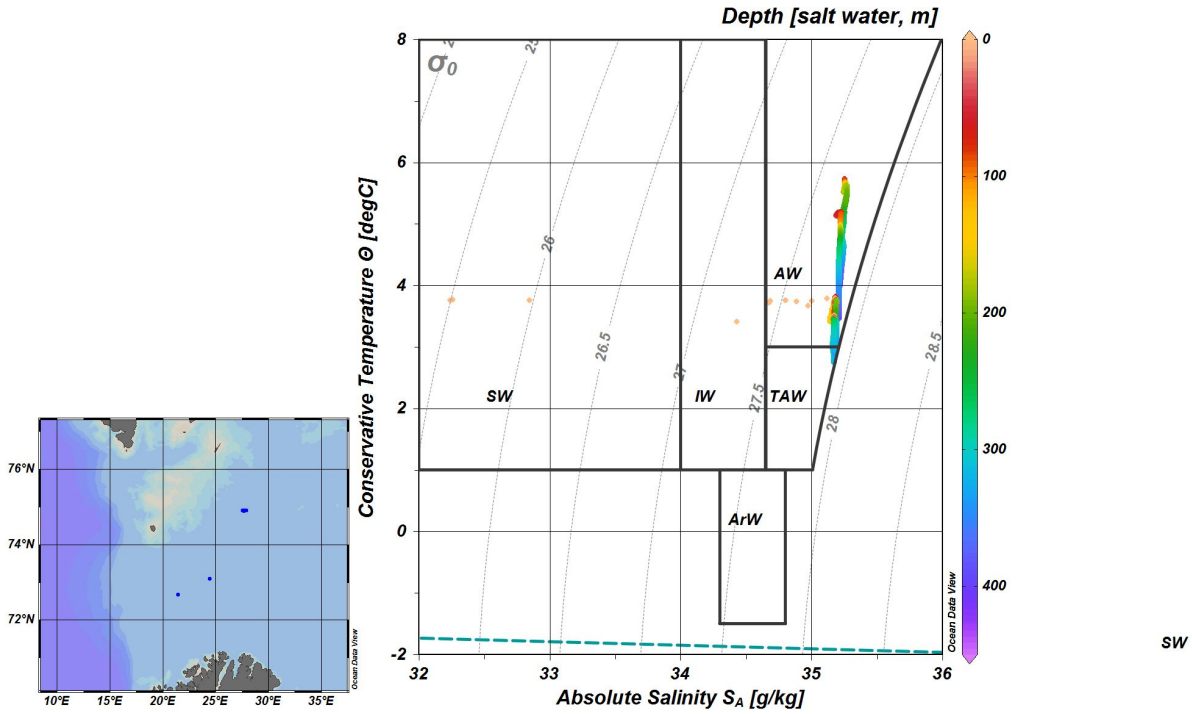

Figure 2. Water samples from the study locations in Maud Basin and the Crater Area. All observed water are within the Atlantic Water (AW) mass classification. Water mass classifications from Cottier et al., (2015) indicate Atlantic water (AW), Transformed Atlantic Water(TAW), Arctic water (ArW), Intermediate water (IW) and Surface water (SW). Blue dashed line indicate the freezing boundary.

3.4 2D Reflection Seismic

Source: During 2D seismic acquisition, two mini GI (Generator-Injector) air guns are used as the seismic source. Mini GI airguns are especially suited for high resolution surveys. The air gun generates seismic waves by releasing compressed air into the water. During the Crater Area 2D seismic acquisition, the total volume of the gun is 60 in^3, where the generator and injector volumes are the same (30 in^3 each). This generates a high frequency signal, which is suitable for studying the shallow subsurface in detail. A compressor supplies air at a pressure of 170 bar to the air gun. Shooting rate was 3 s and sampling rate 0.25 ms.

Streamer: The streamer used during 2D data acquisition is 100 m long with 32 channels separated by 3.125 m. The streamer is composed of four 25 m long P-Cable Sections (see 3D seismic chapter).

Operation: The streamer is towed behind the ship at a distance of 80 m from an arm at ~13 m from the centre of the boat. The air gun is towed at a distance of 33 m behind the ships at a depth of approximately 2 mbsl. See Figure 3 for geometry of the survey.

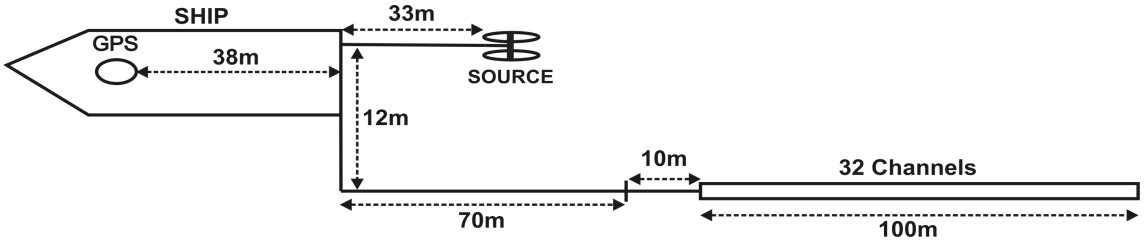

Figure 3. Geometry of the 2D seismic survey during CAGE16-2 expedition.

Seismic lines were collected at both the Maud Basin and Crater Area study sites (section 5.3; e.g., Figures 4-5). Eight lines were collected across the Maud Basin area, with focused surveying over the well, crater and pingo (Figure 8). At the Crater Area 13 lines were collected across the central pingo site (Figure 9). A further 6 regional lines were also collected, 3 to the south (stations 510-512), and 3 to the northwest (stations 538-540), crossing over notable pingos and craters in the area.

3.4.1 Ship-Board Processing

On-board data processing used Radex Pro for data quality control. Seg-y files were imported to Petrel for quality control. On board processing included:

1. *Navigation Files:* Seatrack GPS positioning from the gun raft and stern of the ship is used. These are checked for gaps and interpolated if necessary
2. *Read SegD Files into RadEx Pro*
3. *Single channel display for quality control*
4. *Geometry assignment*
5. *CDP Binning (3.125 x 3.125 m bin size)*
6. *Bandpass filtering using 10-20-350-500 Hz*
7. *Amplitude Correction (spherical divergence and time-variant gain)*
8. *NMO Correction (1600 m/s)*
9. *Stacking*
10. *Migration using Stolt F-K Migration*
11. *Seg-y Output*

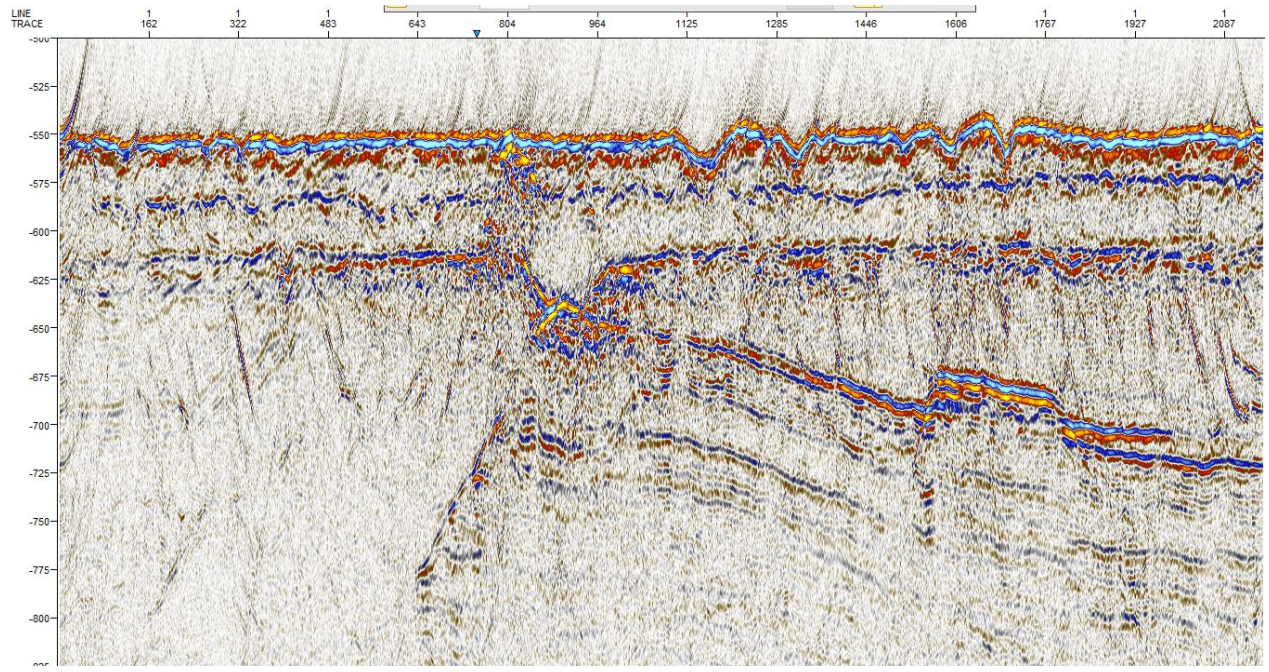

Figure 4: Processed seismic line 495 from Maud Basin pingo area

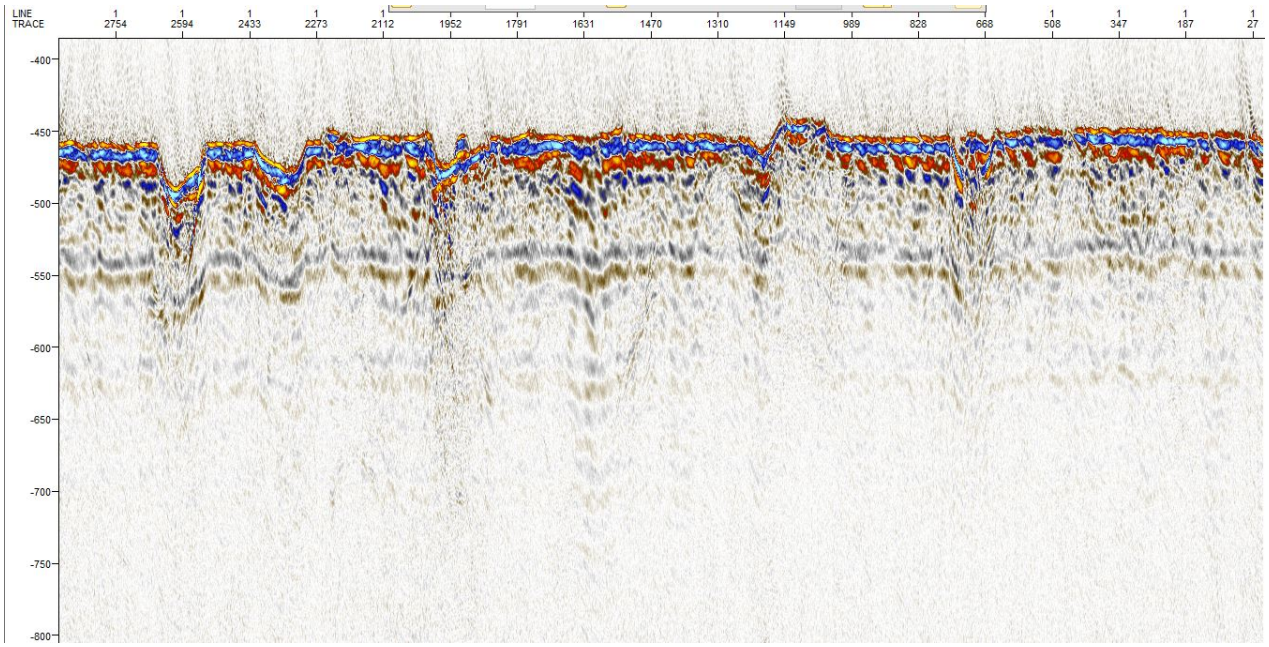

Figure 5: Processed seismic line 497 from the central Crater Area

3.5 Single Beam Echo sounder

Single beam echo sounders are common among all types of ships. Their primary purpose is to estimate the depth of the seafloor. In a single beam echo sounder, the transducer projects a sound pulse through water in a controlled direction and the reflected wave is received. The depth is calculated from the travel time of the sound pulse. R/V Helmer Hanssen has a keel-mounted Simrad EK 60 single beam echo sounder with transducers at three different frequencies, 18 KHz, 38 KHz and 120 KHz. The 18 KHz transducer can be used for depths up to 10 km whereas 38 KHz and 120 KHz can only be used for depths up to 2 km and 500m respectively.

The single beam echo sounder can also be used for detecting gas leakages from the seafloor using 18KHz and 38KHz transducers. We continuously recorded single beam data during the entire cruise and we identified "flares" with QPS Midwater and subsequently plotted in Fledermaus (QPS software) (e.g., Figure 6).

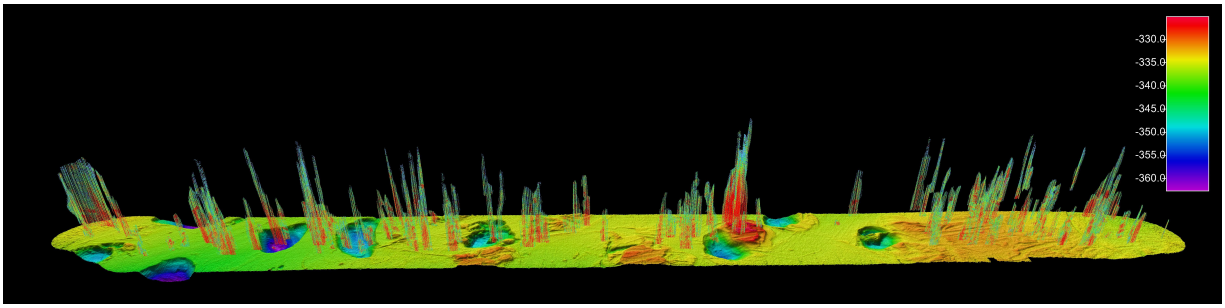

Figure 6: Flares captured over the Crater Area from single-beam echosounder. Newly collected multibeam bathymetry data was gridded at 2.5 m horizontal resolution.

3.6 Sediment coring

Sediment coring in the Crater area was performed in order to collect samples for analysis of gas content and foraminifera assemblages. A total of 8 gravity coring stations (Stations 530-537, see Fig. 6) were attempted although three of those (535-537) came up empty. Recovery was low in general, with a 30 cm retrieval at most (core length). More stations were planned but had to be cancelled due to bad weather and unsafe conditions.

3.7 Gas in bottom sediments

For compositional analyses of hydrocarbon gas (C_1-C_5) conventional headspace sampling preparation technique was applied. Bulk sediments (5ml) were subsamples with a 5 ml cut-off plastic syringe. The sediments were transferred into 20 ml headspace glass vials, containing 5 ml of 1-molar

NaOH solution and 2 glass beads. The vials were immediately capped with rubber septa, sealed with aluminum crimp caps and shaken afterwards. All samples were stored in a fridge with a temperature of +2 C.

For gas analyses we used ThermoScientific Trace 1310 gas chromatograph equipped with a flame-ionization detector (GC-FID) and ThermoScientific TG-BOND alumina (Na_2SO_4) 30m x 0,53mm x 10µm column. Instrument method for our sequence of samples:

- constant column flow (H_2): 30 ml/min
- split ratio 1
- injection volume 100µl
- injector temperature: 150 C
- detector temperature: 180 C
  - oven temperature program: 40 C (0-5 min);
    temperature ramp 10 C/min (5-11 min); 100 C (11-16min); temperature ramp 10 C/min (16-19 min); 130 C (19-25 min)
- air flow: 350 ml/min
- makeup gas (N2) flow: 35 ml/min
- hydrogen flow: 40 ml/min

In order to estimate headspace gas concentrations in ppm (particles per million) we applied 6 calibration levels for methane (5ppm, 10ppm, 50ppm, 100ppm, 4400ppm, 8800ppm) and 3 calibration levels for various C2-C5 hydrocarbon gas (2ppm, 5ppm, 10ppm). We also collected samples for sediment porosity tests, which is necessary for converting our GC-FID results from ppm to nmol. Chromeleon 7 software was used for the instrument control and processing of chromatograms.

Gas in sediment samples were taken from gravity core stations across the central Crater Area only (Figure 9).

3.8 Gas in water

We collected water samples from 9 stations (see CTD) and 8 discrete depths at each station. Water samples were analyzed with a Gas Chromatograph equipped with a FID. The chromatograms allow for detection of hydrocarbon gases such as methane, ethane, ethylene and propane.

Headspace gas extraction method was applied for sample preparation for subsequent GC-FID gas analyses. Water samples from Niskin bottles were placed into 120ml glass vials, We added 1 ml of 1M NaOH solution for preservation. Bottles were sealed with rubber septa and crimped. Subsequently we added 5ml of instrument nitrogen gas into each of the bottles and shake them to equilibrate gas

dissolved in a water sample and headspace gas. Samples were stored in the fridge (+2 C) and analyzed within 0.5-2 hours after the sampling.

For gas analyses we used ThermoScientific Trace 1300 GC-FID with the same hardware configurations. Instrument method for our sequence of samples:

- constant column flow (H_2): 10 ml/min
- splitless injection
- injection volume 100µl
- injector temperature: 170 C
- detector temperature: 180 C
- oven temperature: 40 C
- air flow: 350 ml/min
- makeup gas (N2) flow: 35 ml/min
- hydrogen flow: 40 ml/min

We used calibration gases with known concentrations of 5, 10, 25, 50 and 100ppm to calculate calibration curve for CH_4. For subsequent headspace ppm to water sample nmol/L data conversion we continuously measured temperature of the samples and atmospheric pressure in the laboratory. Salinity data for the conversion was taken from SBE 19 CTD.

A first look at the water column chromatograms show very small (below detection limit) for all hydrocarbons heavier than methane and small (relative to other seep areas) concentrations of methane. Further processing will be made based on the resulting chromatograms and CTD data (temperature, salinity and depth) to calculate the dissolved gas concentrations in the water column.

3.9 Plankton net

Plankton net samples were collected using a Multinet (multi stratified plankton tow Hydrobios, type Midi) equipped with five 63um mesh size. One station was collected from the Reference Site in southern Bjørnøyrenna and we acquired eight stations in the Crater Area along a transect from east to west. Poor weather conditions in Maud Basin meant sample stations were not carried out. At each collected station five depth intervals had been sampled in one stroke, dividing the water column into the following depths intervals: 300-200m, 200-150m, 150-100m, 100-50m and 50-surface.

The contents of each cast were sieved on a 63 um sieves and placed in separate bottles, resulting in 45 bottles in total. Samples were preserved in 96% ethanol solution and buffered with Hexamethylenetetramine. Calcifying organisms including planktonic foraminifera, pteropods and bivalves will be studied from the collected samples. A particular interest will be given to their shell structure ($CaCO_3$) with regard to the ocean chemistry (DIC, CH_4 concentration, pH). The small mesh size and covering of the entire water column allows the analyses of other zooplankton groups (e.g.

copepods, dinoflagellates, cladocerans), which provide additional information about water masses dynamic in the crater area.

3.10 Gas in air

Methane is monitored at the Zeppelin mountain station and on board RV Helmer Hanssen using a Picarro Cavity Ring Down spectrometer (CRDS), model G2401. Both are connected to a heated main sample inlet line with excess air flow. The sample air is dried using a nafion drier to minimise any water correction error in the instrument. A multiport valve on the instrument inlet enables switching between sample air and control samples/working standards. Working standards are calibrated against reference standards from NOAA-CMDL (CH4 scale NOAA2004). The central inlet line is connected to the top of the mast on RV Helmer Hanssen (xx m asl) and on top of a 15 m mast at the Zeppelin station (490 m asl). Sample residence time in the sample line is about 10 secs.

Ethane and propane is monitored at the Zeppelin station by the use of a semi continuous GC-MS system (the Medusa system ref. xxx) sampling every two hours, using the same main sample line as the CRDS system. On board RV Helmer Hanssen, air samples are collected on SUMMA canisters, also using the same sample line as the CRDS system. The canisters are sent to the laboratory at NILU where they are analysed on a Medusa system, similar to the system at Zeppelin. Both instruments are calibrated against AGAGE reference standards (AGAGE scale). The Medusa systems measure a range of hydrocarbons and halogenated trace gases in addition to ethane and propane.

Air samples for analysis of isotopes in methane are sampled on steel and aluminium canisters, daily at the Zeppelin station and at the same time as the hydrocarbon canisters on RV Helmer Hanssen.

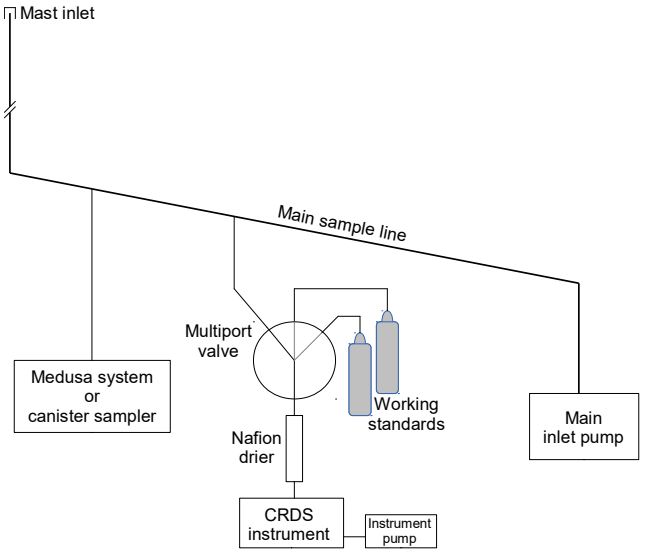

Figure 7: Setup of Picarro sampling station on RV Helmer Hanssen

4. Ship tracks and study areas

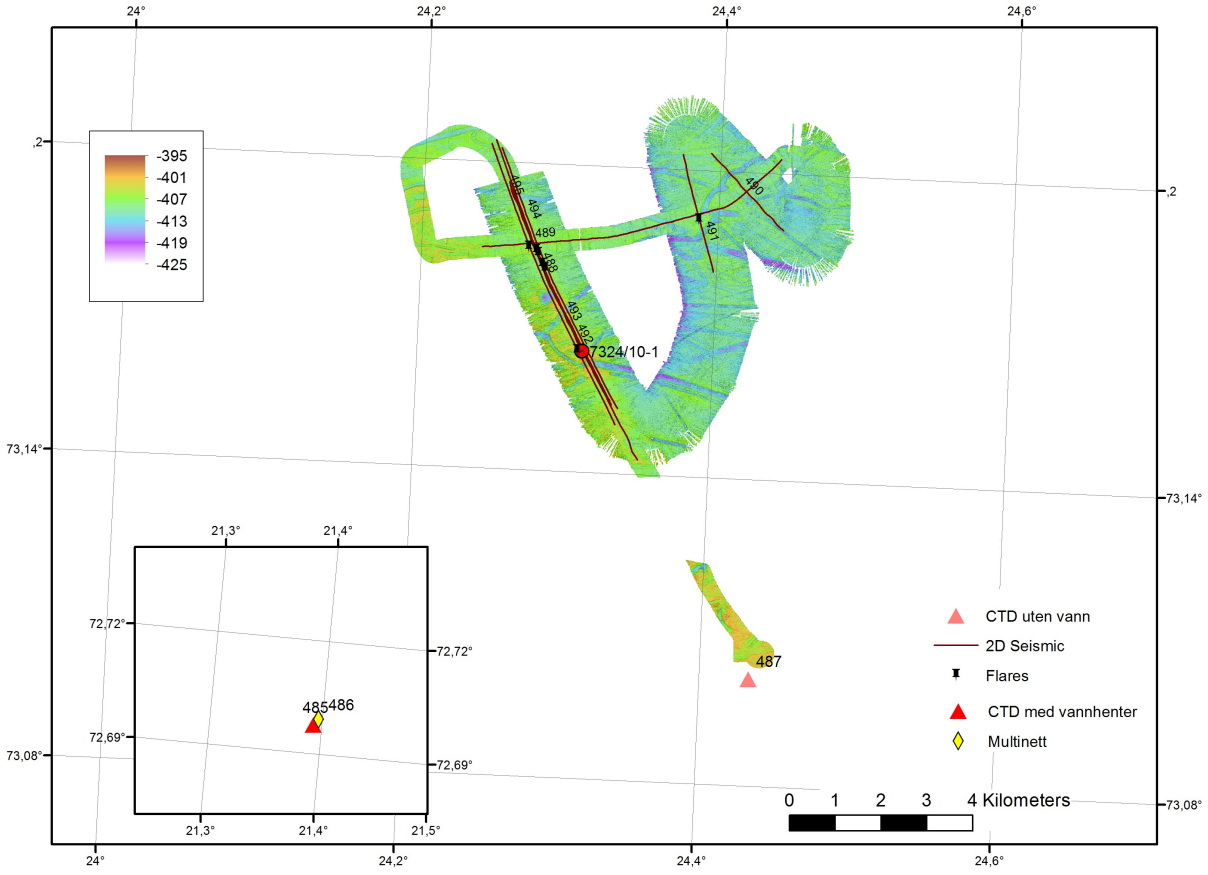

Figure 8: Locations of 2D seismic datasets collected across the Maud Basin area, southern Bjørnøyrenna, and the well 7324/10-1. Multibeam data was gridded to a 5 m horizontal resolution.

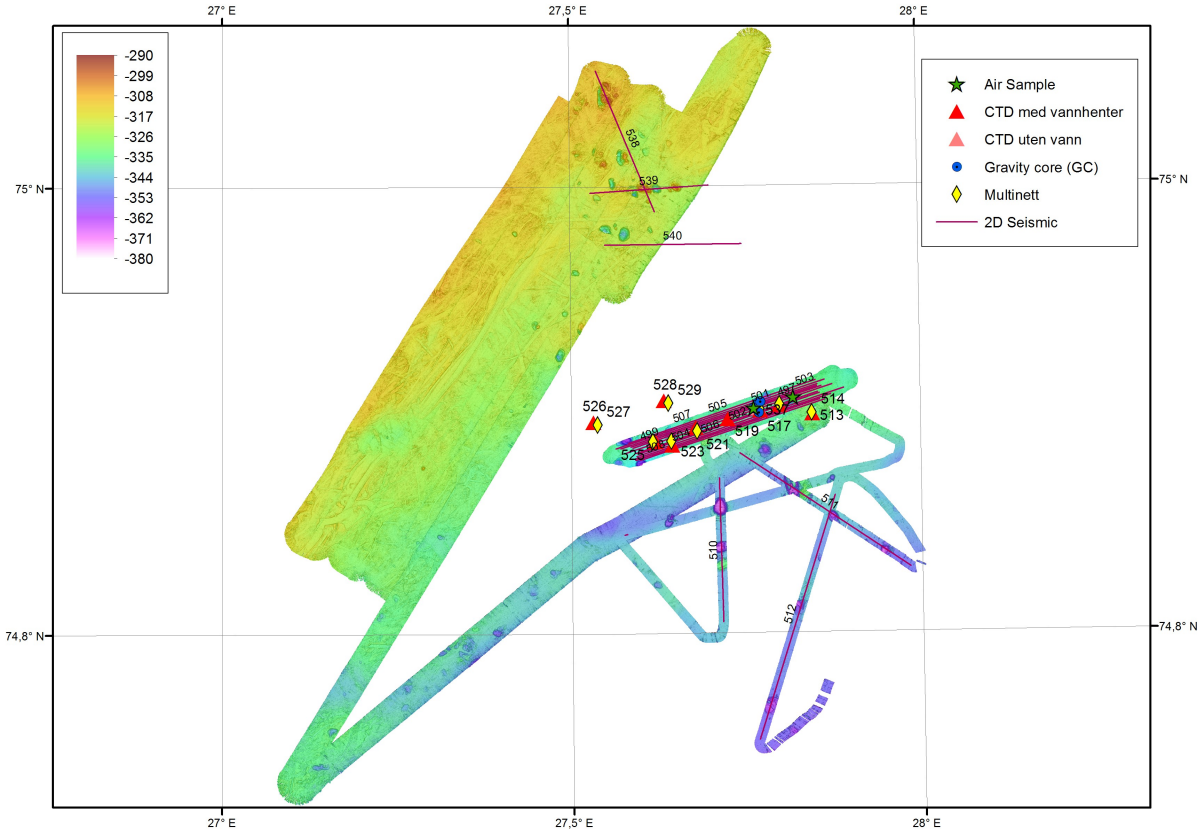

Figure 9: Locations of 2D seismic lines, CTD stations, Gravity Cores, Multinet stations and air sample measurements collected in the Crater Area.

5. Logs

5.1. Event log

Date	UTC	Position	Event
15/4	c. 00:00		Depart Tromsø, heading for Maud Basin area
	17:40	72 41.857 21 23.565	Arrive at Reference site
	17:45	72 41.857 21 23.565	Collected CTD and plankton net samples. Waves too rough for box coring
	19:20		Depart reference site for Maud Basin pingo site.
16.4	01:34	73 06.032 24 26.077	Arrive at Maud Pingo site
	01:37	73 06.075 24 26.004	CTD station for multibeam
	03:05	73 8.643 24 21.038	Start of seismic acquisition, chirp and multibeam
	04:01	73 10.828 24 16.917	First flare
			Weather: large swell & waves (2.5 m) this morning means multibeam & chirp data quality is suffering. Seismic ok.
	07:39	73 10,791 24 23,940	End of first batch of seismic data collection across entire area (stations 488-491)
	08:17	73 9,290 24 19,822	Started second batch of seimic lines and multibeam across well, crater & pingo 1 (stations 492-495)
	12:19	73 8.524 24 20.956	Stopped seismic acquisition
			Conditions still too unsettled to collect cores/plankton net samples
	12:20		Depart Maud Basin area for Crater Area
17.4	02:45	74 55.028 27 46.111	Arrive Crater area
	02:45	74 55.028 27 46.111	First CTD station
	04:37	74 55,584 27 52,750	Start of seismics, chirp and multibeam
18.4	06:15	74 48,352 27 50,918	Had to stop seismic/MB lines due to bad weather (>4 m waves & 20 ms-1 winds) Completed lines 497-512.
18.4	19:14	74 58.922 27 47.614	With improving conditions, started doing multibeam, filling up the coverage west of the Crater Area.
19.4	00:14	74 46.661 27 06.015	Stopped multibeam surveying.
	01:56	74 54,899 27 50,739	Started CTD and plankton net stations over Crater Area
	12:19	74 55,177 27 38,321	Completed CTD and plankton net sampling over Crater Area (stations 513-529)
	13:08	74 55,103 27 46,820	Start of gravity coring over pingo site.
	17:50	74 55,176 27 46,263	Ended gravity coring (stations 530-537).
	18:00	74 55,176 27 46,263	Resumed multibeam surveying west of the Crater.
20.4	07:30	75 02,545 27 31,571	Stopped multibeam survey
	08:40	75 2,538 27 32,458	Started regional seismic lines to the NW of Crater Area
	11:59	74 58,716 27 44,765	Completed seismic lines (stations 538-540)
	12:30		Travel to Longyearbyen
22.4	07:30		Arrive in Longyearbyen

5.2 Station log

Cruise CAGE 16-2
15-22. April 2016
Chief scientist: Karin Andreassen

Area	Cruise	Ship	Ship Station	Sampling device	Nr. of samples	Lat	Long	UTC
Reference site 15/4	CAGE 16-2	HH	485 (484 log file)	CTD	7	72 41.857	21 23.565	17:45
	CAGE 16-2	HH	486	PN	1	72 41.957	21 23.832	18:18
Crater Area 16/4	CAGE 16-2	HH	487	CTD		73 06,075	24 26,005	01:37
17/4	CAGE 16-2	HH	496	CTD		74 55,028	27 46,111	02:45
	CAGE 16-2	HH	Air001	Air	1			05:42
19.feb	CAGE 16-2	HH	513	CTD		74 54,899	27 50,739	01:56
	CAGE 16-2	HH	514	PN	1	74 54,929	27 50,676	02:22
	CAGE 16-2	HH	515	CTD		74 55,089	27 47,956	03:12
	CAGE 16-2	HH	516	PN	1	74 55,107	27 47,900	03:40
	CAGE 16-2	HH	517	CTD		74 54,981	27 46,079	04:23
	CAGE 16-2	HH	518	PN	1	74 55,008	27 46,189	04:45
	CAGE 16-2	HH	519	CTD	9	74 54,798	27 43,434	05:32
	CAGE 16-2	HH	520	CTD	10	74 54,600	27 40,689	06:05
	CAGE 16-2	HH	521	PN	1	74 54,518	27 40,864	06:33
	CAGE 16-2	HH	522	CTD	10	74 54,215	27 38,679	07:22
	CAGE 16-2	HH	523	PN	1	74 54,309	27 38,606	07:44
	CAGE 16-2	HH	524	CTD	10	74 54,296	27 37,235	08:37
	CAGE 16-2	HH	525	PN	1	74 54,299	27 37,017	09:00
	CAGE 16-2	HH	526	CTD	10	74 54,739	27 31,920	09:53
	CAGE 16-2	HH	527	PN	1	74 54,686	27 32,262	10:19
	CAGE 16-2	HH	528	CTD	10	74 55,213	27 37,984	11:05
	CAGE 16-2	HH	529	PN	1	74 55,177	27 38,321	11:28
	CAGE 16-2	HH	530	GC	1	74 55,103	27 46,820	13:08
	CAGE 16-2	HH	531	GC	1	74 55,041	27 47,886	13:59
	CAGE 16-2	HH	532	GC	1	74 54,929	27 46,112	15:13
	CAGE 16-2	HH	533	GC	1	74 54,932	27 46,132	15:44
	CAGE 16-2	HH	534	GC	1	74 55,031	27 45,615	16:16
	CAGE 16-2	HH	Air002	Air	1	74 55,032	27 45,693	16:29
	CAGE 16-2	HH	535	GC	Empty	74 55,024	27 45,643	16:46
	CAGE 16-2	HH	536	GC	Empty	74 55,138	27 46,271	17:24
	CAGE 16-2	HH	537	GC	Empty	74 55,176	27 46,263	17:50

Legend	
GC	Gravity core
PC	Piston core
MC	Multicorer
BC	Box core
GRAB	Van Veen Grab
CTD	CTD samples
SCRAPE	
PN	Plankton net
.....	

5.3 Line log

Cruise CAGE 16-2
15-22. April 2016
Chief scientist: Karin Andreassen

Area	Cruise	Ship	Line #	Instrument	SOL Lat	SOL Long	UTC	EOL Lat	EOL Long	UTC
Maud Basin 16/4	CAGE 16-2	HH	488	*SL, MB, SBP*	73 8.643	24 21.083	03:12	73 11.839	24 15,390	04:24
	CAGE 16-2	HH	489	*SL, MB, SBP*	73 10,980	24 14,016	05:12	73 12,135	24 26,314	06:25
	CAGE 16-2	HH	490	*SL, MB, SBP*	73 11,398	24 26,450	06:51	73 12,227	24 23,558	07:08
	CAGE 16-2	HH	491	*SL, MB, SBP*	73 12,145	24 22,512	07:18	73 10,791	24 23,940	07:39
	CAGE 16-2	HH	492	*SL, MB, SBP*	73 9,290	24 19,822	08:17	73 11,850	24 15,329	09:01
	CAGE 16-2	HH	493	*SL, MB, SBP*	73 12,205	24 14,968	09:23	73 9,222	24 20,030	10:12
	CAGE 16-2	HH	494	*SL, MB, SBP*	73 9,241	24 20,106	10:26	73 12,244	24 14,995	11:12
	CAGE 16-2	HH	495	*SL, MB, SBP*	73 12,175	24 14,763	11:31	73 8,744	24 20,2646	12:19
Crater area 17/4	CAGE 16-2	HH	497	*SL, MB, SBP*	74 55,584	27 52,750	04:31	74 54,084	27 35,103	05:56
	CAGE 16-2	HH	498	*SL, MB, SBP*	74 54,102	27 35,146	06:05	74 55,417	27 51,419	07:22
	CAGE 16-2	HH	499	*SL, MB, SBP*	74 55,529	27 51,642	07:49	74 54,137	27 35,995	08:51
	CAGE 16-2	HH	500	*SL, MB, SBP*	74 54,040	27 35,816	09:06	74 55,394	27 51,834	10:12
	CAGE 16-2	HH	501	*SL, MB, SBP*	74 55,482	27 50,640	10:31	74 54,154	27 34,675	11:34
	CAGE 16-2	HH	502	*SL, MB, SBP*	74 53,980	27 35,889	11:48	74 55,334	27 51,597	12:52
	CAGE 16-2	HH	503	*SL, MB, SBP*	74 55,589	27 51,435	13:13	74 54,220	27 35,064	14:17
	CAGE 16-2	HH	504	*SL, MB, SBP*	74 53,926	27 35,579	14:32	74 55,277	27 51,483	15:40
	CAGE 16-2	HH	505	*SL, MB, SBP*	74 55,747	27 51,847	15:59	74 54,249	27 34,970	17:04
	CAGE 16-2	HH	506	*SL, MB, SBP*	74 53,892	27 35,566	17:22	74 55,242	27 51,514	18:42
	CAGE 16-2	HH	507	*SL, MB, SBP*	74 55,639	27 50,829	19:04	74 54,251	27 34,700	20:05
	CAGE 16-2	HH	508	*SL, MB, SBP*	74 53,888	27 31,284	20:26	74 55,195	27 51,446	21:53
	CAGE 16-2	HH	509	*SL, MB, SBP*	74 53,835	27 57,337	22:32	74 52,244	27 35,000	23:52
18/4	CAGE 16-2	HH	510	*SL, MB, SBP*	74 50,281	27 42,889	00:47	74 53,454	27 42,660	01:39
	CAGE 16-2	HH	511	*SL, MB, SBP*	74 54,027	27 44,479	02:09	74 51,488	27 58,857	03:29
	CAGE 16-2	HH	512	*SL, MB, SBP*	74 53,022	27 52,516	04:16	74 47,717	27 46,030	05:23
20/4	CAGE 16-2	HH	538	*SL, MB*	75 2,602	27 32,294	08:40	74 59,444	27 37,305	09:30
	CAGE 16-2	HH	539	*SL, MB, SBP*	75 0,034	27 41,964	10:02	74 59,872	27 31,774	10:43
	CAGE 16-2	HH	540	*SL, MB, SBP*	75 58,708	27 32,665	11:11	74 58,716	27 44,765	11:59

Legend	
SL	Seismic line
SBP	Sub Bottom Profile
MB	Multibeam
ECO	Echosounder
CTD	
ADCP	
MN	Multinett

5.4 2D Seismic log

5.4.1 Seismic log, Maud basin

Start shot number	Start Lat degree	Start Lat decmin	Start Long degree	Start Long decmin	End (UTC)	End Shot Number	End Lat degree	End Lat decmin	End Long degree	End Long decmin	Shot rate	Ship speed [kn]	Comments			Start Lat decdeg	Start Long decdeg	End Lat decdeg	End Long decdeg
1						58					3s	3	TEST SHOTS FOR 2D (mostly manual trigger shots). Streamer is on port side of the ship			0	0	0	0
59	73	8.643	24	21.038	04:24:00	1498	73	11.839	24	15.390	3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			73.14405	24.35063	73.19731	24.2565
1540	73	10.980	24	14.016	06:25:14	2990	73	12.135	24	26.314	3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT,Wind 15 m/s			73.183	24.2336	73.20225	24.43857
2991	73	11.398	24	26.450	07:08:00	3331	73	12.227	24	23.558	3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT			73.18997	24.44083	73.20378	24.39263
3332	73	12.145	24	22.512	07:39:00	3757	73	10.791	24	23.940	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT			73.20242	24.3752	73.17985	24.399
3758	73	9.290	24	19.822	09:01:00	4646	73	11.850	24	15.329	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT			73.15483	24.33037	73.1975	24.25548
4647	73	12.205	24	14.968	10:12:00	5638	73	9.222	24	20.030	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT			73.20342	24.24947	73.1537	24.33383
5639	73	9.241	24	20.106	11:12:00	6549	73	12.244	24	14.995	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT			73.15402	24.3351	73.20407	24.24992
6550	73	12.175	24	14.763	12:19:00	7516	73	8.744	24	20.2646	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT			73.202917	24.24605	73.145733	

5.4.2 Seismic log, Crater area

Line name	Date	Location	Start (UTC)	Start shot number	Start Lat degree	Start Lat decmin	Start Long degree	Start Long decmin	End (UTC)	End Shot Number	End Lat degree	End Lat decmin	End Long degree	End Long decmin	Shot rate	Ship speed [kn]	Comments			Start Lat decdeg	Start Long decdeg	End Lat decdeg	End Long decdeg
CAGE16-2-000	17.4.	crater_area	03:05:00	1						336					3s	4	TEST SHOTS FOR 2D (mostly manual trigger shots). Streamer is on port side of the ship			0	0	0	0
CAGE16-2-0497	17.4.	crater_area	04:31:00	337	74	55.584	27	52.750	05:56:00	1734	74	54.084	27	35.103	3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.9264	27.87917	74.9014	27.58505
CAGE16-2-0498	17.4.	crater_area	06:05:00	1735	74	54.012	27	35.146	07:22:00	3278	74	55.417	27	51.419	3s	3,5	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.9002	27.58577	74.92361667	27.85698
CAGE16-2-0499	17.4.	crater_area	07:49:00	3279	74	55.529	27	51.642	08:51:00	4502	74	54.137	27	35.995	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.92548	27.8607	74.90228333	27.59992
CAGE16-2-0500	17.4.	crater_area	09:06:00	4503	74	54.040	27	35.816	10:12:07	5807	74.00	55.394	27	51.834	3s	4.4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.90067	27.59693	74.92323333	27.8639
CAGE16-2-0501	17.4.	crater_area	10:31:00	5808	74	55.482	27	50.640	11:34:03	7069	74	54.154	27	34.675	3s	4,2	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 14 m/s			#VALUE!	27.844	74.90256667	27.57792
CAGE16-2-0502	17.4.	crater_area	11:48:49	7070	74	53.980	27	35.889	12:52:00	8372	74	55.334	27	51.597	3s	4,2	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 15 m/s			74.89967	27.59815	74.92223333	27.85995
CAGE16-2-0503	17.4.	crater_area	13:13:00	8373	74	55.589	27	51.435	14:17:40	9685	74	54.220	27	35.064	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.92648	27.85725	74.90366667	27.5844
CAGE16-2-0504	17.4.	crater_area	14:32:00	9686	74	53.926	27	35.579	15:40:00	11058	74	55.277	27	51.483	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.898767	27.592983	74.92128333	27.85805
CAGE16-2-0505	17.4.	crater_area	15:59:00	11059	74	55.747	27	51.847	17:04:00	12357	74	54.249	27	34.970	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 17 m/s			74.92912	27.86412	74.90415	27.58283
CAGE16-2-0506	17.4.	crater_area	17:22:00	12358	74	53.892	27	35.566	18:42:00	13947	74	55.242	27	51.514	3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 17 m/s			74.8982	27.59277	74.9207	27.85857
CAGE16-2-0507	17.4.	crater_area	19:04:00	13948	74	55.639	27	50.829	20:05:54	15177	74	54.251	27	34.700	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.92732	27.84715	74.90418333	27.57833
CAGE16-2-0508	17.4.	crater_area	20:26:37	15178	74	53.888	27	31.284	21:53:10	16907	74	55.195	27	51.446	3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.89813	27.5214	74.91991667	27.85743
CAGE16-2-0509	17.4.	crater_area	22:32:12	16908	74	53.835	27	57.337	23:52:18	18508	74	52.244	27	35.000	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s; sismic line skipped from ships log			74.89725	27.95562	74.87073333	27.58333
CAGE16-2-0510	18.4.	crater_area	00:47:00	18509	74	50.281	27	42.889	01:39:42	19565	74	53.454	27	42.660	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s; sismic line skipped from ships log			74.83802	27.71482	74.8909	27.711
CAGE16-2-0511	18.04.2016	crater_area	02:09:40	19566	74	54.027	27	44.479	03:29:09	21165	74	51.488	27	58.857	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s; seismic line skipped from ships log			74.90045	27.74132	74.85813333	27.98095
CAGE16-2-0512	18.04.2016	crater_area	04:16:56	21166	74	53.022	27	52.516	05:23:58	22505	74	47.717	27	46.030	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s;			74.8837	27.87527	74.79528333	27.76717
CAGE16-2-0538	20.04.2016	crater_area	08:40:00	22567	75	2.601	27	32.294	09:30:00	23575	74	59.444	27	37.305	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 12 m/s;			75.04335	27.53823	74.99073333	27.62175
CAGE16-2-0539	20.04.2016	crater_area	10:02:00	23576	75	0.034	27	41.964	10:43:00	24388	74	59.872	27	31.774	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s;			75.00057	27.6994	74.99786667	27.52957
CAGE16-2-0540	20.04.2016	crater_area	11:11:00	24389	75	58.708	27	32.665	11:59:00	25352	74	58.716	27	44.765	3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 12 m/s;			75.97847	27.54442	74.9786	27.74608

5.4 Seismic log, Crater area

Line name	Date	Location	Start (UTC)	Start shot number	Start Lat degree	Start Lat decmin	Start Long degree	Start Long decmin	End (UTC)	End Shot Number	End Lat degree	End Lat decmin	End Long degree	End Long decmin
CAGE16-2-000	17.4.	crater_area	03:05:00	1						336				
CAGE16-2-0497	17.4.	crater_area	04:31:00	337	74	55.584	27	52.750	05:56:00	1734	74	54.084	27	35.103
CAGE16-2-0498	17.4.	crater_area	06:05:00	1735	74	54.012	27	35.146	07:22:00	3278	74	55.417	27	51.419
CAGE16-2-0499	17.4.	crater_area	07:49:00	3279	74	55.529	27	51.642	08:51:00	4502	74	54.137	27	35.995
CAGE16-2-0500	17.4.	crater_area	09:06:00	4503	74	54.040	27	35.816	10:12:07	5807	74.00	55.394	27	51.834
CAGE16-2-0501	17.4.	crater_area	10:31:00	5808	74	55.482	27	50.640	11:34:03	7069	74	54.154	27	34.675
CAGE16-2-0502	17.4.	crater_area	11:48:49	7070	74	53.980	27	35.889	12:52:00	8372	74	55.334	27	51.597
CAGE16-2-0503	17.4.	crater_area	13:13:00	8373	74	55.589	27	51.435	14:17:40	9685	74	54.220	27	35.064
CAGE16-2-0504	17.4.	crater_area	14:32:00	9686	74	53.926	27	35.579	15:40:00	11058	74	55.277	27	51.483
CAGE16-2-0505	17.4.	crater_area	15:59:00	11059	74	55.747	27	51.847	17:04:00	12357	74	54.249	27	34.970
CAGE16-2-0506	17.4.	crater_area	17:22:00	12358	74	53.892	27	35.566	18:42:00	13947	74	55.242	27	51.514
CAGE16-2-0507	17.4.	crater_area	19:04:00	13948	74	55.639	27	50.829	20:05:54	15177	74	54.251	27	34.700
CAGE16-2-0508	17.4.	crater_area	20:26:37	15178	74	53.888	27	31.284	21:53:10	16907	74	55.195	27	51.446
CAGE16-2-0509	17.4.	crater_area	22:32:12	16908	74	53.835	27	57.337	23:52:18	18508	74	52.244	27	35.000
CAGE16-2-0510	18.4.	crater_area	00:47:00	18509	74	50.281	27	42.889	01:39:42	19565	74	53.454	27	42.660
CAGE16-2-0511	18.04.2016	crater_area	02:09:40	19566	74	54.027	27	44.479	03:29:09	21165	74	51.488	27	58.857
CAGE16-2-0512	18.04.2016	crater_area	04:16:56	21166	74	53.022	27	52.516	05:23:58	22505	74	47.717	27	46.030
CAGE16-2-0538	20.04.2016	crater_area	08:40:00	22567	75	2.601	27	32.294	09:30:00	23575	74	59.444	27	37.305
CAGE16-2-0539	20.04.2016	crater_area	10:02:00	23576	75	0.034	27	41.964	10:43:00	24388	74	59.872	27	31.774
CAGE16-2-0540	20.04.2016	crater_area	11:11:00	24389	75	58.708	27	32.665	11:59:00	25352	74	58.716	27	44.765

Shot rate	Ship speed [kn]	Comments			Start Lat decdeg	Start Long decdeg	End Lat decdeg	End Long decdeg
3s	4	TEST SHOTS FOR 2D (mostly manual trigger shots). Streamer is on port side of the ship			0	0	0	0
3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.9264	27.87917	74.9014	27.58505
3s	3,5	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.9002	27.58577	74.92361667	27.85698
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.92548	27.8607	74.90228333	27.59992
3s	4.4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s			74.90067	27.59693	74.92323333	27.8639
3s	4,2	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 14 m/s			#VALUE!	27.844	74.90256667	27.57792
3s	4,2	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 15 m/s			74.89967	27.59815	74.92223333	27.85995
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.92648	27.85725	74.90366667	27.5844
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.898767	27.592983	74.92128333	27.85805
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 17 m/s			74.92912	27.86412	74.90415	27.58283
3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 17 m/s			74.8982	27.59277	74.9207	27.85857
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.92732	27.84715	74.90418333	27.57833
3s	3	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s			74.89813	27.5214	74.91991667	27.85743
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s; sismic line skipped from ships log			74.89725	27.95562	74.87073333	27.58333
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s; sismic line skipped from ships log			74.83802	27.71482	74.8909	27.711
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s; seismic line skipped from ships log			74.90045	27.74132	74.85813333	27.98095
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 16 m/s;			74.8837	27.87527	74.79528333	27.76717
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 12 m/s;			75.04335	27.53823	74.99073333	27.62175
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 13 m/s;			75.00057	27.6994	74.99786667	27.52957
3s	4	Shooting interval 3 s, recording length 1.5 s, sampling rate 0.25 ms, gun volume 30/30 in3, pressure 180 bar Preamp gain 8dB. Gun 33 meters behind AFT, Wind 12 m/s;			75.97847	27.54442	74.9786	27.74608