Cruise Report

BGR13-2

Project: PANORAMA-1

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

Geophysics, Geomicrobiology

RV OGS EXPLORA

16 August – 17 September 2013

Tromsø – Longyearbyen

BUNDESANSTALT FÜR GEOWISSENSCHAFTEN UND ROHSTOFFE (BGR), HANNOVER
FEDERAL INSTITUTE FOR GEOSCIENCES AND NATURAL RESOURCES

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Fahrtbericht
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16 August – 17 September 2013
Tromsø – Longyearbyen

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SUMMARY

Volkmar Damm

The research cruise PANORAMA-1 onboard the Italian vessel OGS Explora was carried out within 2 legs in the period August, 16th – September 17th. The designated survey area was located in a sector of the European Arctic north of Svalbard covering an area north of 80°N between 15°E and 35°E.

Main objectives were to acquire new geophysical data and extract near surface sediment samples in an underexplored area of the European Arctic with special focus on the transition zone from the North Barents shelf towards the oceanic Nansen basin.

During leg 1 of the cruise a 20 days geophysical survey 1056 km of multi-channel seismic data was acquired supplemented by a 221 km long sonobuoy profile. Additionally, magnetic and sediment echosounding data was acquired along these profiles. During all operations within the survey area gravity and multibeam echosounding data was continuously acquired.

After a 1 day stopover in Longyearbyen in order to exchange part of the scientific crew OGS Explora returned to the survey area to continue survey operations during leg 2. Within these 10 days period near surface sediments were extracted by means of a gravity corer at 12 locations and heat flow soundings were conducted at 7 locations. Gravity, sediment and multibeam echosounding data was continuously acquired along all transit lines within the survey area during leg 2. Total line length of magnetic data was 2658.7 km. Over all track lines with bathymetric and gravity data amount to 5665.8 km in total.

ZUSAMMENFASSUNG

Die Forschungsfahrt PANORAMA-1 wurde in 2 Fahrtabschnitten im Zeitraum 16. August bis 17. September durchgeführt. Als Forschungsplattform stand das italienische Forschungsschiff OGS Explora zur Verfügung. Vorgesehenes Arbeitsgebiet war der Europäische Sektor der Arktis nördlich von Svalbard in einem Sektor nördlich von 80°N zwischen 15°E und 35°E.

Ziel der Messfahrt war die Erhebung neuer geophysikalischer Daten und die Entnahme oberflächennaher Sedimentproben in einem bislang wenig untersuchten Gebiet mit Schwerpunkt auf den Übergangsbereich vom Nordbarents-Schelf in das Nansen-Becken im Arktischen Ozean.

Während des 20-tägigen ersten Fahrtabschnittes wurden geophysikalische Profilarbeiten durchgeführt. Dabei wurden insgesamt 1056 km mehrkanalseismische Daten und 221 km weitwinkelseismische Daten aufgezeichnet. Zusätzlich wurden entlang dieser Profillinien magnetische und Sedimentecholot-Daten erhoben. Während des gesamten Aufenthalts im Arbeitsgebiet wurden zusätzlich kontinuierlich Schweredaten und bathymetrische Daten mit Multibeam-Echolot registriert.

Nach einem eintägigen Aufenthalt in Longyearbyen zum Austausch eines Teils der wissenschaftlichen Besatzung kehrte OGS Explora ins Arbeitsgebiet zurück. Im Verlauf dieses 10-tägigen zweiten Fahrtabschnittes wurden oberflächennahe Sedimente mittels Schwerelot an insgesamt 12 Lokationen beprobt und an weiteren 7 Lokationen Wärmestrommessungen vorgenommen. Gravimetrische Daten, Sedimentecholot- und bathymetrische Daten wurden auch während dieses Fahrtabschnitts kontinuierlich aufgezeichnet. Die Gesamtlänge magnetischer Messprofile der gesamten Messfahrt beträgt 2658.7 km. Bathymetrische und gravimetrische Daten wurden auf insgesamt 5665.8 km erhoben.

1. SCIENTIFIC PROGRAMME

Volkmar Damm

The European sector of the Arctic Ocean is one of the main frontier areas for hydrocarbon exploration. Currently, more than 70% of the natural gas annually consumed in Germany is imported from coastal states of the Arctic Ocean. Because of its vicinity to the European mainland the region is expected to play an important role for Germany's future energy supply.

Over the last decades BGR conducted several onshore and offshore research projects in the Arctic to study the structural inventory and plate tectonic evolution of the circum-Arctic fold belts and evolution of theNorth Atlantic and West Greenland margins (Fig. 1 right).

Results of these investigations and new survey data will be used in combination with new data compilations and recently published data on the area to subsequently estimate the resource potential of this frontier area. Within the framework program PANORAMA (Potentialanalyse des Europäischen Nordmeeres und angrenzender Randmeere der Arktis – Petroleum Assesment of the Arctic North Atlantic and adjacent marine areas) BGR strives in a first step to complete the basic information required for a reliable assessment of the hydrocarbon potential (oil and gas deposits) of the European sector of the Arctic. Within the period 2013 – 2018 several research cruises are planned to complete the geoscientific database of the region. Special focus will be given to the Northeast Greenland margin, the East Greenland margin including Jan Mayen, the North Barents margin with the transition into the Eurasian Basin and the West Barents Sea (Fig. 1).

Further, with microbiological investigations we want to study the microbial formation and degradation of hydrocarbons in Arctic sediments by widely unknown microbial communities. Results of these investigations will help to quantify the microbial degradation processes in the Arctic and to estimate consequences of potential leackages and the environmental impact which could arise from the economic development and hydrocarbon production in the Arctic.

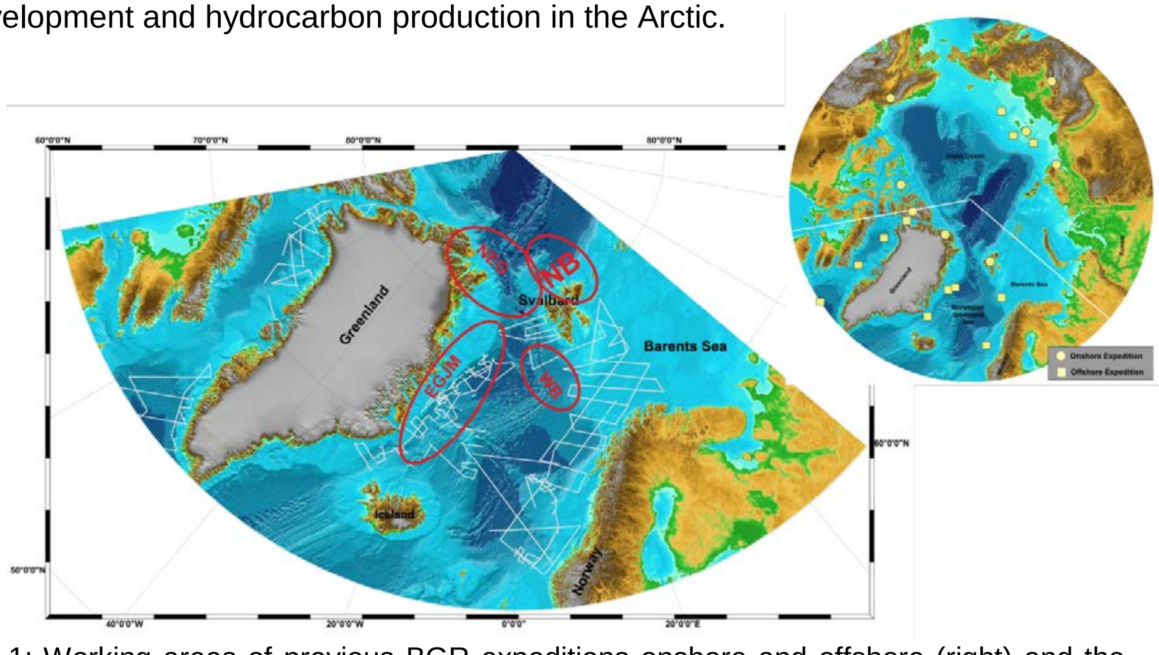


Fig. 1: Working areas of previous BGR expeditions onshore and offshore (right) and the individual working areas within the framework program PANORAMA (left) with track lines of multichannel seismic profiles acquired during previous expeditions (white lines).

1.1. Geological and tectonic framework

The continental margin north of Svalbard is the northernmost extension of the Eurasian plate and forms the transition into the Eurasian Basin (Fig. 2). It is a structurally complex basin province with unequal facies evolution in the eastern and western part formed in response to Late Mesozoic and Cenozoic break-up of the Pangea supercontinent and subsequent seafloor spreading (Vogt et al., 1979). The platform areas northeast of Svalbard are underlain by Palaeozoic sequences. Cenozoic basin development has been accompanied by uplift of Svalbard (Grogan et al., 1999). The eastern part of the continental margin forms the transition into the oceanic Nansen Basin of the Eurasia Basin. This deep basin is more than 300 km wide and extends for 1700 km with up to 4000m water depth. In its deepest parts the sediment thickness is between 1500 – 2000 m (Weigelt, 1998) with 4500 m at maximum close to the Svalbard margin (Jokat and Micksch, 2004).

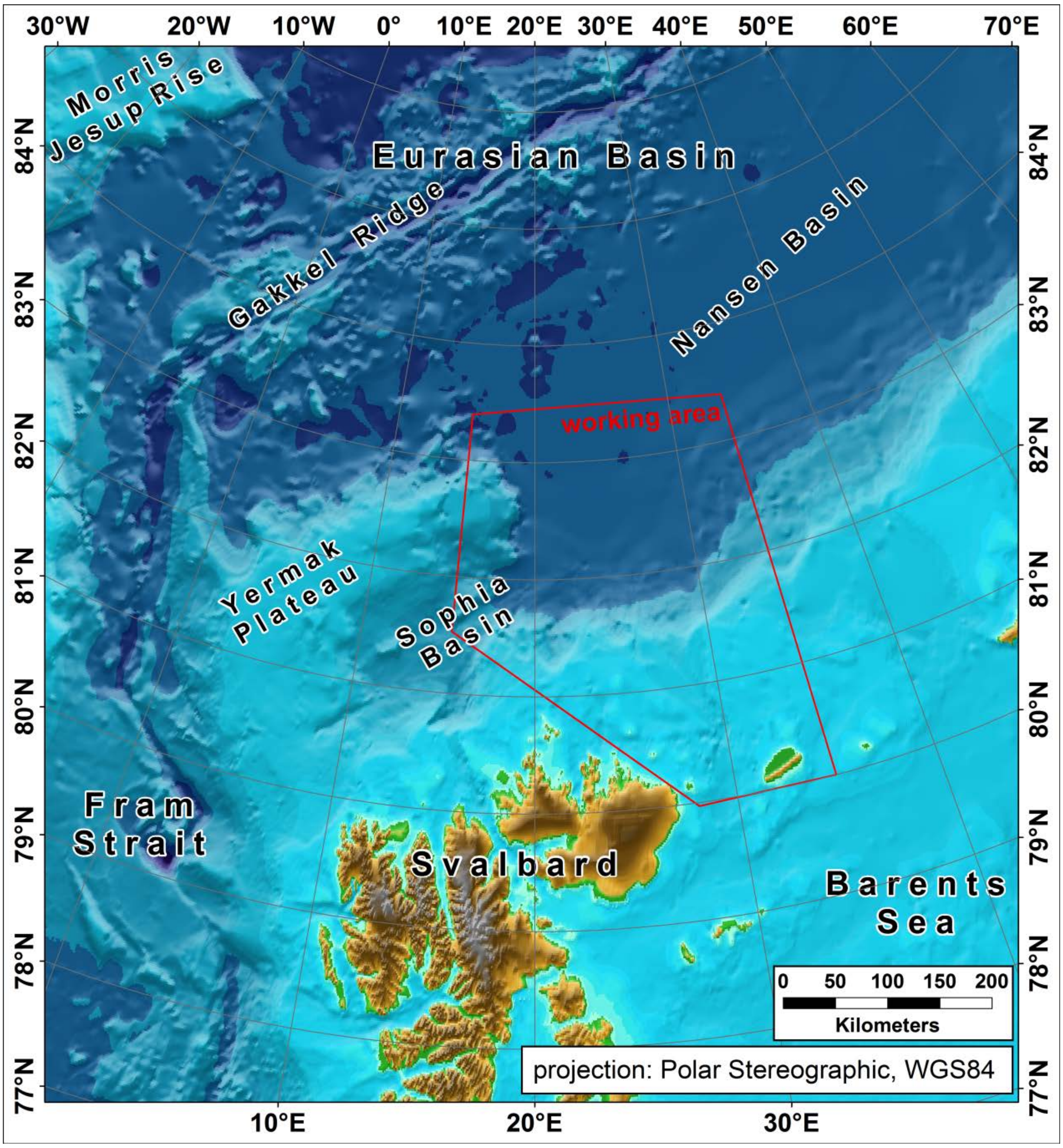


Fig. 2: Regional overview of the working area.

The western part of the north Barents margin, which is bordered by the Fram Strait to the west, experienced obviously a different structural evolution. It comprises sub-basins and shows partly deep basins with thick sediment infill (Geissler et al., 2011). To the north the continental margin is built up by the Yermak Plateau, a prominent bathymetric feature northwest of Svalbard with its conjugate expression in the Morris Jesup Rise at the Greenland side. The crustal nature of the Yermak Plateau is not well constrained (Jackson et al., 1984; Jokat et al., 2008). It was probably formed as a result of continental rifting influenced by extension-related magmatism during Palaeocene to Eocene times (Vogt et al., 1979). Riefstahl et al. (2013) analysed dredge samples from the Yermak Plateau and concluded that parts of the Yermak Plateau are composed of stretched continental crust strongly affected by alkaline magmatism.

The Sophia Basin, a deep basin between Svalbard and the Yermak Plateau, is also interpreted to be a result of these extension-related processes north of Svalbard (Riefstahl et al., 2013).

Based on spreading anomalies the opening of the Nansen Basin along the ultra-slow Gakkel Ridge and the Eurasian continental margin is suggested to have started at 56 Ma (anomaly 24) (Vogt et al., 1979) with an probably early rift evolution since the Mesozoic (Jokat et al., 1995). The established magnetic anomalies in the Eurasia Basin were recently updated with anomaly 2a (3.5 Ma) through anomaly 25 of Late Paleocene (58 Ma) age (Brozena et al., 2003; Glebovsky et al., 2006).

Although, only few data are available Grogan et al. (1999) and Riis et al. (2008) postulate a petroleum potential for the inner shelf and the continental margin north of Svalbard. Potential hydrocarbon source rocks are identified at many stratigraphic levels onshore Svalbard, in shallow boreholes in the platform areas (Alsgaard, 1993; Mørk and Bjorøy, 1984). Oil shows have been reported for Triassic rocks in the northern Barents Sea and on Svalbard. Devonian and Early Carboniferous shales are interpreted to have generated large volumes of hydrocarbons in the Russian Barents (Johansen et al., 1993).

Mesozoic source rocks are of greater relevance for the continental margin province north of Svalbard. For the platform area Palaeozoic source rocks are of local occurrence. Riis et al. (2008) reconstructed the Triassic shelf evolution of the northern Barents Sea region based on new seismic data and deduced a sediment infill mainly from the southwest for the platform area. Due to low subsidence these Mesozoic sediments experienced mostly only limited burial depth (Grogan et al., 1999).

1.2. Previous surveys and existing data

So far, the northern Barents Sea is not a licensed area. Over the last decade the Norwegian Petroleum Directorate (NPD) carried out a number of seismic data acquisition campaigns in the area in order to aid their assessment for hydrocarbon resources, however this data is still un- released. Moreover, owing to the harsh ice conditions in the past and before the beginning of rapid threat of Arctic sea ice the region was only limited accessible for seismic measurements. Therefore only sparse data exist from this time (Kristoffersen et al., 1985). Beginning in the 1990s, several geophysical cruises were conducted by AWI Bremerhaven using RV Polarstern. Eiken (1993, 1994), Ritzmann et al. (2004), Ritzmann and Jokat (2003), Geissler and Jokat (2004), Czuba et al. (2005), Engen et al. (2008), Jokat et al. (2008), Ehlers and Jokat (2009) and Geissler et al. (2011) published seismic data from different parts of the Yermak Plateau and the northern Svalbard continental margin. Most data cover the western part of the continental margin north of Svalbard.

Only few data was acquired in the eastern part of the margin close to the Russian border north of Kvitoya Island in the transition zone from the platform to the Nansen basin.

Due to the prevailing bad ice conditions in the past the majority of the multichannel seismic data was acquired with short streamers of 600 m active length, which often results in reduced quality of the seismic data. Fig. 3 shows the locations of seismic profiles which were acquired during several expeditions in the past mainly by AWI and NPD.

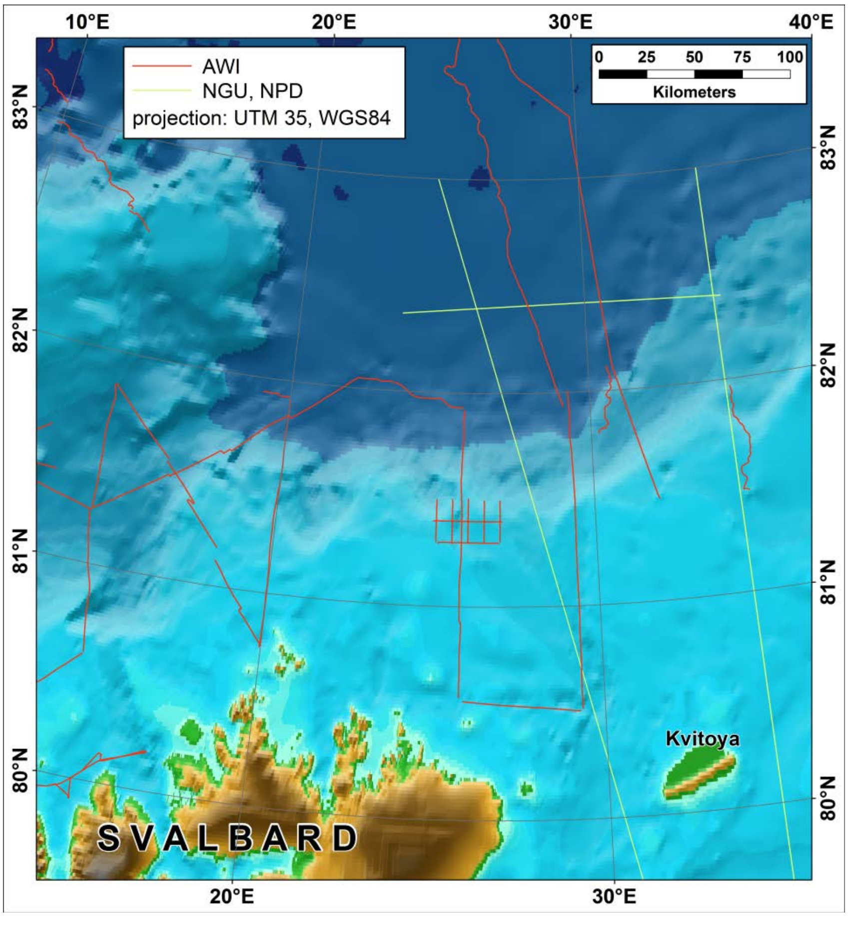


Fig. 3: Overview of pre-existing seismic profiles in the survey area.

1.3. Objectives and work at sea

The main target area of the research cruise was situated in the northeast of the Svalbard Archipel. The preliminary survey layout of the multichannel seismic lines as per schedule is given by the red lines in Fig. 4, however, the final layout was subject of the sea ice conditions. As stated in the notification of proposed research to the Norwegian authorities, no line was planned to be located closer than 12 nautical miles to the shore base line.

Coordinates of outer limits of the survey area according to the granted Norwegian research license (Fig. 4):

79.97035°N	28.07896°E
81.52752°N	15.17611°E
83.39315°N	15.38986°E
83.39315°N	33.95°E
80°N	34.95°E

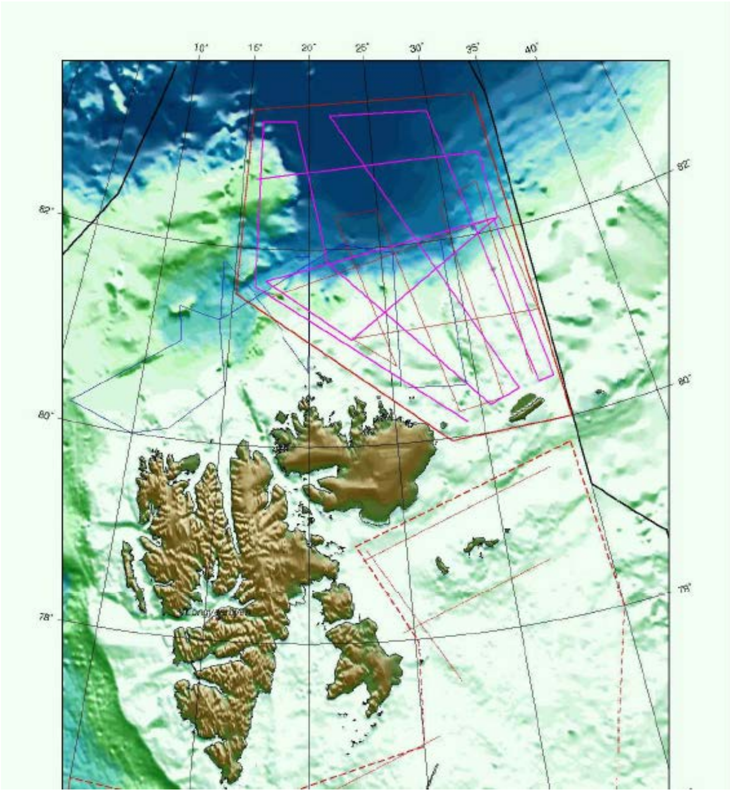


Fig. 4: Map of planned survey lines.

The overall objectives of the cruise in this part of the underexplored high Arctic were to gain information about the structure of the Earth's crust down to the crystalline basement along the continental margin northeast of Svalbard towards the Eurasian Basin and to contribute to better understand the opening of the Eurasian Basin and the plate tectonic situation for the entire Arctic.

The structural data were addressed to be used for reconstructing the geological evolution of the north Barents Sea margin, to identify sedimentary sequences for deducing margin stratigraphy, to localize rift related sedimentary basins and subsequently evaluate their hydrocarbon potential. Microbiological and geochemical investigations using cored sediment samples were planned to be conducted to analyze the degradation potential of microbial communities in sediments of the high Arctic. These results will be brought into context with Arctic biodiversity studies and risk assessment of hydrocarbon production in the area.

The following geophysical and geological methods were employed:

- Multichannel seismics
  - up to 3900m active digital streamer cable towed behind the research vessel, total length including lead-in cable and tail buoy approx. 4200 m.
  - up to 32 litres airgun volume separated to two arrays towed behind the vessel
  - up to 20 sonobuoys for wide angle registration
- Gravity
  - Gravimeter
- Magnetics
  - Magnetic gradiometer with two magnetometry probes towed behind the research vessel
- Bathymetry
  - deep water and shallow water multi-beam
  - sub bottom profiler
- Heatflow
  - 3 m heat flow probe to acquire data on thermal properties and heat flow of the sediments
- Coring
  - Gravity corer (up to 5 m)

Considering the high latitude of the survey area, the final survey layout was subject to the prevailing ice conditions. It was not planned to survey within moderate or even dense sea ice conditions in order to prevent any risks to the crew, the environment and the equipment.

1.4. Survey platform

We used the Italian vessel OGS Explora for survey operations. This multi-purpose research vessel is owned by the Italian Istituto Nazionale di Oceanografia e di Geofisica Spermintale (OGS) Trieste and operated by Argo Srl – Ship Management & Services, Pozzuoli (Napoli) and DIAMAR S.r.l. Napoli.

The vessel was successfully used by BGR during several geophysical expeditions in the past between 1976 and 1988. The ship is well maintained and equipped with state of the art technique to conduct geophysical and geological research cruises.

The vessel’s specifications are as following:

Tab. 1: R/V OGS EXPLORA specifications

The Vessel	
Built by	Elsflether Werft A.G., Germany, 1973
Owner	OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale)
Flag	Italy
Classification	Scientific or technological research RINA 100-A-1.1 IAQ-1; Ice Class B
LOA	65.42 m
Beam / Draft	11.8 m / 6.55 m
Gross tonnage	1408 T
Workboat	Zodiac Ribo 600 (6m, 70 Hp)
Endurance	50 days
Propulsion	2 x 1294.5 Kw (1780 Hp)
Cruising speed	13 Knots
Accomodation	12 technician 17 crew 1 doctor

Maritime Navigation & Communication	
VHF	2 VHF SKANTI 1000 DSC (GMDSS A4)
Immarsat	- Inmarsat C SKANTI Scansat (GMDSS A4) - Immarsat B-M NERA SATURN - Immarsat Fleet77 Thrane
Radars+ARPA	FR2117 FURUNO + AIS TM 340AM SPERRY X band Bridgemaster DECCA
Gyro Compass	3 Gyro Star II Anshutz
Autopilot	1 Naviplot AP50 FURUNO
Echo sounder	1 EA600 Simrad
Log	1 Dopplerlog EML500 Yokogawa
GPS	1 GPS Acquarius 1 GPS GB500 TOPCON 1 LANDASTAR Veripos 1 RS500 SHIPMATE (maritime only)
Magnetic Comp.	Navipol II Plath
Network	Ethernet
Network speed	100 Mb / sec

Safety	
MOB	Rescue boat PESBO BSC (40 m)
Lifeboat	Rescue boat PESBO BSC (42 people)
Life Rafts	5 x 25, 1 x 20, 1 x 6 (156 people)
Survival suits	48
Fire Fighting	- Hydrants, hoses and nozzles (3 fire pumps + 1 emergency fire pump) - 58 portable fire extinguishers (6 kg – 9 lt – 5 kg) -5 fire estiguisher 50 kg
Engine Room	CO_2
Compressor Room	Estinguisher + fixed fire CO_2

2. CRUISE NARRATIVE

15th August 2013 Thursday

00:00 Port of Tromsoe 69.675158° N – 018.981862°E
06:00 Project configuration and equipment testing
09:00 Embarkation of scientific crew
15:00 Pilot on board
15:30 Unberthed from Tromsoe Harbour, start transit to survey area

16th August 2013 Friday

00:00 In transit, position 70.853333° N, 021.20° E, hdg 12

17th August 2013 Saturday

00:00 In transit, position 75.101333°N, 026.213333°E, hdg 21
08 :38 MBES 8111 start acquisition 76.678648°N 028.666723°E, hdg 25
09:10 Speed decreased to 4.5 knots to start OGS magnetometer deployment
09:15 Start OGS magnetometer test
11:02 End OGS magnetometer test , start recovering on board
11:28 OGS magnetometer on board
12:20 Start BGR magnetometer deployment
12:25 Start BGR magnetometer test
12:58 End of BGR magnetometer test , start recovering on board
13:18 BGR magnetometer on board , speed increased to 10.8 knots

18th August 2013 Sunday

00:00 Position 78.888333°N, 032.65°E, hdg 21
07:31 One engine switched off, speed reduced to perform SVP probe
07:48 **SVP** in water
08:01 **SVP on bottom,** Lat 80.199407°N, Lon 034.801886°E, wd 235m
08:09 **SVP** on board
08.17 Start preparing deployment seismic equipment
08:24 SVP 20130818_080100 applied
08:35 Start streamer deployment
10:56 Streamer deployed
11:00 Start magnetometer deployment
11:07 Start MMO observation
12:03 Magnetometer deployed
12:08 Start port and stbd guns deployment
12:28 End of MMO observation
12:32 Port and stbd guns deployed
12:38 Start of Ramp-up
13:00 End of Ramp-up
13 :03 **SOL BGR13-201** Lat 80.476021°N Lon 034.492508°E hdg 348.5
Start MBES 8111 acquisition PDS2000 line: BGR13-101.0-20130818-130301

19th August 2013 Monday

00:00 Position 81.2234°N, 034.1479°E, hdg 348.5, in acquisition **BGR13-201**
02:30 Rough sea at stern affects MBES data quality
06:35 MB 8150 switched on
06:55 MB8111 switched off
07:10 switched bathymetry acquisition from DTM PANORAMA-1_15m [cell-size 15x15] to DTM PANORAMA-1_80m [cell-size 80x80]
09:07 End of seismic acquisition for bad meteo conditions. Last FIX 5865 Start recovering port g-guns
09:24 Port G-guns onboard, start recovering stbd G-guns
09:33 Stbd G-guns recovered, start recovering streamer, start recovering magnetometer
09:51 end of MB8150 acquisition
11:09 Magnetometer on board
12:54 Streamer recovered on board
12:55 Heading North to check the ice edge's position and conditions, Multibeam still logging.
15:46 Start CHIRP logging file BGR13_2Transit03
21:50 First ice at Lat 82.8117°N Lon 032.6855°E

20 th August 2013 Tuesday

00:30 Position: 82.8336°N 033.2255°E hdg 333.2, MB 8150 and SBP acquisition
10:25 **SVP** deploying on WP SVP20130820_102500
11:08 **SVP on bottom** Lat 82.8107°N Lon 32.7838°E wd 3476 m
11:55 **SVP** on board
12:05 Start deploying Stbd Guns, followed by Port Guns
12:30 Guns in the water
12:36 Soft start begins
12:58 Soft start end, keep shooting every 120 seconds
13:41 **SOL BGR13-2R1** fix 1
13:58 **Sonobuoy 1** in water WD 3394 Shot number 34
Lat 82° 43.9904'N Long 033° 21.7186'E
15:23 **Sonobuoy 2** in water WD 3287 Shot number 204
Lat 82° 39.3871'N Long 033° 24.6687'E
16:56 **Sonobuoy 3** in water WD 3173 Shot number 390
Lat 82° 34.1542'N Long 033° 27.9218'E
18:27 **Sonobuoy 4** in water WD 3058 Shot number 572
Lat 82° 28.7629'N Long 033° 31.1623'E
20:06 **Sonobuoy 5** in water WD 2896 Shot number 770
Lat 82° 22.7220'N Long 033° 34.7488'E
21:34 **Sonobuoy 6** in water WD 2758 Shot number 947
Lat 82° 17.3176'N Long 033° 37.8949'E
22:53 **Sonobuoy 7** in water WD 2633 Shot number 1105
Lat 82° 12.6751'N Long 033° 40.5302'E

21th August 2013 Wednesday

00:10 Position: Lat 82.1393°N Long 033.7156°E hdg176 in acquisition **BGR13_2R1**
00:34 **Sonobuoy 8** in water WD 2499 Shot number 1304
Lat 82° 07.2727'N Long 033° 43.5110'E
02:11 **Sonobuoy 9** in water WD 2351 Shot number 1499
Lat 82° 01.8459'N Long 033° 46.4856'E

03:39 **Sonobuoy 10** in water WD 2183 Shot number 1676
Lat 81° 56.5496'N Long 033° 49.02860'E
05:07 **Sonobuoy 11** in water WD 1953 Shot number 1851
Lat 81° 50.9814'N Long 033° 52.2155'E
06:44 **Sonobuoy 12** in water WD 1730 Shot number 2045
Lat 81° 45.7326'N Long 033° 57.8747'E
08:19 **Sonobuoy 13** in water WD 802 Shot number 2235
Lat 81° 40.4230'N Long 033° 57.5090'E
08:28 MB 8111 switched on
08:32 switched bathymetry acquisition from DTM PANORAMA-1_80m[cell-size 80x80] to
DTM PANORAMA-1_15m [cell-size 15x15]
09:18 MB8150 switched off
10:04 **Sonobuoy 14** in water WD 250 Shot number 2446
Lat 81° 34.4867'N Long 034° 00.3475'E
11:25 **Sonobuoy 15** in water WD 198 Shot number 2609
Lat 81° 29.5378'N Long 034° 02.7349'E
13:01 **Sonobuoy 16** in water WD 178 Shot number 2801
Lat 81° 23.5414'N Long 034° 05.5167'E
14:07 **Sonobuoy 17** in water WD 181 Shot number 2934
Lat 81° 18.9908'N Long 034° 07.5988'E
15:30 **Sonobuoy 18** in water WD 176 Shot number 3097
Lat 81° 13.2997'N Long 034° 10.1590'E
16:52 **Sonobuoy 19** in water WD 248 Shot number 3262
Lat 81° 07.8111'N Long 034° 12.5440'E
18:08 **Sonobuoy 20** in water WD 211 Shot number 3415
Lat 81° 02.7499'N Long 034° 14.7802'E
22:28 **EOL BGR13-2R1** Fix 3910 WD 173m 80.795496°N 034.349745°E
22:30 Start recovering G guns
22:40 G guns recovered, start deploy magnetometer
23:29 Magnetometer deployed
23 :55 **SOL BGR13-2M1** WD 205 m Lat 80.6417°N Lon 34.3929°E hdg 169

22th August 2013 Thursday

00:00 Position: Lat 80.631180°N Lon 034.391118°E hdg 169 in acquisition
BGR13-2M1
00:10 several tests on magnetometer
01:00 **EOL BGR13-2M1** WD 131 m Lat 80.4639°N Lon 34.4722°E
01 :02 **SOL BGR13-2M2** WD 126 m Lat 80.4610°N Lon 34.4669°E hdg 348.5
08:10 MB8150 switched on
08:28 MB8111 switched off, changed DTM from Panorama-1 15m[shallow water]
to Panorama-1 80m [deep water]
09:27 **EOL BGR13-2M2** WD 1830 m Lat 81.7976 °N Lon 33.8397 °E hdg 348.5
09:30 start recovering Magnetometer
09:52 Magnetometer on the deck
10:30 Start streamer deployment and changing damaged sections
13:40 Streamer deployment finished
13:40 Start Mammal Observer mitigation observation
14:21 Ship on line
14:22 Increasing velocity to 5,5 knots, due to sinking streamer
14:29 Start Stbd G-gun deployment
14:25 Stbd G-gun in the water
14:30 Speed reduced to 4,5 knots
14:39 Magnetometer in the water

14:40 Start Port G-guns deployment
14:47 Port G-guns in the water
14:56 Ramp up start
15:19 Soft start finished
15:19 **SOL BGR13-202** Lat 81.744310°N Lon 033.923143°E hdg 349 First FIX is #2
19:46 Switch off compressor, no shot lost

23th August 2013 Friday

00:00 Position: Lat 82.3042°N Lon 033.6226°E in acquisition **BGR13-202** hdg 349
08:28 Position: Lat 82.8500°N Lon 033.2850°E in acquisition **BGR13-202**
14:48 **EOL BGR13-202** Lat 83.2641 °N Long 032.9964 °E Last FIX 6863
14:49 Loop start, guns keep on shooting every 90 seconds
14:50 Start Stbd guns recovery
14:58 Stbd Guns on board to check
15:25 Start Stbd guns deployment
15:35 Guns in the water
16:39 **SOL BGR13-203** Lat 83.2083°N Long 033.1459°E hdg 208 First FIX is number 1

24th August 2013 Saturday

00:10 Position: Lat 82.7825°N Lon 30.8240°E in acquisition **BGR13-203** hdg 208.4
01:30 **EOL BGR13-203** Lat 82.7060 °N Long 030.4628 °E Last FIX 2690
01:31 Start transit to next line BGR13-204
04:29 **SOL BGR13-204** Lat 82.7318 °N Lon 030.5626 °E hdg 176.6 Fist FIX is number 1
15:32 Clock sinchronization lost, PDS2000 frozen, lost 325m of data acquisition. Fix numbering continue without interruption.
23:06 Switched on MB 8111

25th August 2013 Sunday

00:13 Position: Lat 81.04065°N Lon 030.5338°E in acquisition **BGR13-204** hdg 176.6
00:20 switched bathymetry acquisition from DTM PANORAMA-1_80m[cell-size 80x80] to DTM PANORAMA-1_15m [cell-size 15x15]
11:45 Stop Gun n°4 Port. Air hose broken.
16:50 **EOL BGR13-204** Lat 80.2815 °N Long 030.5161 °E Last FIX 10952
16:52 Start time shooting every 90 seconds
16:53 Start Port G-guns recovery for manteinance
17:05 Guns on board
17:38 Start guns deployment
17:50 Guns back in the water
18:35 Speed increased to 5.5 because of shallow water (magnetometer)
18:40 Speed set to 4 knots
18:57 **SOL BGR13-205** Lat 80.3043 °N Lon 030.6046 °E hdg 300 Fist FIX is number 1
22:45 **EOL BGR13-205** Lat 80.4463°N Lon 029.3008°E Last Fix is number 1169
22:45 Stop acquisition Seismic line and magnetometer line for increasing bad weather conditions and start recovering stbdside G-guns.
23:01 Stbdside G-guns recovered, start recover portside G-guns
23:09 Portside G-guns recovered, magnetometer recovered, start recovering streamer

26th August 2013 Monday

00:20 Position: Lat 80.4234°N Lon 029.0483°E recovering streamer
01:20 Streamer recovered, stdby meteo, still acquiring MBES and SBP, steer to W/NW
20:32 Anchor dropped at Phippsøya Lat 80.6943°N Lon 020.7193°E for stdby meteo

27th August 2013 Tuesday

00:00 Position : Lat 80.6943°N Lon 020.7193°E anchor dropped at Phippsøya for stdby meteo

28th August 2013 Wednesday

00:00 Position : Lat 80.6943°N Lon 020.7193°E anchor dropped at Phippsøya for stdby meteo

29th August 2013 Thursday

00:00 Position : Lat 80.6943°N Lon 020.7193°E anchor dropped at Phippsøya for stdby meteo

30th August 2013 Friday

00:00 Position : Lat 80.6926°N Lon 020.7227°E anchor dropped at Phippsøya for stdby meteo
06:24 Weather conditions improved, leaving Phippsøya and transit to new SOL 81.2250°N 019.7666°E
09:51 Turned one engine off, start deploying streamer, start MBES and SBP acquisition on line BGR13-206
10:15 Start Mammal Observer mitigation observation
11:32 Deployment interrupted, software problems
13:21 MB8150 Switched on
13:24 Deployment restart
14:15 Ship turns to go to SOL
15:43 Streamer deployed
17:30 On the line, start Magnetometer deployment
17:46 Magnetometer in the water
17:50 Start magnetometer profile with PDS2000 file BGR13-106.0-20130830-175022
19:58 MB8111 switched off

31th August 2013 Saturday

00:00 Position: Lat 81.6398°N Lon 018.9266°E hgd349.68 in acqusition magnetometer line BGR13-2M3
03:53 Stop logging magnetometer Lat 81.9463°N Lat 018.2472°E wd 3290 and recovered onboard
04:25 Speed reduced to 2.5 knts to recover streamer onboard.
04:30 Start recovering streamer onboard
07:46 Streamer recovered and fixed the problem
08:13 Start deploying magnetometer
08.39 SOL UserLine(2).1 hdg 170 in transit to SOL **BGR13-206** speed 10 kts
10:51 EOL UserLine(2).1 Stop magnetometer logging, start turning
11:43 Start streamer deployment

12:15 Start Mammal Observer mitigation observation
13:14 Streamer in the water
13:15 Start Stbd G-Guns deployment
13:28 Guns in the water
13:29 Start Port G-Guns deployment
13:35 Guns in the water
13:40 Ramp up shooting start
14:02 **SOL BGR13-206** Lat 81.9257 °N Lon 018.2961 °E hdg 350 First FIX is number 1
15:26 Clock sync lost, PDS2000 stop triggering, lost 223m between shots 406 and 407
18:51 **EOL BGR13-206** Lat 82.2339°N Lon 017.5590°E Last Fix is number 1448.
Keep on shooting with only 4 guns every 90 seconds during the loop
20:54 **SOL BGR13-207** Lat 82.2095°N Lon 017.5572°E hdg 60 First Fix is number 1

01th September 2013 Sunday

00:08 Position: Lat82.3478°N Lon018.8268°E hdg 60 in acquisition **BGR13-207**
07:05 At Fix 3100 start turn 30° stbd for ice presence on route
07:16 At Fix 3164 on line BGR13-107.0-20130901-042938 stop magnetometer acquisition to avoid damages caused by ice, Mag recovering onboard
07:35 Mag recovered, carrying on acquiring with a stbd offset of 4450 m from the line
11:29 Start turning Stbd to next line, keep on shooting
11:39 **EOL BGR13-207** Lat 82.7781°N Lon 023.6996°E Last Fix is number 4508.
11:43 **SOL BGR13-208** Lat 82.7771°N Lon 023.7398°E hdg 131 First Fix is number 1
13:04 Magnetometer deployed
13:06 Magnetometer acquisition restart at fix 421 on file BGR13-108.0-20130901-113921

02th September 2013 Monday

00:00 Position: Lat 82.2360°N Lon 028.5920°E hdg 131 in acquisition **BGR13-208**
13:00 MBES 8111 switched on on file BGR13-108.0-20130902-112446
13:40 MBES 8150 switched off on file BGR13-108.0-20130902-132634
17:00 **EOL BGR13-208** Lat 81.4069°N Lon 034.1938°E Last Fix is number 8900.
17:01 Start time shooting every 90 seconds with only 4 guns
18:35 Start ramp up for 4 guns
18:59 **SOL BGR13-209** Lat 81.4224°N Lon 034.1292°E hdg 232 First Fix is number 1
19:11 **ABORTED LINE** Synchro problems, restart line
19:19 Restart line **BGR13-209** Lat 81.4001°N Lon 033.9913°E hdg 232
First Fix is number 1

03th September 2013 Tuesday

00:39 Position: Lat81.2203°N Lon 031.9727°E in acquisition on line **BGR13-209** hdg 232
04:36 Cross BGR13-204 line at Fix n° 2812
10:51 Shallow water, Magnetometer recovered close to the ship (about 200m).
14:43 **EOL BGR13-209** Lat 80.6664°N Lon 027.0235°E Last Fix is number 5891.
14:45 Start Port guns recovery
14:56 Port guns onboard
14:56 Start magnetometer recovery
14:57 Start Stbd guns recovery
15:08 Stbd guns onboard
15:17 Magnetometer onboard
15:22 Start streamer recovery

17:55 Streamer onboard
17:56 Transit to Longyearbyen acquiring MBES and CHIRP
22:29 Start loop calibration, recorded on PDS2000 file BGR13-109.0-20130903-222943, speed 3knts
22:50 End of calibration loop restart transit to Longyearbyen acquiring MBES and SBP.
23:59 End of acquisition in permits area.

04th September 2013 Wednesday

00:00 Position: Lat 81.0415°N Lon 20.0935°E hdg 243 transit to Longyearbyen
00:00 End of acquisition in permits area – **End of First Leg**.

05th September 2013 Thursday

00:00 Position: Lat 78.2333°N Lon 11.3667°E hdg 153 transit to Longyearbyen
05:52 Drop anchor in Longyearbyen Lat78.2319°N Lon 15.6229°E
12:30 Ship moves from anchorage to berth in Longyearbyen harbour

06th September 2013 Friday

00:00 Position: Longyearbyen harbour
11:30 Transit to working area for Second Leg

07th September 2013 Saturday

00:00 Position: Lat 79° 25'N Lon 009° 51'E hdg 10 transit to working area
08:00 Drill (abandon ship,fire and MOB)
13:15 reduce speed
13:45 deployment of magnetometer
13:50 SOL BGR13-2M5
15:29 Clock synchronizing error restored at 15:31
17:57 change heading to WP46
17:59 EOL BGR13-2M5 Lat 82.0663N Long 015.2227E W.D. 2233
18:39 SOL BGR13-2M6 Lat 82.1304N Long 015.6978E W.D. 2485
23:16 EOL BGR13-2M6 Lat 81.3778N Long 017.6037E W.D. 824

08th September 2013 Sunday

00:00 Vessel Position: Lat 81.4170°N Lon 018.1111E hdg 360 moving to start of line BGR13-2M7
00:30 SOL BGR13-2M7 Lat 81.4917N Long 017.9589E W.D. 1645
04:40 EOL BGR13-2M7 Lat 82.1524N Long 016.4441E W.D. 2386
04:40 SOL BGR13-2M8 Lat 82.1524N Long 016.4441E W.D. 2386
05:30 EOL BGR13-2M8 Lat 82.2270N Long 017.2778E W.D. 2342
05:32 Start magnetometer recovery
06:05 Stop logging
06:10 End magnetometer recovery
06:51 Start gravity corer deployment (core01) Lat 82.2503 Long 17.5841
07:55 Start GC recovery (core01 fix)Lat 82.243182 Long 17.484586 W.D. 2024
08:35 problems with winch, still 400 m to go
09:30 winch is running again
09:45 GC on deck
11:47 Heading towards HF1 location
11:52 Heatflow probe deployed to water

12:30 Stopped for calibration/temperature adjustment, position:
lat=82.2598N, lon=17.5603E, depth 1964 m
12:40 Heatflow probe lowered to the ground
12:41 HF probe reached ground, keep position: lat=82.2601N, lon=17.5581E,
depth 1964 m
12:47 HF measurement finished, recovering the instrument
13:30 Heading to the next waypoint for heatflow measurements (HF2),
cable (and instrument) is 500m in water
14:33 Stop for calibration, HF probe at 1935m, lat=82.2432, lon=17.8466, depth 1970
14:40 HF probe reached ground, keep position: lat=82.2434N, lon=17.8463E,
depth 1970.48 m
14:54 HF measurement finished, recovering the instrument
15:00 Heading to the next waypoint for heatflow measurements (HF3)
15:08 cable (and instrument) is 500m in water
15:45 HF probe brought on deck for inspection
16:00 HF probe back in the water
16:00 HF probe at 1800 m, continue to the HF calibration site
16:30 Stop for calibration, lat=82.2691N, lon=18.1198E, depth 1897
16:41 HF probe reached ground, keep position: lat=82.2691N, lon=18.1198E, depth 1896.9 m on single beam, 2058m reported from back deck!!
16:49 HF measurement finished, recovering the instrument
17:44 HF probe brought on deck
18:00 Ships moves on BGR13-2M9
18:42 Start MBES acquisition
19:31 Ship free from ice, Magnetometer deployment start
20:04 Magnetometer deployed and tested
20:09 SOL BGR13-2M9 Lat 82.1385N Long 018.5660E W.D. 2467
23:29 EOL BGR13-2M9 Lat 81.5864N Long 019.7312E W.D. 1688
23:29 SOL BGR13-2M10 Lat 81.5864N Long 019.7312E W.D. 1688

09th September 2013 Monday

00:00 Vessel Position: Lat 81.5595°N Lon 019.1172E hdg 261 on line BGR13-2M10
00:32 EOL BGR13-2M10 Lat 81.5392N Long 018.5530E W.D. 1867
00:32 SOL BGR13-2M11 Lat 81.5392N Long 018.5530E W.D. 1867
04:03 EOL BGR13-2M11 Lat 82.1112N Long 017.1894E W.D. 2626
04:19 SOL BGR13-2M12 Lat 82.1236N Long 017.4473E W.D. 2566
05:28 EOL BGR13-2M12 Lat 81.9334N Long 017.9276E W.D. 3119
05:30 Magnetometer recovery start
05:47 Magnetometer on deck
05:48 Ship moves to Gravity core 2 position
06:00 Stop logging
06:45 Start gravity corer deployment (core02) Lat 81.9221 Long 18.2511 WD 3280
07:26 Data logging started Runline coring0909, for Mag calibration
07:46 GC released Lat 81.92951 Long 18.2880 WD 3284
09:30 GC on deck
09:35 Heading towards core4 location
12:20 Gravity core 4 location Lat 82.1363N Lon 17.7368E, depth 2398m
12:40 Ship moves to Gravity core 5 position
13:35 Recovered core on deck
14:25 Start gravity corer deployment (core05) Lat 82.2434N, Long 17.9702E, depth 2042
15:05 Deployed gravity core 5
15:15 Start recover gravity core 5, Lat 82.2547N, Long 17.9485E, Depth 2006
16:15 Recovered core on deck

16:50 Attempting to follow M13, not on track yet
17:13 Start Magnetometer deployment
17:17 Magnetometer deployed for testing only
17:29 Magnetometer deployed for measurements
17:36 Increase speed (to max 11 knots) SOL BGR13-2M13
Lat 82.1566 N Long 018.1141E W.D. 2311
18:07 EOL BGR13-2M13 Lat 82.0792N Long 018.2945E W.D. 3214
18:07 SOL BGR13-2M14 Lat 82.0792N Long 018.2945E W.D. 3214
18:31 Ice on the route, ship turns Stbd
18:35 EOL BGR13-2M14 Lat 82.1101N Long 018.6515 W.D. 3164
18:36 Start recovery magnetometer
18:45 Magnetometer recovered close to the stern
18:45 Ship try to find a way trough the ice
19:16 Magnetometer back to the water
19:23 Line BGR13-2M14 restart from Lat 82.0708N Long 018.8071 W.D. 3338
following ice edge

10th September 2013 Tuesday

00:00 Vessel Position: Lat 81.8773°N Lon 021.8676°E hdg 137 on line BGR13-2M14
following ice edge
06:33 Start recovery magnetometer EOL BGR13-2M14 Lat 82,18694°N Lon 28,36488°E
06:52 Magnetometer on deck
07:04 Start deployment GC C44
08:41 Fix GC C44 Lat 82.217598°N Lon 28.731679°E W.D. 3600 m
10:40 Recovered core on deck
10:50 Transit to HF_NC1
14:40 Slowing down to 2-3 knots
15:00 Heatflow device in water, heading to HF_NC1
15:38 (approx. timing and location) Stop for calibration, lat=81.6927, lon=32.4461,
depth 1750
15:46 (approx. timing and location) Measurement finished, lat=81.6932, lon=32.4560,
depth 1821
16:30 HF probe brought on deck
17:33 Magnetometer deployed, en route to M15
17:57 SOL BGR13-2M15 Lat 81.6886N Long 032.4579E W.D. 1746
19:54 EOL BGR13-2M15 Lat 82.0017N Long 031.3103E W.D. 3046
19:54 SOL BGR13-2M16 Lat 82.0017N Long 031.3103E W.D. 3046
23:18 EOL BGR13-2M16 Lat 82.6193N Long 031.1686E W.D. 3545
23:18 SOL BGR13-2M17 Lat 82.6193N Long 031.1686E W.D. 3545

11th September 2013 Wednesday

00:00 Vessel Position: Lat 82.7074°N Lon 031.8845°E hdg 42 on line BGR13-2M17
00:21 EOL BGR13-2M17 Lat 82.7455N Long 032.2550E W.D. 3506
00:21 SOL BGR13-2M18 Lat 82.7455N Long 032.2550E W.D. 3506
04:26 EOL BGR13-2M18 Lat 82.0111N Long 032.9107E W.D. 2657
04:26 SOL BGR13-2M19 Lat 82.0111N Long 032.9107E W.D. 2657
05:26 EOL BGR13-2M19 Lat 81.8672N Long 033.7052E W.D. 2107
05:28 Start recovery magnetometer
05:44 Magnetometer on deck
05:45 Ship moves to HF-NE4 position
06:10 HF probe deployed, heading to HF_NE4

06:57 HF probe reached sea floor Lat 81.834836°E 33.877176°E
transit to HF-NE3 towing the HF probe
09:10 position HF-NE3 reached
09:18 HF probe reached sea floor Lat 81.776599°N Lon 33.90422°E W.D. 1751
09:31 start HF probe recovering
10:25 HF probe brought on deck
12:32 HF probe deployed, Problems detected-no data transmission
12:44 HF probe back on deck
13:00 Decided to abandon HF_NC2 point, go to next coring target C48
14:05 Start deployment GC C48
14:41 GC C48 deployed, start recovery (see C48 fix coordinates), depth 900 m
14:55 Gravity corer on deck
15:10 Heading towards C47
15:50 Start deployment GC C47
16:35 GC C47 deployed, start recovery (see C47 fix coordinates), depth 1450 m
16:50 (approx. timing) Gravity corer on deck
17:30 Prepare to go towards BGR13-2M20
17:45 Magnetometer deployed
18:06 SOL BGR13-2M20
21:00 EOL BGR13-2M20, SOL BGR13-2M21, Lat 81,67°N; Lon 29,05°E; depth=2400

12th September 2013 Tuesday

00:00 Vessel Position: Lat 82.0414°N Lon 026.2421°E hdg 313 on line BGR13-2M21
00:51 EOL BGR13-2M21 Lat 82.1442N Long 025.4612E W.D. 3765
00:51 SOL BGR13-2M22 Lat 82.1442N Long 025.4612E W.D. 3765
01:51 EOL BGR13-2M22 SOL BGR13-2M23
06:30 EOL BGR13-2M23 SOL BGR13-2M24
08:11 EOL BGR13-2M24 Lat 81.7929 Long 31.7192 W.D. 2900
08:15 start recovery of magnetics
start deploying gravity corer station C45
09:54 fix C45 Lat 81.79377°N Long 31.78325°E W.D. 2891
11:40 Gravity corer on deck
13:30 Heading to Heatflow target HF-NW1
15:30 Heatflow probe deployed
16:00 Heatflow calibration
16:05 Heatflow probe on the seafloor, depth 1750m
16:08 Lifted slightlyfrom seafloor to be left on sea-bottom again shortly
16:16 Start to recover the probe
16:37 Heatflow probe on the seafloor again, depth 1737m
16:42 Start to recover the probe
17:20 Heatflow probe on deck
18:29 Start magnetometer deployment
18:45 Magnetometer in the water
18:49 Start acquisition on file coring0912.1-20130912-184945 heading East, waiting for the night acquisition plan Lat 81.5803N Long 031.0807E W.D. 1326
19:15 Acquisition plan received, logging on line BGR13-2M25 files
19:37 MBES 8111 switched on
21:36 MBES 8150 switched off
21:59 EOL BGR13-2M25 Lat 81.5494N Long 033.3610E W.D. 235
21:59 SOL BGR13-2M26 Lat 81.5494N Long 033.3610E W.D. 235

13th September 2013 Friday

00:00 Vessel Position: Lat 81.4467°N Lon 031.9358°E hdg 238 on line BGR13-2M26
02:24 EOL BGR13-2M26 Lat 81.3165N Long 030.3050E W.D. 135
02:24 SOL BGR13-2M27 Lat 81.3165N Long 030.3050E W.D. 135
07:17 EOL BGR13-2M27
07:27 start recovery Magnetics
07:55 start deployment gravity corer C6
08:11 gravity corer in the ground
08:22 core on deck. Empty, will be repeated
08:57 gravity corer C6, Lat 81.2366 °N, Lon 34.1408°E
11:30 start deployment gravity corer C5
11:45 GC5 dropped
11:55 gravity core C5 on deck
12:05 Heading towards C3
15:10 Stop 1 engine, slow down
15:30 start deployment gravity corer C3
15:38 GC3 dropped, start recovering
15:42 gravity core C3 on deck –almost empty!
15:50 Prepare for the second coring, same site
16:05 start deployment gravity corer C3
16:15 GC3 dropped
16:22 gravity core C3 on deck, heading to C2 coring location
16:50 GC2 dropped, lat=80.62320, lon=34.42750, depth=200m
16:55 gravity core C2 on deck
17:10 Prepare for the second coring, same site
17:15 start deployment gravity corer C2
17:17 GC2 (2) dropped, start recovery
17:24 gravity core C2 (2) on deck
18:06 Start magnetometer deployment
18:24 Magnetometer in the water
18:32 SOL BGR13-2M28 Lat 80.6192N Long 034.6180E W.D. 198
20:06 Ship turn Stbd because of shallow water
20:20 EOL BGR13-2M28
20:30 Start magnetometer recovery
20:50 Magnetometer on board
20:50 Ship slow down waiting for new operational plan
21:18 After a 360° turn ship moves to position C25A for coring

14th September 2013 Saturday

00:00 Vessel Position: Lat 80.5663°N Lon 032.6146°E hdg 250
06:00 Coring programme canceled due to unfavorable weather, heading to Longyearbyen, until end of survey area only MB, CHIRP and gravity data acqusition
14:32 Weather improved, change direction towards C99 coring site, heading 300
15:30 clock synchronisation error
22:10 reached coring site C99
22:27 GC in the water
22:41 fix GC C99 Lat 81.30339 °N Long 19.86340°E W.D. 561 m
22:55 GC on deck
23:20 Ship moves to Longyearbyen, MBES, CHIRP and gravitymeter still acquiring data

15th September 2013 Sunday

00:00 Vessel Position: Lat 81.2290°N Lon 020.0245°E hdg 178
01:25 Ship exit from working area, stop logging Lat 81.2571N Long 020.0028E
01:25 Transit to Longyearbyen

16th September 2013 Monday

11:45 Drop anchor in Longyearbyen Lat 78.2319°N Lon 15.6229°E

17th September 2013 Tuesday

00:00 Anchorage in Longyearbyen,
12:00 Disembarkation of scientific crew

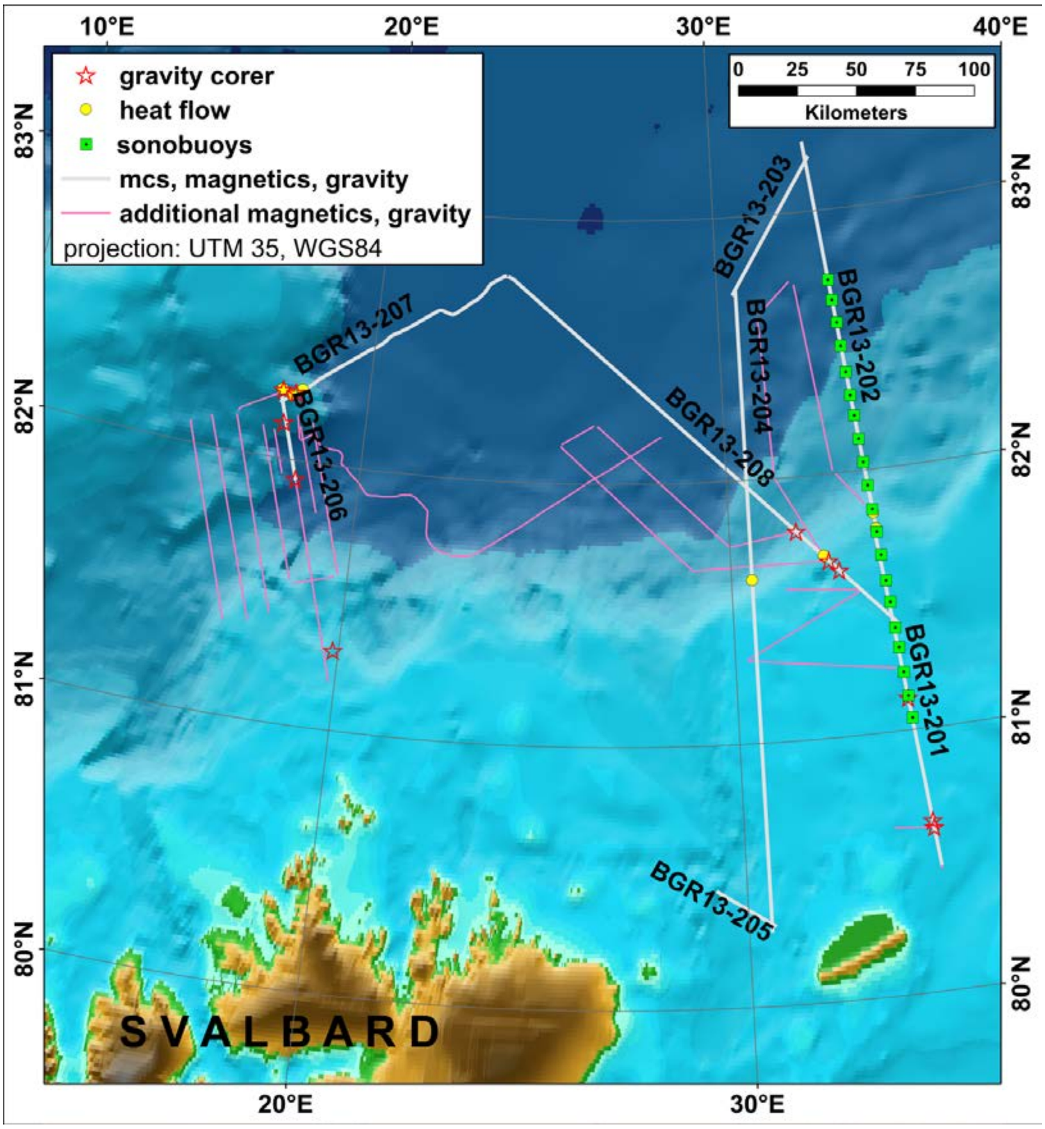


Fig. 5: Survey lines and location of heat flow and coring stations.

3. NAVIGATION AND DATA MANAGEMENT

Lorenzo Facchin

The navigation is managed by means of Teledyne Reson PDS2000 software. This software is capable to collect the data coming from the connected devices installed onboard, and send different outputs to the equipements as well.

Additional tasks of PDS2000 are: to create guidance (routes, acquisition runlines, waypoints, ecc); to do computations (as requested); data quality control; messaging output towards external acquisition systems and events marks towards external acquisition systems too, by means of serial port. For the seismic acquisition, in PANORAMA-1 project, the PDS2000 navigation system was configured to send the firing command (event) to the gun controller every 25 m distance. The ship is equipped with three GPS positioning systems [Ashtec Aquarius (primary); Topcon GB-500 (GPS+GLONASS); Landstar MK Veripos (also DGPS)] ,directly interfaced to the inertial navigation system MRU (Motion Reference Unit) that sends heading and attitude values, position and speed both to PDS2000 and MBES; the Multibeams Systems - Reson Seabat 8150 and Reson Seabat 8111 and the Singlebeam Simrad EA600, all connected to the navigation system that receives and logs the data coming from the Gravitymeter and the Gradiometer as well. The CHIRP system receives the position information from the GPS, and the depth from the echosounder.

All data coming from the connected instruments can be visualized, real-time, both in navigation room and on the bridge.

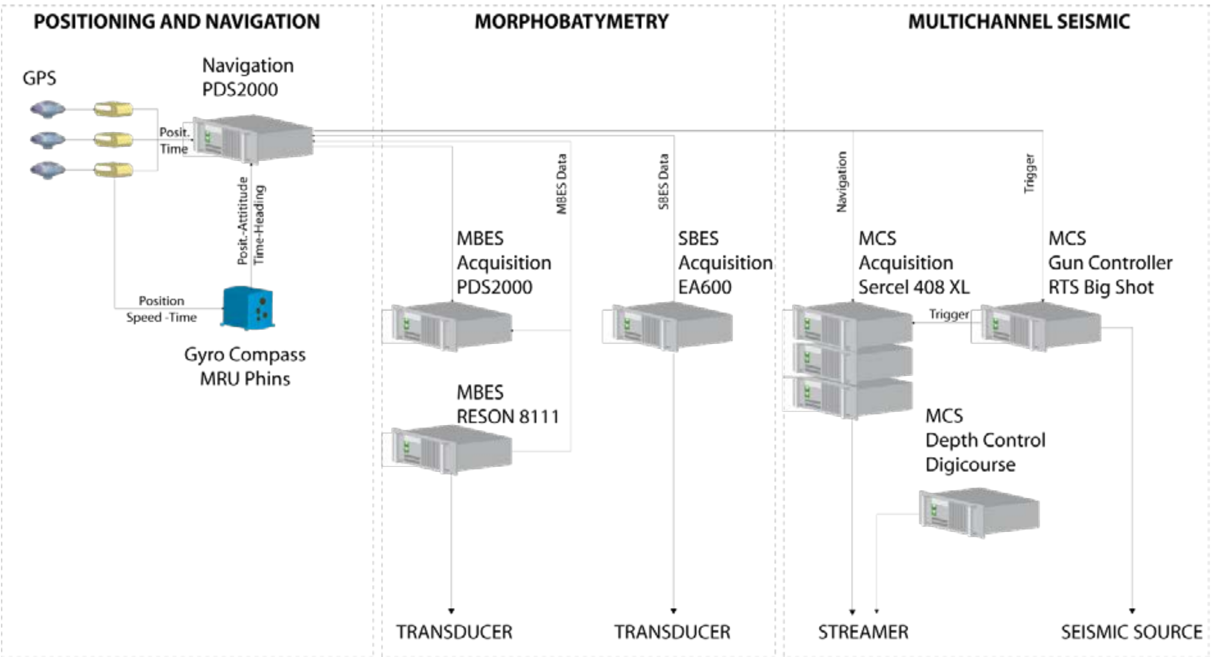


Fig. 6: General block diagram of navigation and data management.

Tab. 2: Relative positions of ship mounted instruments

Instrument	**X**	**Y**	**Z**
ACQUARIUS	2.24	8.20	20.00
EA600	0.29	27.23	-4.46
G- GUN array	2.24	-54.32	-6,0
GRAVITYMETER	0,00	0,00	0,18
MB 8111	-0.29	17.89	-4.82
MB 8150	0.00	16.49	-4.50
OCTANS	-0.27	-0.28	0.25
SBP	-0.63	6.93	-4.32
STERN	0.00	-29.32	7.12
TOPCON	2.69	8.60	20.36
VERIPOS	-2.13	8.36	20.28
Zero Offset	0.00	0.00	0.00
Streamer nearoffset	2.24	-203.57	-12

All the information received by PDS2000 can be exported with the requested format.

For every acquired profile, depending on the instrument to which it is referred, different files have been exported.

- The "MRU" files with *Date and Time*, *Lat and Long* in DegMinSec format, and *Heading Pitch* and *Roll* values.
- The "Magnetometer" files with *Date and Time*, *Lat and Long* in Decimal degrees format, *Water Depth* and all the data coming from the towed Magnetometer.
- The "Gravitymeter" files containing *Date and Time*, *Lat and Long* in Decimal degrees format, *Water Depth* and all the data coming from the Gravitymeter.
- The "Shiptrack" files with *Date and Time*, *Lat and Long* in Decimal degrees format, and *Water Depth* from the Multibeam

4. SINGLE-BEAM ECHOSOUNDER (SBES)

Lorenzo Facchin

The Simrad EA600 Oceanic Depth Echosounder, manufactured by Kongsberg Maritime, is a Single Frequency 18 kHz system, with a maximum power of 2 kW, 160 dB of dynamic range and a transducer 12-16-60 with 16° circular, 60° passive beams. Depth values are logged by the main navigation system (PDS2000) via the RS-232 serial connection.

Tab. 3: EA600 features and technical specifications

Manufacturer	Simrad Kongsberg
Model	EA600
Installation	Hull mounted
Transducer type	18-11
Frequency	18 kHz
Pulse duration	8 ms
Beam angle	11°
Beam width	382 Hz
Transmit power	2000 W
Range bottom	7000
Gain function	20 log TVG, 30 log TVG, 40 log TVG, or none
Ping rate	Adjustable
Start depth and range	5 to 15.000 m in manual or auto range
Bottom detector	Software tracking algorithm

5. MULTI-BEAM BATHYMETRY

Lorenzo Facchin, Kai Berglar

5.1 Technical specifications

The R/V OGS Explora is equipped with two keel mounted Multibeam Echosounders: the Reson SeaBat 8111 (Tab. 4) for shallow water (up to 500 m WD); and the Reson SeaBat 8150 (Tab. 5) for deep water.

The SeaBat 8111 operates at a frequency of 100 kHz; it illuminates a swath on the sea floor that is 150° across track by 1.5° along track. The swath consists of 101 individual 1.5° by 1.5° beams with a bottom detection range resolution of 3.7 cm. The maximum swath width (7.4 times the water depth) is reached with the system working in less than 150 metres of water. The 8111 employs Pitch Stabilization to steer the transmitted beam so that it remains vertical through pitch angles of ±10 degrees. The data are logged through the PDS2000 acquisition software.

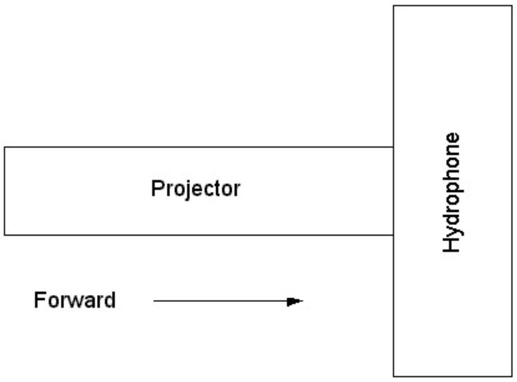
5.2 Data acquisition

Data acquisition was carried out from 17th of August at 08:38 (UTC TIME) before reaching the area with permission of seismic acquisition until the 15th of September at 01:25 (UTC TIME) as the ship exit the working area. The keel mounted shallow-water MB 8111 was run for depths from about -18.0 m to -650.0 m. Its operating frequency is 100 kHz for 101 beams with beamwidht across and along track of 1.5°; and a 150° of max swath; while the keel mounted ocean deep-water MB 8150 was run from about -450.0m to -4200.0m. Its operating frequency is 12 kHz for 234 beams with beamwidth of 2°x2° and a maximum swath coverage equal to 5 times the water depth. Quality data was good for both the shallow-water and deep-water multibeams. All acquired data was logged both as "pds" and "xtf" files format. PDS is native format for PDS200, XTF format is a standard that can be read by many processing softwares. The data acquired during previous cruises was loaded as background on the navigation software, and was helpful for real time acquisition mainly in shallow water area where lot of sudden changes in water depth are present. The different data sets fits well. As echosounders compute the water depth from the travel time of the acoustic signal from the transducer to the seafloor and back it is very important to know the exact sound velocity in the water column. Thus it has been necessary to perform Sound Velocity measurements by means of a sound velocity probe (SVP VALEPORT) to get realtime correction of the incoming raw water depth data (see chapter 6). These corrections were computed and applied to the data automatically by PDS2000 software. The total coverage of acquired multi-beam bathymetry is shown in Fig. 7.

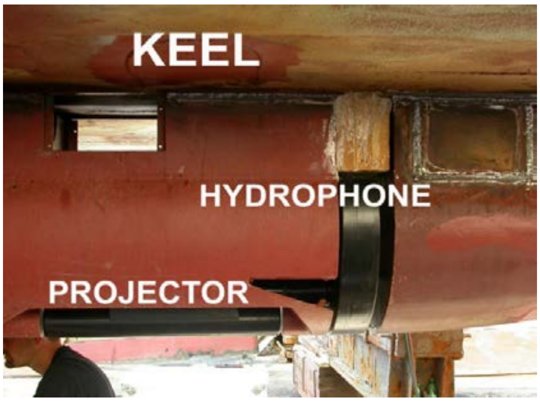
Tab. 4: SEABAT 8111 features and technical specifications

Manufacturer Model Installation	Reson SeaBat 8111 Hull mounted
Number of beams Beamwidth across track Beamwidth along track Center-to-center beam separation Max Swath Max swath coverage	101 1.5° 1.5° 1.5° 150° 7.4 x water depth
Operating frequency Pulse length Depth range Max ping rate	100 kHz Variable, operator selectable 600 m (max scale 1400 m) 35 swaths per second
Max vessel speed Stabilization	20 knots Pitch stabilization within +/- 10°
Sound probe Acquisition software Processing software	Reson SVP 24 PDS2000 PDS2000

SEABAT 8111 SYSTEM CONFIGURATION



Head orientation

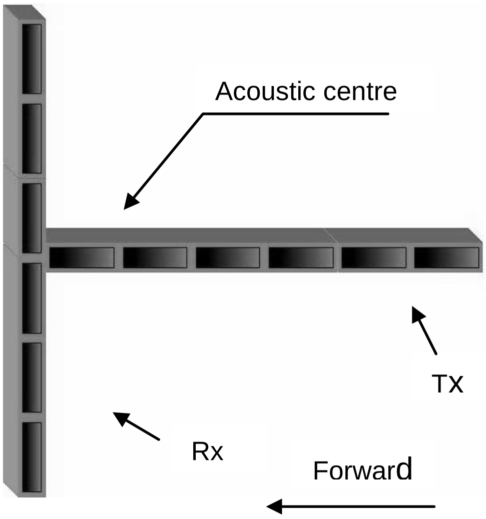


The keel mounted Reson SeaBat 8111.

Tab. 5: SEABAT 8150 features and technical specifications

Manufacturer	Reson
Model	SeaBat 8150
Installation	Hull mounted
Number of beams	234
Number of transmitters (Tx)	6 - configuration B
Number of receivers (Rx)	6 - configuration B
Beam width	2 x 2°
Max swath coverage	5 x water depth
Operating frequency	12 kHz
Pulse length	0.5 – 20.4 ms
Depth range	12000 m
Max update rate	15 swaths per second
Update rate	Range dependent
Pitch motion compensation	+/- 10°
Roll motion compensation	+/- 10°
Sound probe	Reson SVP 25
Acquisition software	PDS2000
Processing software	PDS2000

SEABAT 8150 - B CONFIGURATION



The keel mounted Reson Seabat 8150 .

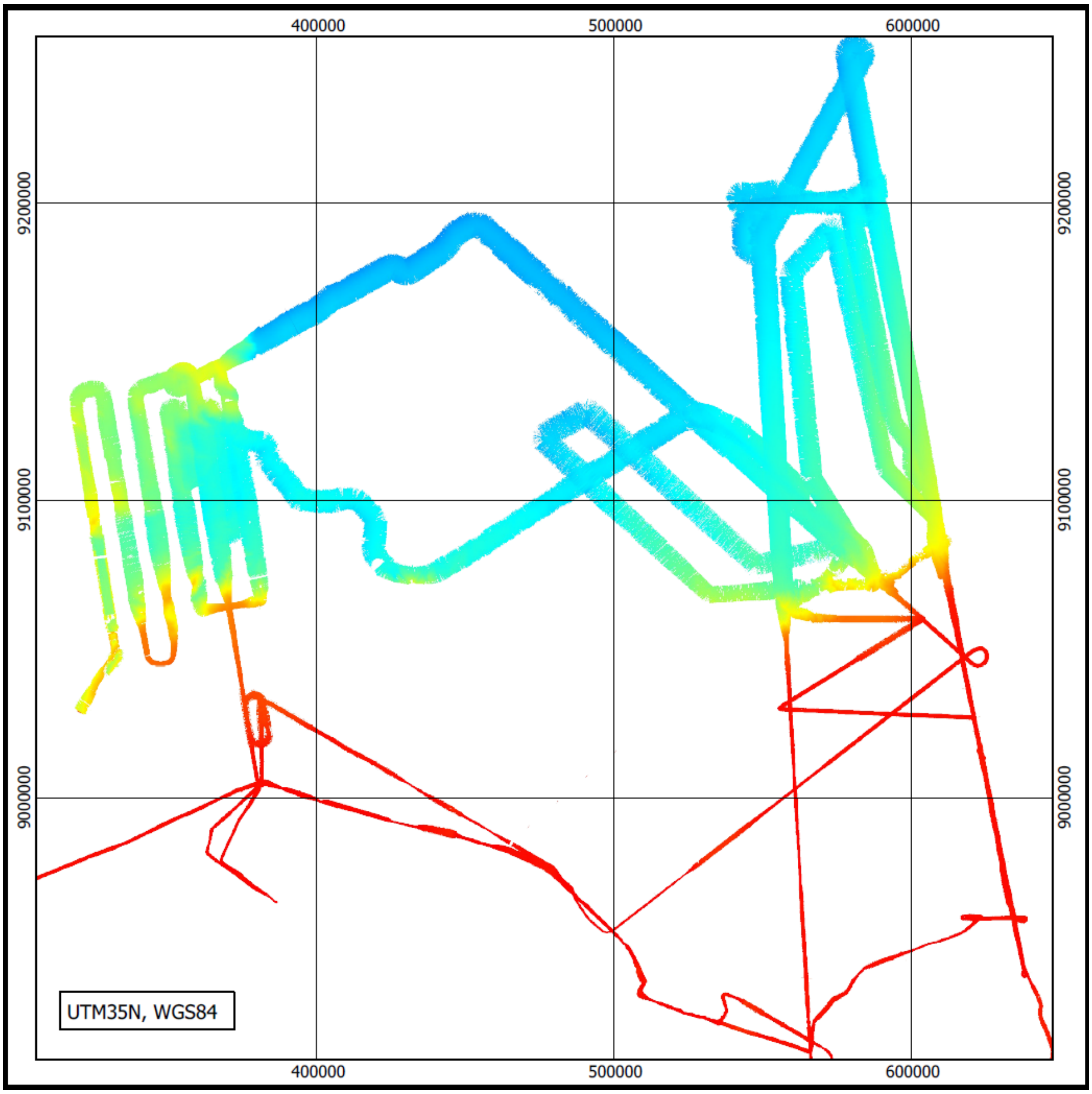


Fig. 7: Coverage of bathymetric mapping.

6. SOUND VELOCITY PROFILES

Lorenzo Facchin

Sound velocity profile measurements are needed for real time correction of the incoming raw water depth data. They are supplied on a daily basis by means of a Sound Velocity Probe SVP-VALEPORT that also logs temperature measures along the water column. The probe is operated by a winch located on the second deck and is placed in the sea by hanging it on to the portside lateral frame pulley.

Fig. 8: SVP-VALEPORT deployment.

7. SEDIMENT ECHOSOUNDING

Kai Berglar

7.1 Method and instrument control

R/V OGS EXPLORA is equipped with a hull-mounted Datasonics CAP-6600 Chirp II system allowing the acquisition of high-resolution sediment echosoundings. Technical specifications are as followed:

Tab. 6: SBP features and technical specifications

Manufacturer	Benthos
Model	Chirp II
Installation	Hull mounted
Number of transducers	16
Transducers type	AT 471
Signal generator / DSP	CAP-6600 Chirp II Workstation
DSP Sonar Signal Processing	16 bit A/D, continuous FFT
Operating sweep frequency	2 – 7 kHz
Ping rate	Variable, operator selectable (max 12 ping/sec)
Sweep Length	Variable, operator selectable
Multiping option	yes
Gain	Automatic gain control
Bottom tracking	Interactive
Navigation / Annotation	NMEA 0183
Data format	XTF or SEG Y
Real time printer	EPC
Acquisition software	SwanPRO / ChirpScan II
BENTHOS CHIRP II	
The system consists of sixteen hull mounted AT 471 transducers	

The Chirp II system is controlled by the acquisition software SwanPro (v 1.57). It allows adjusting the recording depth via changing the trigger rate (0.25 s - 0.625 s) preserving a fixed number of samples per record (8192) thus altering the sample rate and recording window. Data is stored in the proprietary XTF-format. Conversion to SEG-Y format is done after acquisition with the software SwanConv (v. 0.05).

Data quality heavily depends on the weather conditions, as strong roll and pitch of the vessel results in a sideward reflection of the emitted signal. For details see the watch protocol (Tab. 7).

7.2 Processing

The SEG-Y converter SwanConv resamples the data to a constant sample rate (15 kHz were used to preserve all frequencies of the sweep), looks for the minimum and maximum time in one or several XTF files and creates new traces of this length written to a SEG-Y file. This procedure can result in very large files, e.g. on the slope or in deep waters with data outliers at zero depth.

The SEG-Y files are further processed with the open source software packages seismic unix (v. 43R3) and GMT (v. 4.5.6).

Main processing steps are:

(1) Positional data and static correction

The navigation system of OGS EXPLORA provides precise UTM-coordinates (zone 35 for this survey) and z-values in meters (calculated from the motion sensor data) at a frequency of 20 Hz for all ship-mounted instruments.

Depending on the variable recording frequency the Chirp system triggers about two to three times per second. As GPS times are updated only every second, an individual timestamp in 10th of seconds is interpolated for each trace using the GMT filter1d function and correlated with the data provided by the navigation system. The coordinates are written to the source and receiver trace header words. For static correction the z-values are calculated to time with a sound velocity in water of 1440 meters per second, divided by the sample rate to get the number of samples for static correction which is then applied to the trace.

(2) Time gates for data reduction

Measured water depths from the vessel's 18 kHz pinger system are calculated to time (1440 m/s) and used to cut a time window of 100 ms out of the traces containing the relevant data to reduce data volume. Trace delay is written to trace header word bytes 109-110, water depth to trace header word bytes 181-184.

(3) Signal processing

To improve the signal, de-clipping, trace normalization and attribute calculation (envelope) are applied.

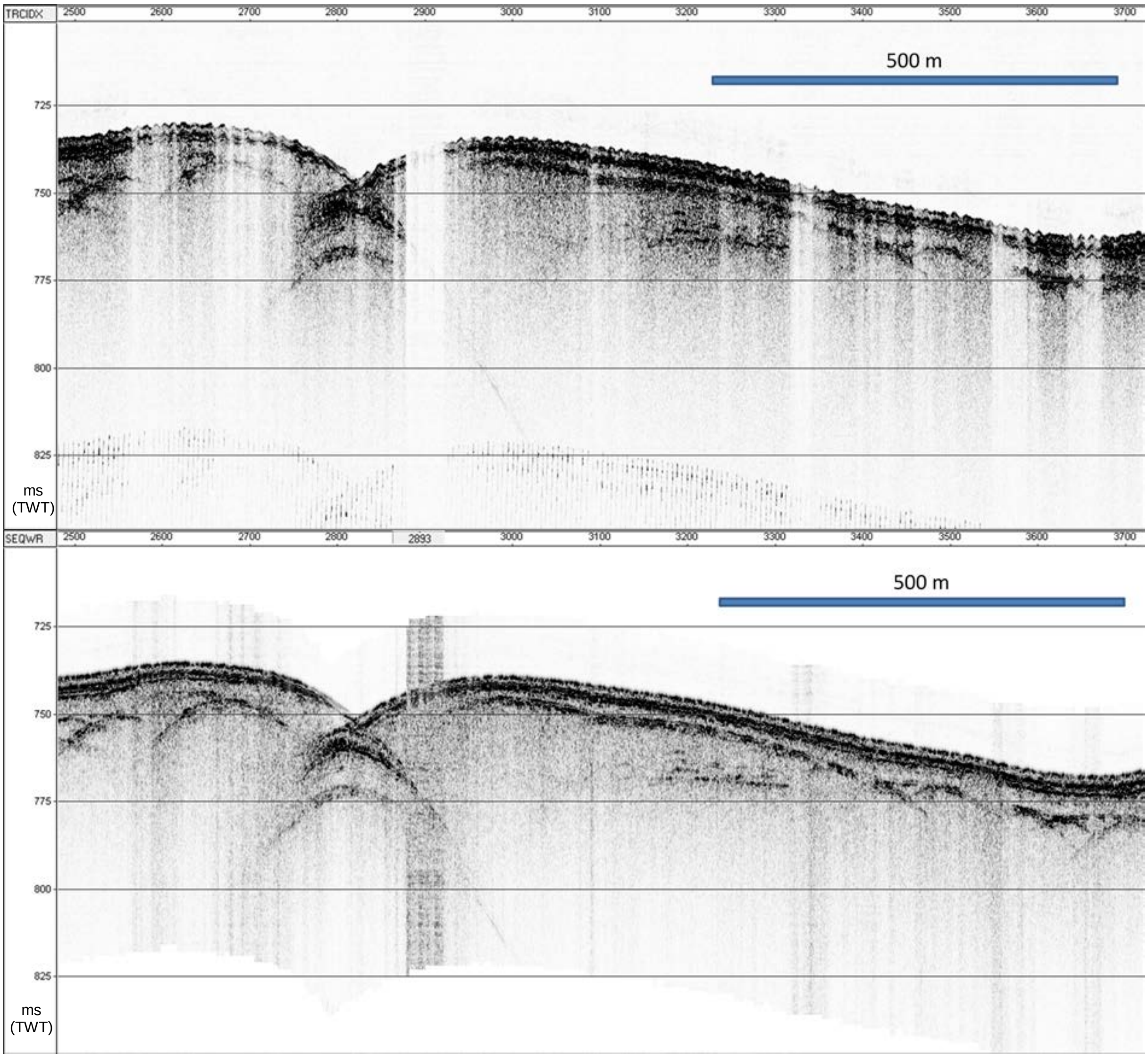


Fig. 9: Chirp data set before (top) and after (bottom) processing applied.

7.3 Watch protocol

Lines are named according to seismic and magnetic profiles. Lines with hydro-acoustic measurements only are either named “transit” or according to gravity corer stations.

Tab. 7: Sediment echosounder watch protocol

no	Line	Date/time start	Date/time stop	remarks
0	BGR13-2transit01	13/08/18 12:20	13/08/18 13:03	Direct SEGY acquisition
1	BGR13-201	13/08/18 13:03	13/08/19 09:07	Switched to Resons XTF format on file 05. Partly poor data quality due to bad weather conditions
2	BGR13-2transit02	13/08/19 09:07	13/08/19 09:57	Poor data quality due to bad weather conditions
3	BGR13-2transit03	13/08/19 15:46	13/08/19 22:15	17:23-17:25 acq. Failure Poor data quality due to bad weather conditions
4	BGR13-2transit04	13/08/19 22:15	13/08/19 22:45	22:35 acq. Failure Poor data quality due to bad weather conditions
5	BGR13-2transit05	13/08/19 23:38	13/08/20 13:41	Tested SEGY-recording. No delay record time-hw in trace headers. Switched back to XTF-format recording (file 06). 01:45 poor data quality due to rough sea Poor data quality due to bad weather conditions
6	BGR13-2r1	13/08/20 13:41	13/08/21 22:28	Several software crashes/restarts (17:10, 20:20, 21:50, 01:59, 05:45, 08:10) Poor data quality due to bad weather conditions
7	BGR13-2transit06	13/08/21 22:28	13/08/21 23:55	
8	BGR13-2m1	13/08/21 23:55	13/08/22 01:45	
9	BGR13-2m2	13/08/22 01:45	13/08/22 09:27	
10	BGR13-202	13/08/22 16:00	13/08/23 14:48	Renamed (original: BGR13-201A) Seismic section ends at 14:48
11	BGR13-2transit07	13/08/23 14:48	13/08/23 16:39	
12	BGR13-203	13/08/23 16:39	13/08/24 01:30	
13	BGR13-2transit08	13/08/24 01:30	13/08/24 04:29	
14	BGR13-204	13/08/24 04:29	13/08/25 16:50	
15	BGR13-2transit09	13/08/25 17:13	13/08/25 18:57	
16	BGR13-205	13/08/25 18:57	13/08/25 22:45	
17	BGR13-2transit10	13/08/25 22:45	13/08/26 16:51	Stopped, leaving permit area
18	BGR13-2transit11	13/08/30 10:00	13/08/30 17:46	
19	BGR13-2m3	13/08/30 17:46	13/08/31 03:53	01:45 computer reboot necessary
20	BGR13-2transit12	13/08/31 03:53	13/08/31 14:02	
21	BGR13-206	13/08/31 14:03	13/08/31 18:51	
22	BGR13-2transit13	13/08/31 19:00	13/08/31 20:55	
23	BGR13-207	13/08/31 20:55	13/09/01 11:42	System crash caused data loss from 13/09/01 07:29 to 21:13 (empty files) Reboots necessary (13/09/02 01:00,
24	BGR13-208	13/09/01 11:42	13/09/02 17:00	

				03:18)
25	BGR13-2transit14	13/09/02 17:01	13/09/02 18:52	
26	BGR13-209	13/09/02 18:53	13/09/03 14:43	
27	BGR13-2transit15	13/09/03 14:44	13/09/03 23:59	**End of Leg 1**
28	BGR13-2m5	13/09/07 13:37	13/09/07 17:58	Renamed (original: BGR13-2m4)
29	BGR13-2m6	13/09/07 18:39	13/09/07 23:16	
30	BGR13-2m6_to_m7	13/09/07 23:16	13/09/08 00:30	
31	BGR13-2m7	13/09/08 00:30	13/09/08 04:40	
32	BGR13-2m8	13/09/08 04:40	13/09/08 05:35	
33	BGR13-2m9	13/09/08 20:09	13/09/08 23:30	
34	BGR13-2m10	13/09/08 23:30	13/09/09 00:33	
35	BGR13-2m11	13/09/09 00:33	13/09/09 04:20	
36	BGR13-2m12	13/09/09 04:20	13/09/09 05:48	EOL 05:28, recording continued to GC-site core02
37	BGR13-2m13	13/09/09 17:29	13/09/09 18:07	
38	BGR13-2m14	13/09/09 18:10	13/09/09 18:59	Starts with file 04
39	BGR13-2m14A	13/09/09 19:20	13/09/09 22:15	Irregular line direction due to ice conditions 22:15 no signal, switched off system. Hydrophone frozen? Water temperature: -1.7°C Checked every 30-60 minutes.
40	BGR13-2m14B	13/09/10 02:30	13/09/10 06:42	Signal back 03:40 system crash, restart, file 04 skipped
41	BGR13-2transit16	13/09/10 11:03	13/09/10 16:06	
42	BGR13-2m15	13/09/10 17:45	13/09/10 19:55	
43	BGR13-2m16	13/09/10 19:55	13/09/10 23:17	
44	BGR13-2m17	13/09/10 23:17	13/09/11 00:20	
45	BGR13-2m18	13/09/11 00:20	13/09/11 04:26	
46	BGR13-2m19	13/09/11 04:26	13/09/11 05:49	
47	BGR13-2m20	13/09/11 18:20	13/09/11 21:00	
48	BGR13-2m21	13/09/11 21:00	13/09/12 00:51	
49	BGR13-2m22	13/09/12 00:51	13/09/12 01:51	Poor data quality due to strong swell
50	BGR13-2m23	13/09/12 01:51	13/09/12 06:42	EOL 2m23 06:30
51	BGR13-2m24	13/09/12 06:42	13/09/12 07:17	Switched off, no reasonable data acquisition possible due to rough sea
52	BGR13-2m25	13/09/12 19:10	13/09/12 21:59	
53	BGR13-2m26	13/09/12 21:59	13/09/13 02:24	
54	BGR13-2m27	13/09/13 02:24	13/09/13 07:33	
55	BGR13-C6_C5	13/09/13 09:13	13/09/13 10:29	Also part of BGR13-2m02
56	BGR13-C5_C3	13/09/13 12:17	13/09/13 15:19	
57	BGR13-C3_C2	13/09/13 16:35	13/09/13 16:47	
58	BGR13-2m28	13/09/13 18:33	13/09/13 20:20	Poor data quality due to strong swell
59	BGR13-2to25A	13/09/13 21:32	13/09/14 06:24	Poor data quality due to strong swell
60	Longyearbyen	13/09/14 06:24	13/09/14 22:20	
61	Longyearbyen_A	13/09/14 23:18	13/09/15 01:21	**End of survey**

7.4 Data Examples

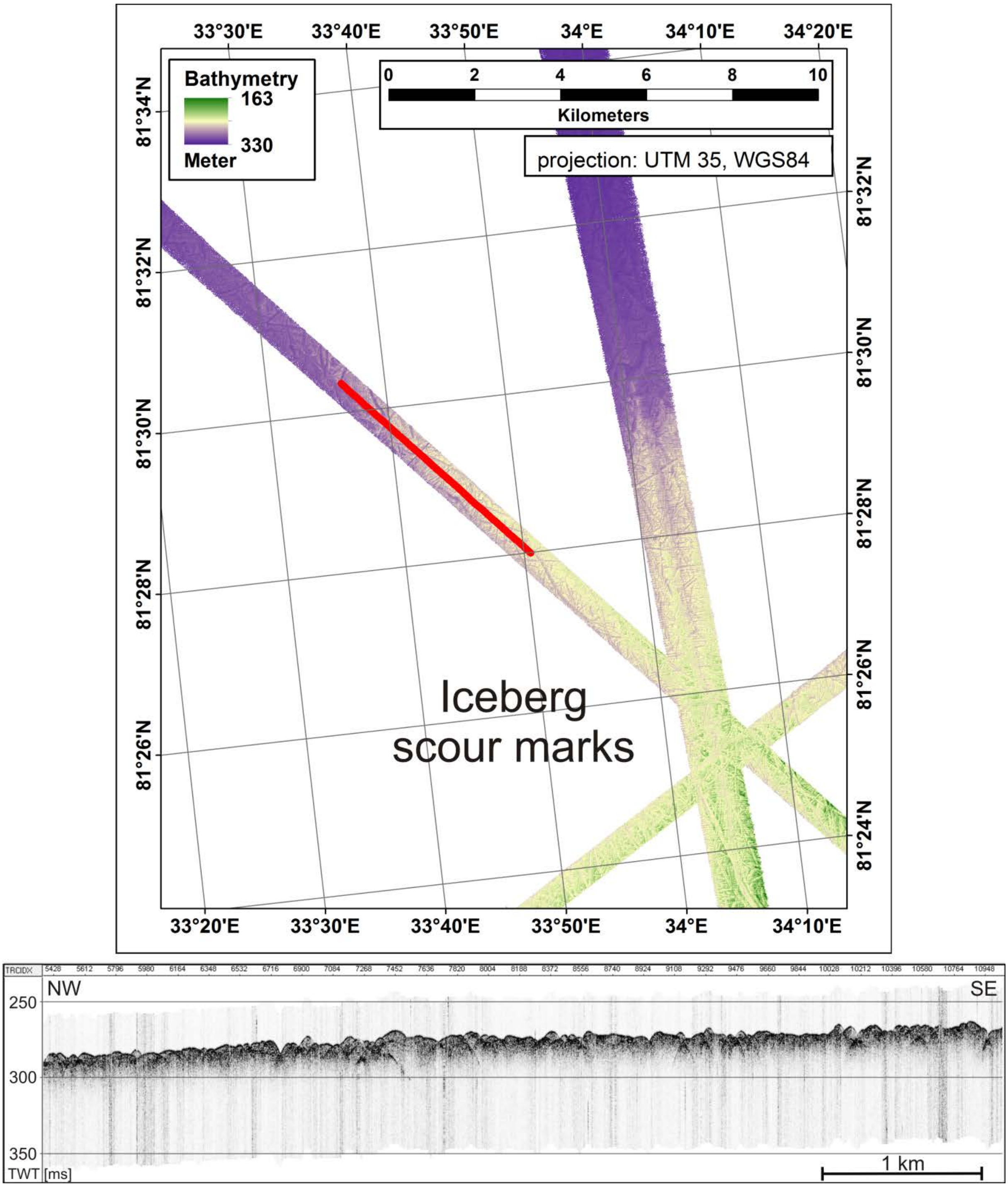


Fig. 10: Iceberg scour marks in the SE working area. Bathymetry (top) images the scratched sea floor. Red line is the location of sediment echosounder profile (bottom).

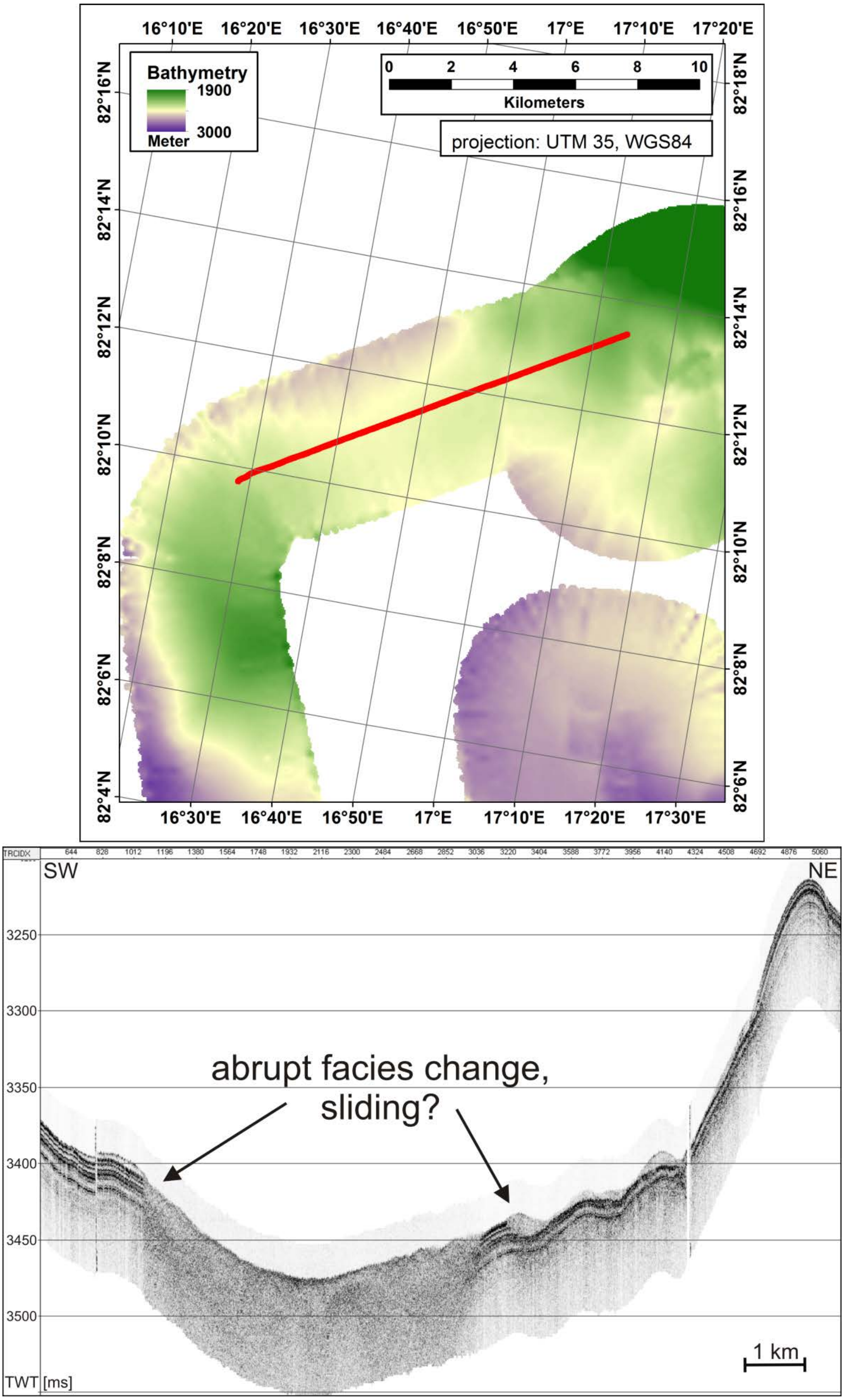


Fig. 11: Abrupt facies change from well stratified to chaotic in the Sophia Basin, possibly due to sediment slides.

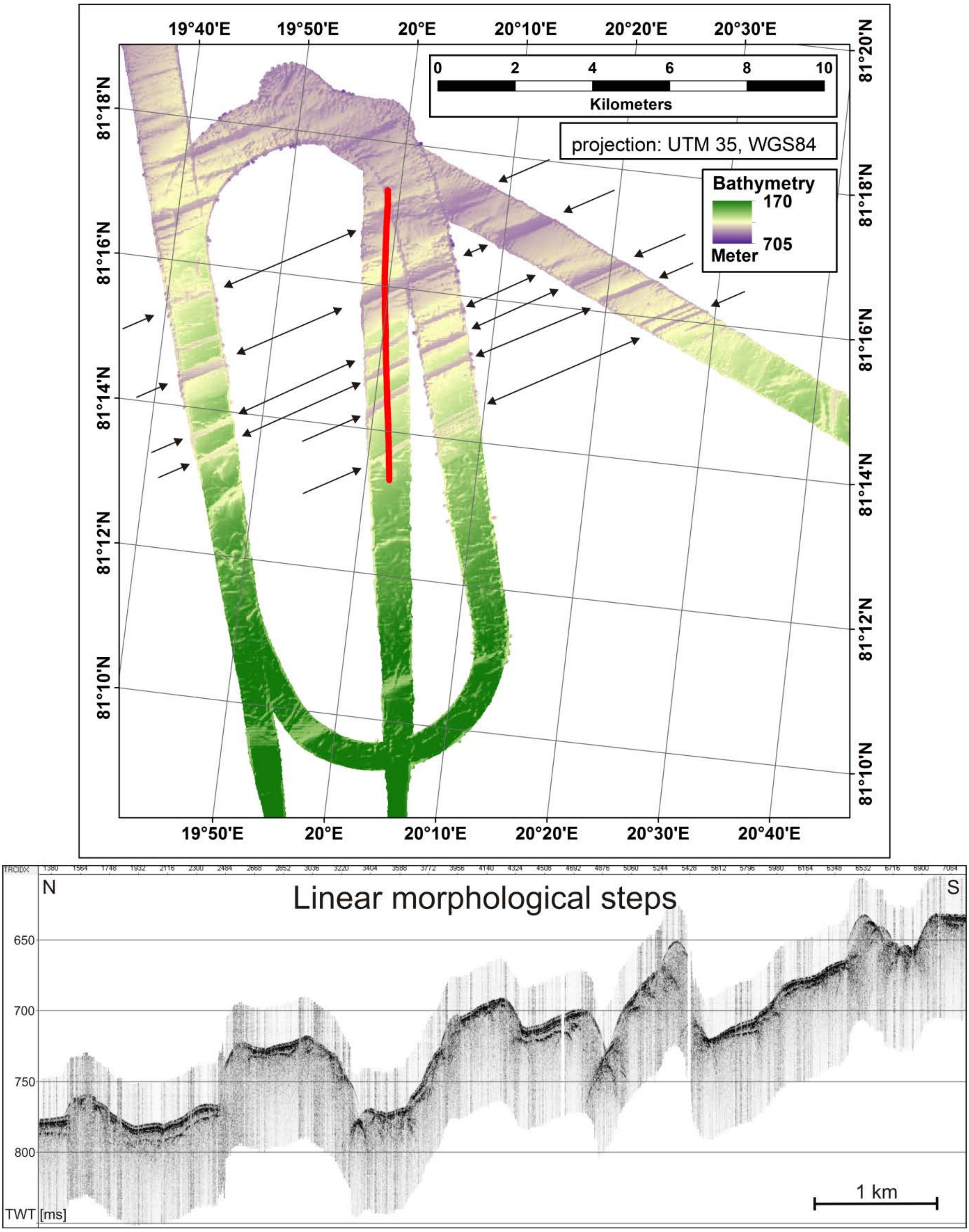


Fig. 12: Linear features on the north Svalbard slope.

8. GRAVIMETRY

Ingo Heyde

8.1 The sea gravimeter system KSS31

During the cruise PANORAMA-1 the OGS owned sea gravimeter system KSS31, serial no. 14, was used. The KSS31 is permanently installed on RV OGS EXPLORA in the gravimeter room one level below the main deck (Fig. 13). The sea gravimeter is located near the vessel's nominal center of gravity 4.7 m above the vessel's keel and 29.32 m in front of the stern (see Fig. 26).

The gravimeter system KSS31 is a high-performance instrument for marine gravity measurements, manufactured by Bodenseewerk Geosystem GmbH. The KSS31 system consists of two main assemblies: the gyro-stabilized platform with the gravity sensor and a rack with the power supply, the system electronics and the data handling subsystem.

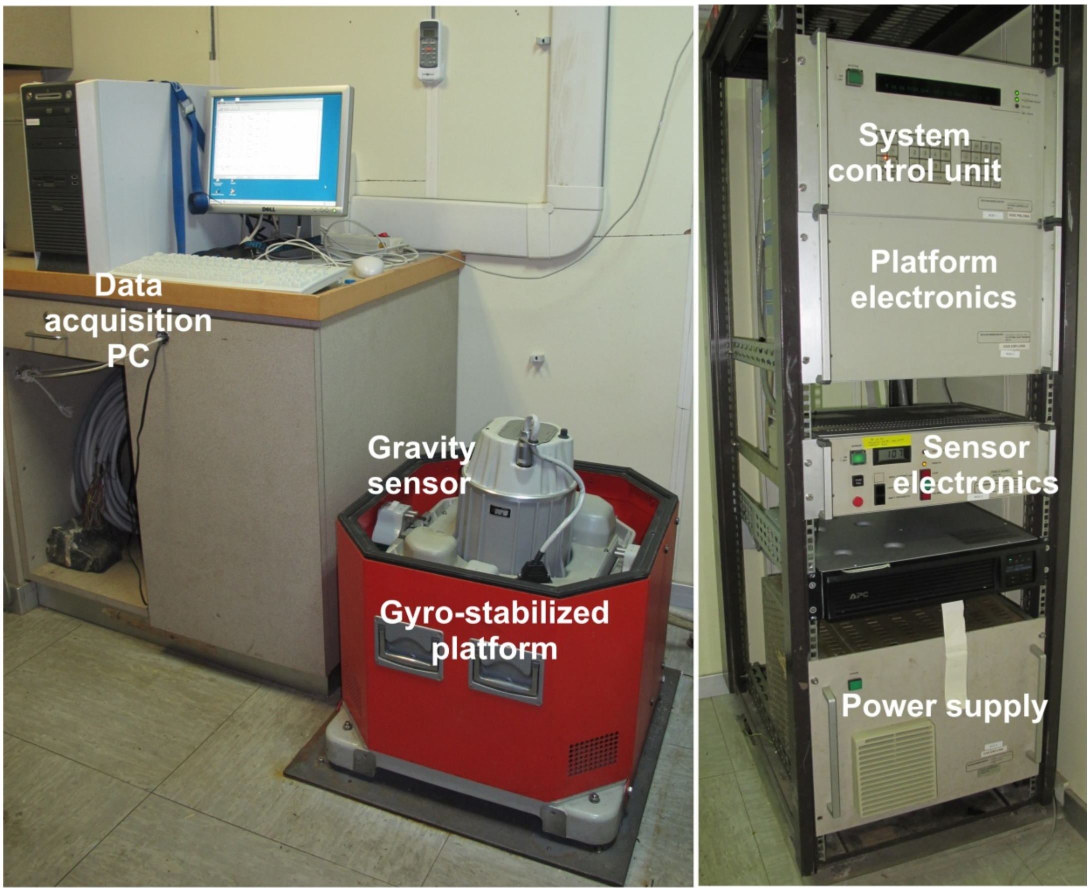


Fig. 13: KSS31gravimeter system (platform with sensor and electronics rack) in the gravimeter room on RV OGS EXPLORA.

The gravity sensor GSS31 (Fig. 14) consists of a tube-shaped mass that is suspended on a metal spring and guided frictionless by 5 threads. It is non-astatized and particularly designed to be insensitive to horizontal accelerations. This is achieved by limiting the motion of the mass to the vertical direction. Thus it is a straight line gravity meter avoiding cross coupling effects of beam type gravity meters. The main part of the total gravity acceleration is compensated by the mechanical spring, but gravity changes are compensated and detected by an electromagnetic system. The displacement of the spring-mass assembly with respect to the outer casing of the instrument is measured using a capacitance transducer.

The leveling subsystem consists of a platform stabilized in two axes by a vertical, electrically erected gyro. The stabilization during course changes can be improved by providing the system with online navigation data. The control electronics and the power supply of the platform are located in the data handling subsystem unit. The measured data are transmitted to the PDS2000 system and online navigation data from this system are sent with a rate of 1 Hz to support the stabilizing platform. The support is realized as follows: The horizontal position of the gyro-stabilized platform is controlled by two orthogonal horizontal accelerometers. The platform is leveled in such a manner that the horizontal accelerations are zero. If the ship describes a curve, the additional horizontal acceleration will cause the platform to be leveled according to the resulting apparent vertical axis. This axis may differ substantially from the true vertical axis and will result in reduced gravity values and additionally in an effect of horizontal accelerations on the measured gravity. The latter effect is eliminated by supplying the system with online navigation data. A microprocessor calculates the leveling errors from this input and enters them into the platform electronics which corrects the platform accordingly.

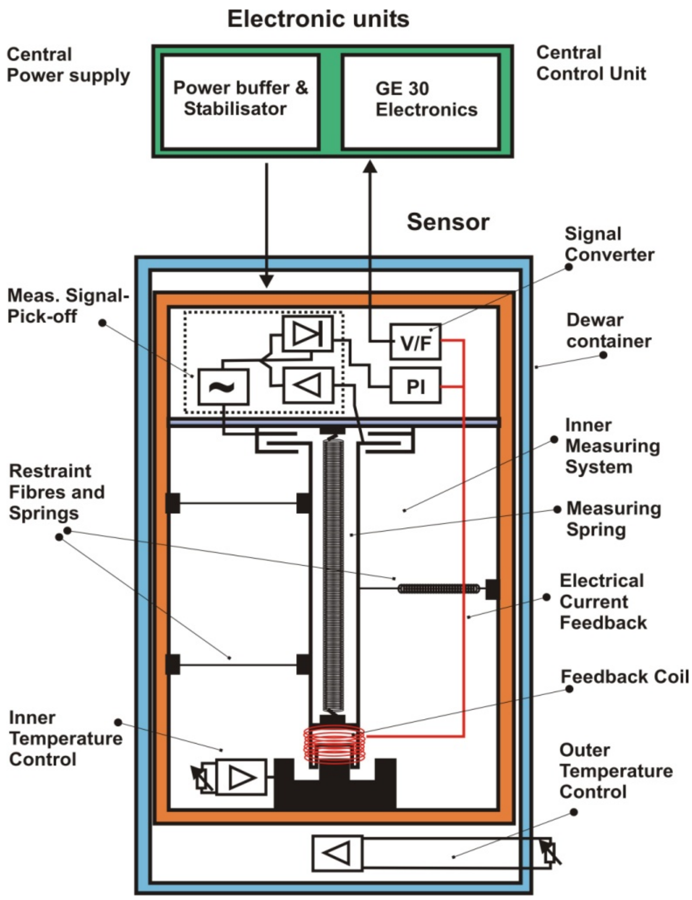


Fig. 14: Principle sketch of the gravity sensor GSS31 of the gravimeter system KSS31.

8.2 Gravity data processing

The raw and processed gravity data from the system are recorded by the PDS2000 system in the navigation room with a data rate of 0.25 Hz and parallel by a separate BGR PC installed in the gravimeter room with a data rate of 0.2 Hz using the printer interface.

Processing of the gravity data consists essentially of the following steps:

- a time shift of 76 seconds due to the overcritical damping of the sensor,
- conversion of the output from reading units (r.u.) to mGal by applying a conversion factor
  of 0.808 mGal/r.u.. On this cruise this was done in the system itself by hardware settings
- connection of the harbour gravity value to the world gravity net IGSN 71,
- correction for the Eötvös effect using the navigation data,
- correction for the instrumental drift (not performed until completion of the cruise),
- subtraction of the normal gravity (WGS67).

As a result, we get the so-called free-air anomaly (FAA) which in the case of marine gravity is simply the Eötvös-corrected, observed absolute gravity minus the normal gravity.

Outliers were removed manually. Addition low pass filtering was mostly not necessary in the survey area. During higher sea state conditions like on profile BGR13-2R1, however, the data had to be low pass filtered.

8.3 Gravity ties to land stations

To compare the results of different gravity surveys the measured data have to be tied to a world-wide accepted reference system. This system is represented by the International Gravity Standardization Net IGSN71 (Morelli, 1974). The IGSN71 was established in 1971 by the International Union of Geodesy and Geophysics (IUGG) as a set of world-wide distributed locations with known absolute gravity values better than a few tenths of mGal. According to the recommendations of the IUGG, every gravity survey, marine or land, should be related to the datum and the scale of the IGSN71.

Therefore, gravity measurements on land have to be carried out to connect the gravity measurements at sea with the IGSN71. The marine geophysical group of BGR uses a LaCoste&Romberg gravity meter, model G, no. 480 (LCR G480) for the gravity connections. In Bremerhaven the reference gravity station in the AWI building was used (01). The point descriptions and absolute gravity values of reference stations in Tromsø and Longyearbyen were kindly provided by NGU in Trondheim. In Tromsø two reference stations are located at the Tromsø University Museum (02, 03). In Longyearbyen a reference station at the airport (04) was used.

For mobilization RV OGS EXPLORA moored outside the Kaiserdock II at Lloyd shipyard in Bremerhaven about 40 m from the northern end of the pier (Fig. 15). On August 7, tie measurements to point A on the pier opposite the gravity room on RV OGS EXPLORA have been made. The connection measurements resulted in an average absolute gravity value of 981357.437 mGal (IGSN71, reduced to the gravity sensor level +0.18 m above the water level of 1.8 m) for point A. The reading of the KSS31 at the same time (August 7, 2013, 7:40 UTC) was 729.72 mGal.

In Tromsø RV OGS EXPLORA moored at the Breivika pier about 15 m from the south-western end of pier position No. 20 (Fig. 16). On August 15, tie measurements to point B on the pier opposite the gravimeter room have been made. The connection measurements resulted in an average absolute gravity value of 982556.76 mGal (with water level –3 m, IGSN71) for point B at the water level. The sensor is located 0.18 m above the water level resulting in an absolute gravity value of 982556.714 mGal. The reading of the KSS32-M at the same time (August 15, 2013, 10:00 UTC) was 1943.43 mGal. The KSS31 readings in Bremerhaven and Tromsø would imply an instrumental drift of +14.993 mGal in 8.0972 days. This drift is by far too large and we suspect that a correction factor to the scale factor of the sensor has to be applied. However this factor could be determined only after the return of RV OGS EXPLORA to Bremerhaven on September, 24, 2013 and the identification of the true instrumental drift.

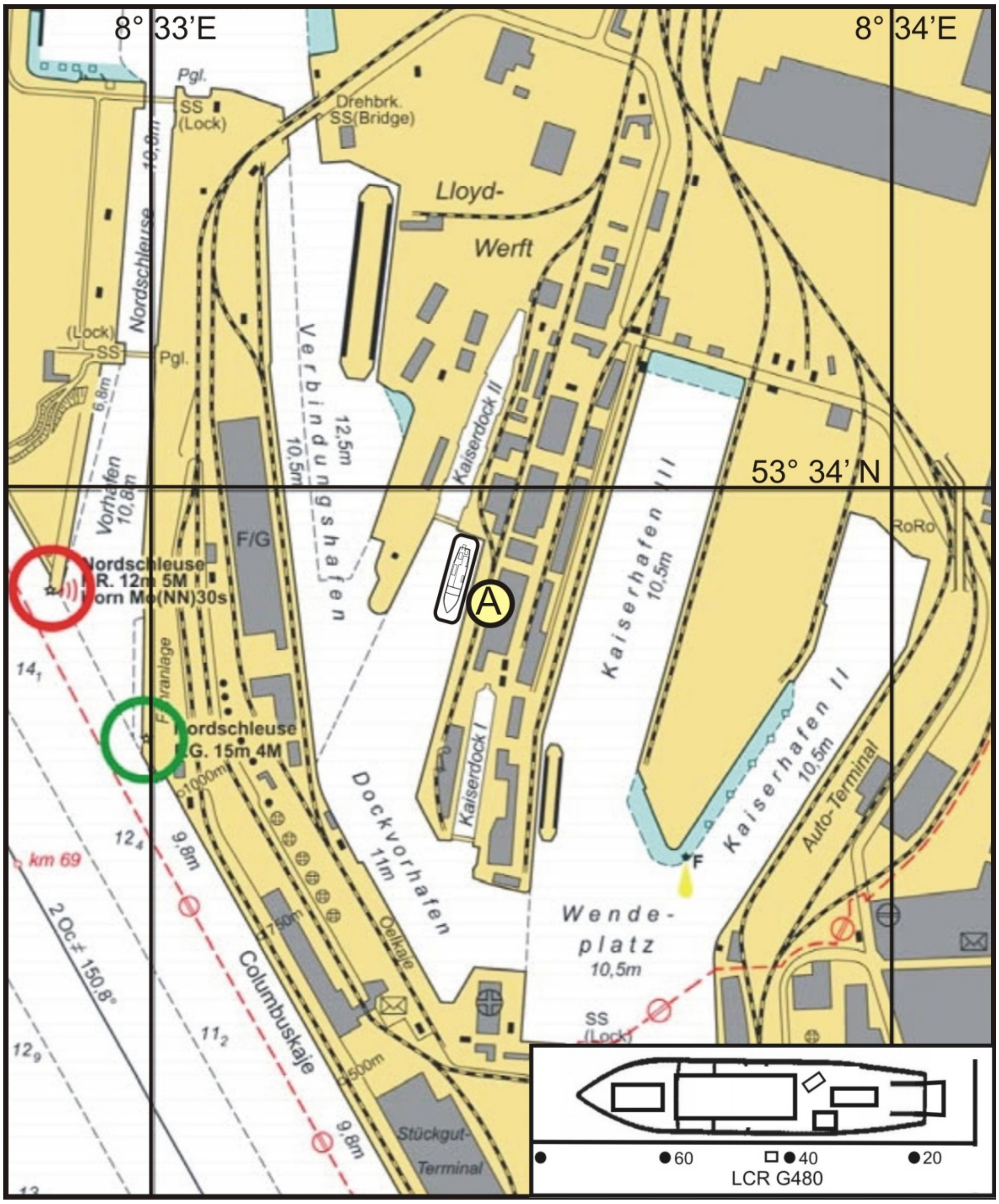


Fig. 15: Location of the mooring site of RV OGS EXPLORA at the Lloyd shipyard in Bremerhaven (A).

Tab. 8: Observation report of the gravity tie measurements in Bremerhaven, Tromsø and Longyearbyen

Station	Observer	Date	Time UTC	Reading units	Gravity value [mGal]
A	H	07.08.13	07:45	4905.89	4988.728
01	H	07.08.13	09:00	4905.59	4988.422
A	H	07.08.13	10:04	4905.85	4988.688
B	H	15.08.13	08:31	6080.05	6186.793
02	H	15.08.13	09:10	6076.18	6182.844
03	H	15.08.13	09:18	6075.40	6182.048
B	H	15.08.13	09:56	6079.80	6186.538
C	S, H	06.09.13	07:43	6480.25	6595.106
04	S, H	06.09.13	08:20	6479.17	6594.004
C	S, H	06.09.13	08:53	6481.36	6596.239
C	H	06.09.13	09:25	6481.45	6596.330
Observer: S, H = Schreckenberger, Heyde. Gravity in mGal using LCR G 480 scaling table.					

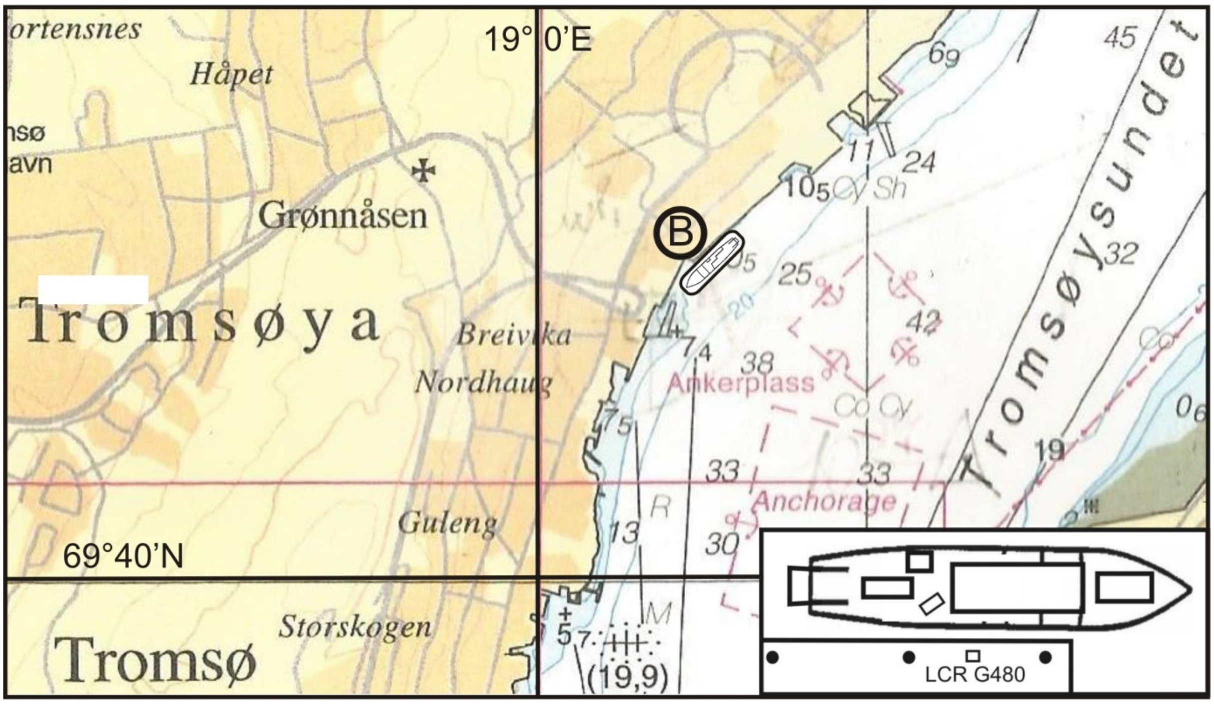


Fig. 16: Location of the mooring site of RV OGS EXPLORA at Breivika pier in Tromsø (B).

Reference Stations:

01: Bremerhaven, AWI building, Room 0082 981356.720 mGal (IGSN71)

02: Tromsø University Museum, Seismograph Room, Bolt R (69°38.08'N, 18°54.76'E, 27.30 m above MSL) 982552.140 mGal (IGSN71)

03: Tromsø University Museum, Main Entrance, Bolt Q (69°38.09'N, 18°54.84'E, 29.61 m above MSL) 982551.448 mGal (IGSN71)

04: Longyearbyen airport, Old Terminal Building, near entrance (78°14.7'N, 15°29.9'E) 982962.784 mGal (IGSN71)

Gravity stations:

A: Bremerhaven harbour, outside Kaisedock II at Lloyd shipyard

B: Tromsø, Breivika pier, 15 m from the south-western end of pier position No. 20

C: Longyearbyen, 45 m from the southeastern end of the main pier

Differences between reference and gravity stations:

01 – A	= -0.286 mGal
Absolute gravity at A:	981357.006 mGal

Absolute gravity for A (reduced to sensor level -1.62 m) 981357.437 mGal (IGSN71 system) used for the gravity tie on 07.08.2013 (07:40 UTC).

Reading of sea gravimeter KSS31 at that time: 729.72 mGal.

Difference between reference and gravity station:

02 – B	= -3.822 mGal
03 – B	= -4.617 mGal
Absolute gravity at B:	982555.962 mGal from 02
	982556.065 mGal from 03

Absolute gravity for B (reduced to sensor level –2.82 m) 982556.714 mGal (IGSN71 system) used for the gravity tie on 15.08.2013 (10:00 UTC).

Reading of sea gravimeter KSS31 at that time: 1943.93 mGal.

Difference between reference and gravity station:

04 – C	= -1.635 mGal
Absolute gravity at C:	982964.419 mGal

Absolute gravity for B (reduced to sensor level –3.07 m) 982965.238 mGal (IGSN71 system) used for the gravity tie on 06.09.2013 (08:53 UTC).

Reading of sea gravimeter KSS31 at that time: 2360.81 mGal.

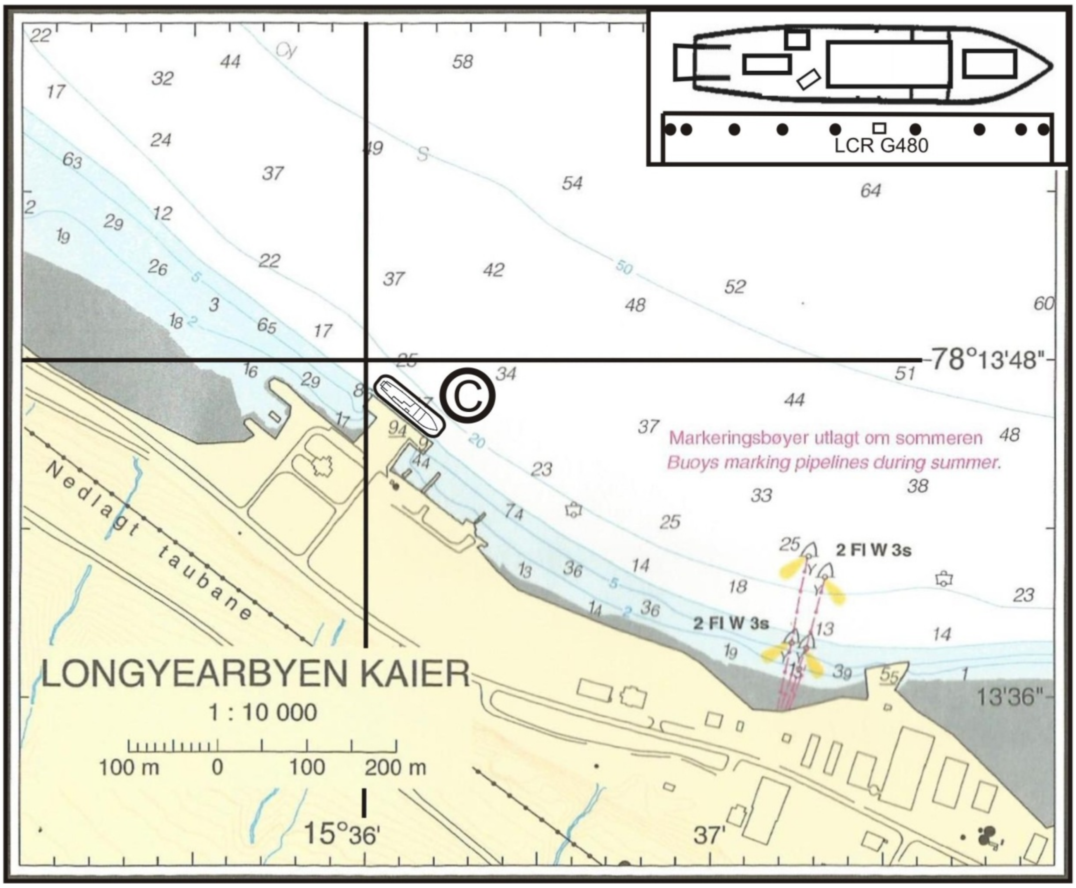


Fig. 17: Location of the mooring site of RV OGS EXPLORA in Longyearbyen (C).

On September 5 RV OGS EXPLORA moored at the main pier in Longyearbyen (Fig. 17). Tie measurements to point C on the pier opposite the gravimeter room have been made. Point C is located about 45 m from the southeastern end of the pier. The connection measurements resulted in an average absolute gravity value of 982965.286 mGal (with water level –3.25 m, IGSN71) for point A at the water level. The sensor is located 0.18 m above the water level resulting in an absolute gravity value of 982965.238 mGal. The reading of the KSS31 at the same time (Sep 6, 2013, 08:53 UTC) was 2360.81 mGal. The readings in Tromsø and Longyearbyen would imply an instrumental drift of +8.356 mGal in 21.9535 days. This drift is by far too large so that a correction factor to the scale factor of the sensor has to be applied.

On September 24 RV OGS EXPLORA returned to Bremerhaven and moored at the same location as during the stay in August outside the Kaiserdock II at Lloyd about 40 m from the northern end of the pier (Fig. 15). The reading of the KSS31 was 736.54 mGal at 17:30 UTC. The water level and the draught of the vessel were the same as on August 7. Thus the instrumental drift amounted to +6.82 mGal / 48.4097 days or +0.1409 mGal/d. This drift rate is rather large but lies within the normal drift range of marine gravity measurements with the KSS31. Marine gravity measurements were recorded from 15.08.13 (18:35 UTC) till 15.09.13 (1:29 UTC), i.e drift started with +1.191 mGal and ended with +5.458 mGal.

After applying this drift rate to the observed gravity values in Tromsø and Longyearbyen a correction factor for the scale factor could be determined. The average value for the correction factor amounted to 0.9879557. This factor was applied to all observed raw gravity differences with regard to the reading in Tromsø.

8.4 Data quality

In order to check the accuracy of the data quantitatively, the values along profiles measured repeatedly and at crossovers of gravity profiles were compared. During the cruise gravity data along one profile were measured twice. Fig. 18 shows the comparison for profiles BGR13-201 and BGR13-2M2.

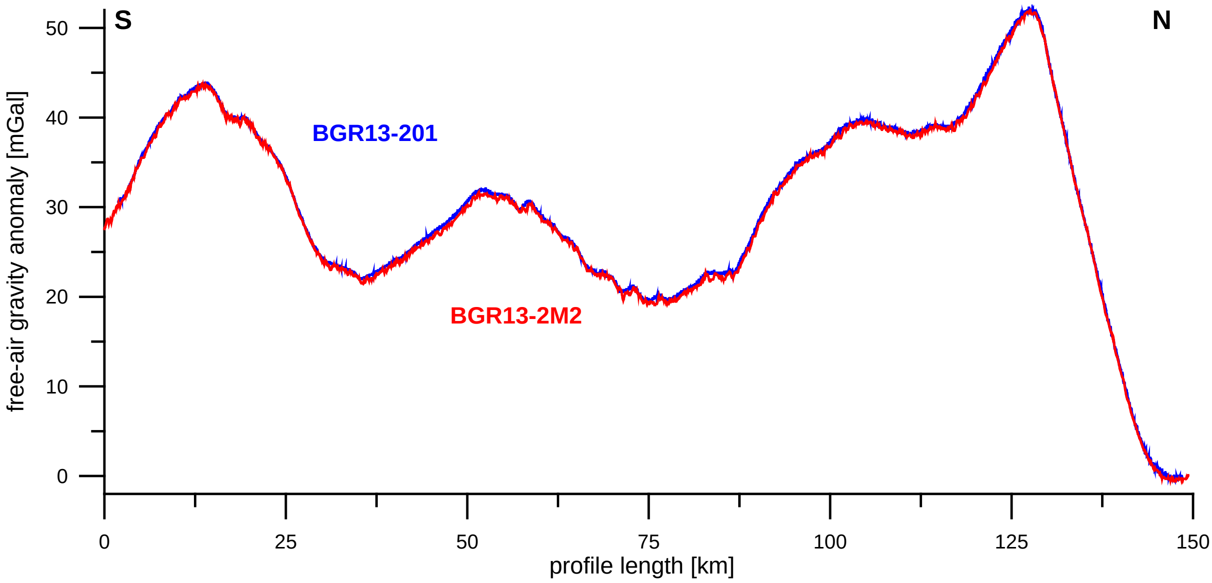


Fig. 18: Comparison of free-air gravity anomalies along profiles BGR13-201 and -2M2.

The coincidence is nearly perfect and the differences amount to less than 1.5 mGal. The ship velocity was considerable higher during BGR13-2M2 (10 kn vs. 4.1 kn) which explains the higher noise in the free-air gravity data. After drift correction the average crossover error in the KSS31 data for 11 crossovers along the track of leg 1 is 0.25 mGal (1σ = 0.7 mGal). The biggest difference found was 1.49 mGal. The general accuracy, however, is about 0.5 mGal.

8.5 Gravity data: description and preliminary results

8.5.1 Gravity database

Gravity measurements were carried out continuously during the cruise from Tromsø to Longyearbyen. Thus gravity data along all 39 profiles with a total length of 3071 km were measured. In addition about 3000 (resp. 300 working area only) km of the acquired data along transits and curves were useable. Despite the coverage of the survey area is rather sparsely, a map of the free-air gravity anomalies was prepared. Fig. 19 shows the map based on a 1 x 1 (arc-)minutes grid together with the survey tracks. The map is drawn up to a distance of 10 kilometres from the survey track.

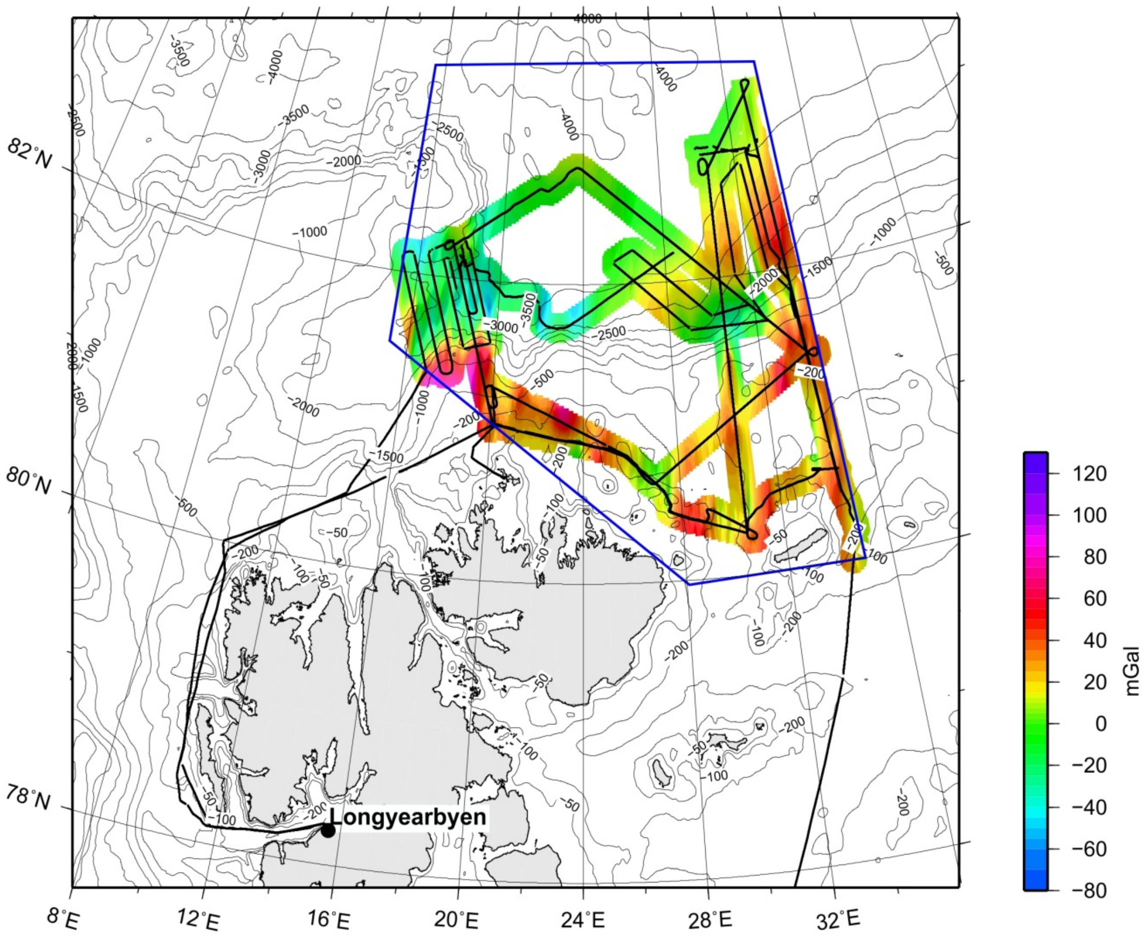


Fig. 19: Map of the free-air gravity anomalies in the survey area of cruise PANORAMA-1. The map is drawn up to a distance of 10 kilometers from the tracks and underlain by the bathymetry of Andersen (2010).

8.5.2 Comparison with gravity anomalies derived from satellite altimetry

The analysis of crossover errors shows that our gravity measurements are far more precise than alternate methods to measure the marine gravity field such as the calculation of free-air gravity anomalies from satellite altimeter measurements. A satellite altimeter uses a pulse-limited radar to measure the altitude of the satellite above the closest point to the sea surface. Global precise tracking coupled with dynamic orbit calculations provide an independent measurement of the height of the satellite above the ellipsoid. The difference between these two measurements is equal to the geoid height. So in marine areas the free-air anomaly can be calculated from the slope of the geoid. Closely spaced satellite altimeter profiles collected during the GEOSAT Geodetic Mission (~ 6 km) and the ERS 1 Geodetic phase (~ 8 km) were used by different groups to calculate grids of the free-air gravity anomalies.

Our data set can serve as a reference for the satellite gravity data compilation from the DTU Space Centre, Copenhagen (Andersen, 2010) referred to as DTU10 here. The gravity data compilation of Sandwell and Smith (2005), version 21.1 could not be considered as this data are limited to 80.738°N.

Subtracting the 1 x 1 minute grid of the DTU10 data from the 1 x 1 minute grid of the shipboard data one obtains the map of the differences shown in Figure Fig. 20.

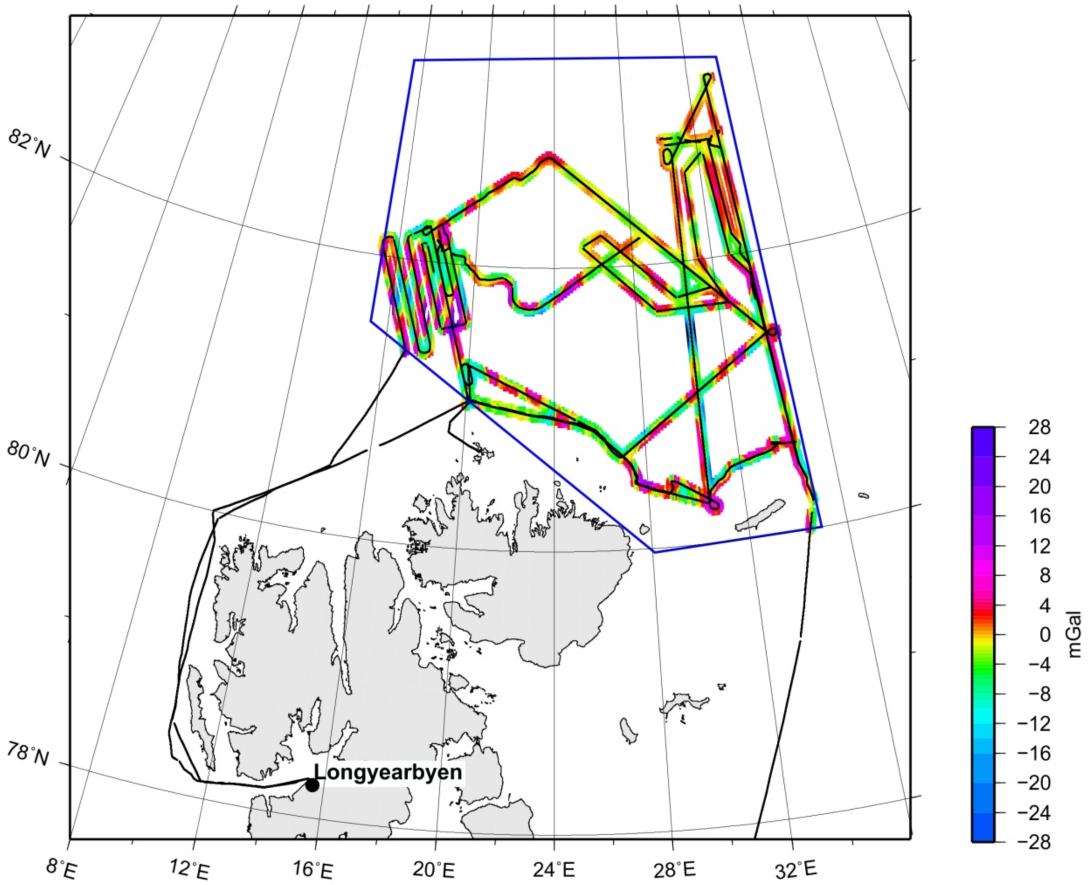


Fig. 20: Differences of the shipboard free-air gravity data and the DTU10 gravity dataset derived from satellite altimetry (Andersen, 2010). The maps are masked beyond a distance of 4 kilometres from the PANORAMA 1 profiles.

The differences of both datasets range between +28 and -20 mGal, but the differences are below ±10 mGal along most tracks. Higher differences are found in the Sophia Basin and on the shelf. Satellite gravity anomalies along the complete track were additionally calculated with bicubic interpolation out of the 1 x 1 minute grids and subtracted from the shipboard data (Fig. 21). The mean difference is -1.00 mGal with a standard deviation of 4.27 mGal. Nevertheless the DTU10 data set will be used for further gravity map compilations in areas where no PANORAMA-1 shipboard data were measured.

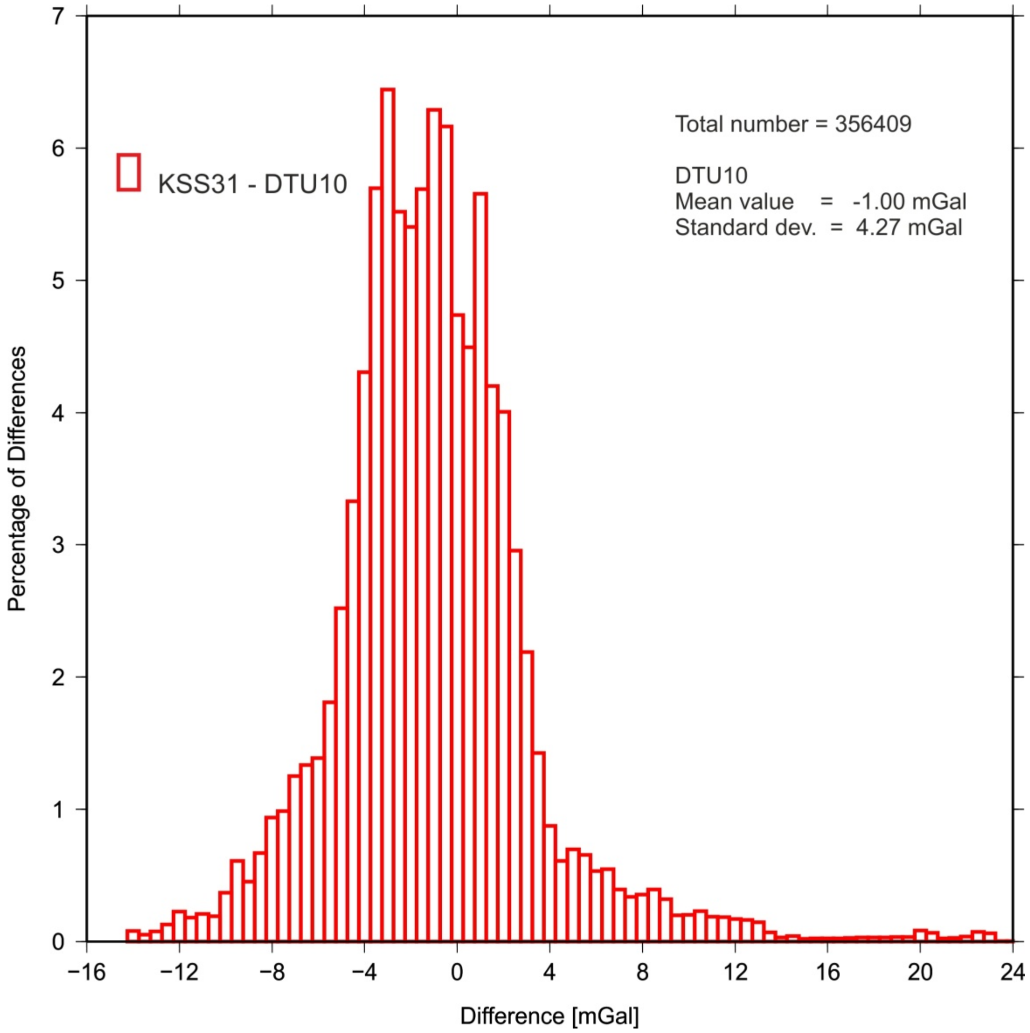


Fig. 21: Histogram of differences between shipboard KSS31 free-air gravity anomalies and the corresponding gravity datasets derived from satellite altimetry.

To illustrate the differences between the data sets in detail, Fig. 22 shows exemplarily a comparison along profiles BGR13-204 and -208. The wavelength range of satellite and shipboard anomalies is comparable in case of water depths greater than 1000 m. However, on the shelf anomalies of short wavelength are not resolved in the satellite data. This reflects the limited resolution of the DTU10 data set in areas of shallow water and close to the coast.

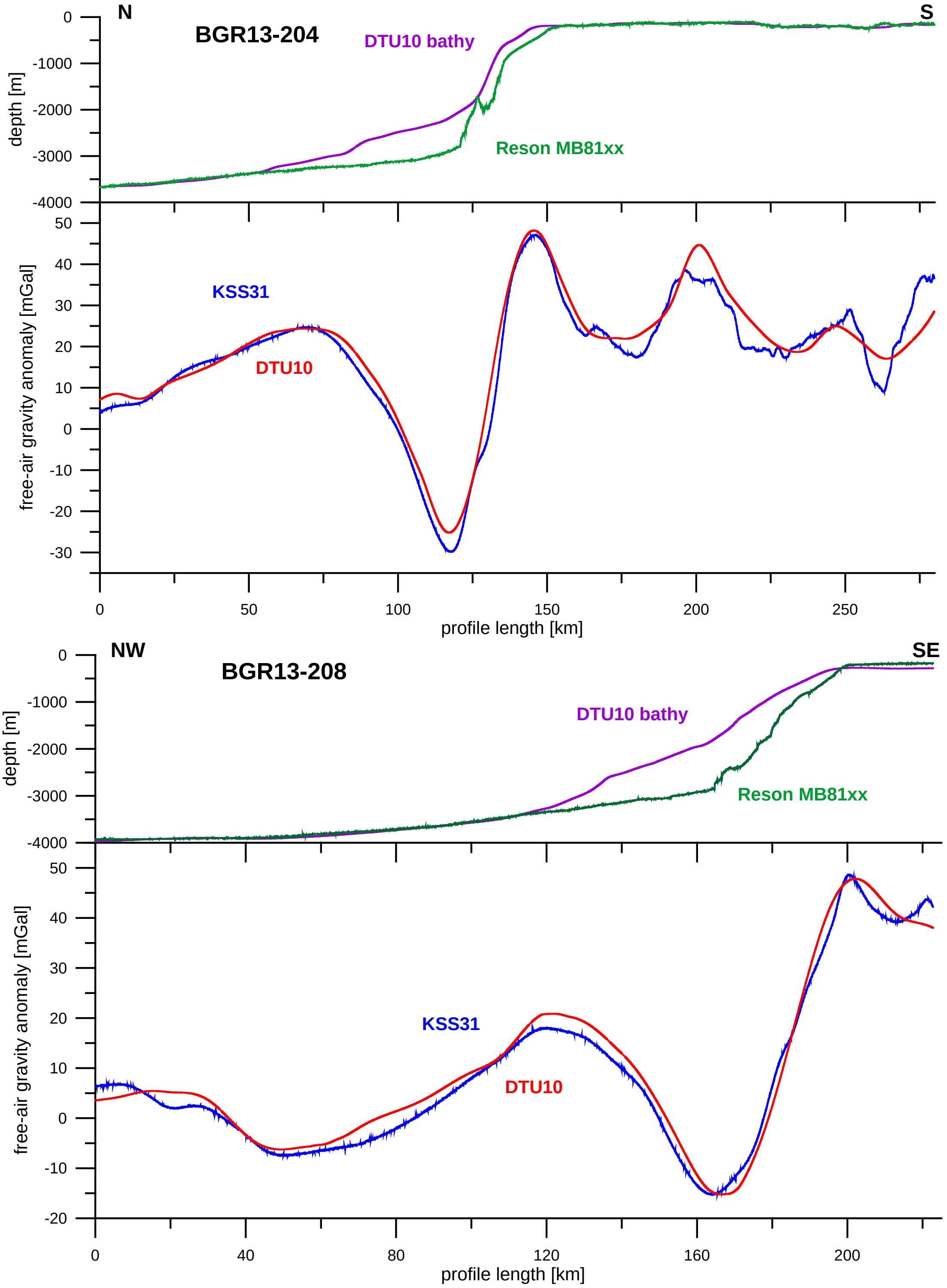


Fig. 22: Comparison of the ship-based KSS31 and satellite free-air gravity anomalies along profiles BGR13-204 (above) and BGR13-208 (below) together with the corresponding bathymetry measured with the Reson MB81xx multibeam systems and from the global bathymetry of Andersen et al. (2010).

To conclude, the free-air gravity anomalies derived from satellite altimetry are of great importance to get an overview of the gravity field in an oceanic area. For detailed investigations, however, shipboard gravity measurements are indispensable.

8.5.3 Gravity anomaly maps

Combined free-air gravity anomaly map

In order to get a complete overview of the gravity field in the survey area the DTU10 gravity data were included in areas with no shipboard data for the compilation of the free-air gravity map shown in Fig. 23. The anomalies range from -60 mGal north of the Yermak Plateau to +120 mGal on the shelf north of Spitsbergen.

The oceanic crust in the northern Nansen Basin is characterized by free-air gravity anomalies from about -10 and to +20 mGal. In this area water depths of more than 3500 m are reached. Higher gravity values can be correlated partly with topographic highs on the oceanic crust. The Sophia Basin and the southern Nansen Basin show slightly lower anomaly values. The prominent negative anomaly striking EW at about 81.8°N does not correlate with the bathymetry. Southward the gravity anomaly values increase considerably. The map reveals prominent positive anomalies parallel to the shelf break (up to +120 mGal). These anomalies are typical for rifted continental margins which are characterized by prominent free-air gravity anomalies elongated parallel to the ocean-continent transition. For example, these features could be observed along large portions of the Atlantic margins (Watts and Fairhead, 1999). Sleep and Fuyita (1997) demonstrated that a simplified ocean-continent transition (oceanic crust bordering directly on continental crust, both of uniform thickness and isostatically compensated) produces an asymmetric free-air anomaly located at this boundary with a high on the outer shelf and a low on the oceanic crustal edge. Also on the Yermak Plateau values up to +80 mGal are reached. On the broad Svalbard shelf the gravity anomalies vary considerably between +80 and -20 mGal. These variations could be explained partly by changes in the bathymetry. However a detailed investigation has to be performed. Especially gravity lows could give indications to sediment filled rift basins.

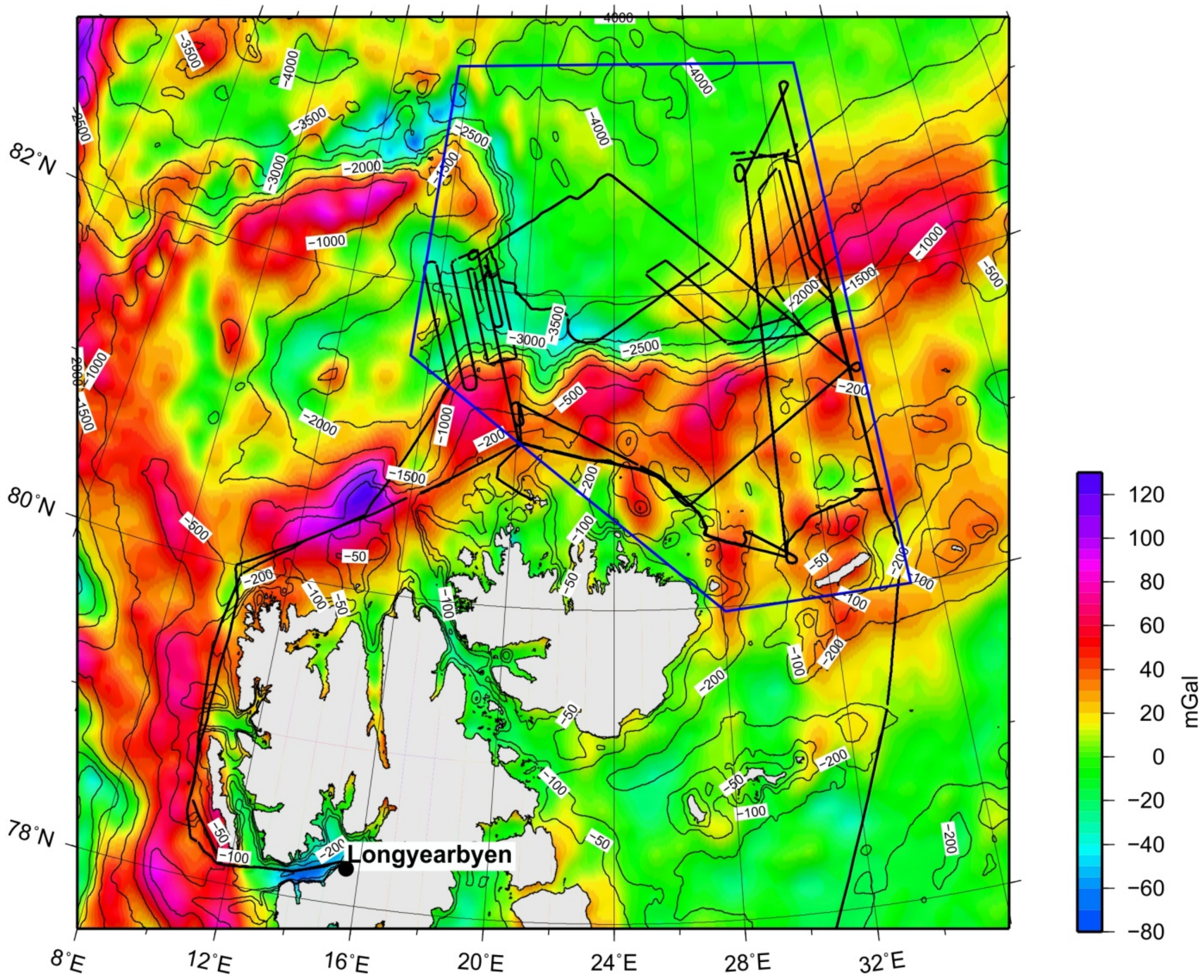


Fig. 23: Map of the free-air gravity anomalies. The underlying gravity grid was compiled by merging shipboard gravity observations and DTU10 gravity data derived from satellite altimetry. The map is based on a 1 x 1 (arc-)minutes grid and is underlain by the DTU10 bathymetry (Andersen, 2010).

Bouguer gravity anomaly map

The underlying grid of gravity was compiled by merging PANORAMA 1 gravity observations and DTU10 gravity data derived from satellite altimetry. The water depth values were taken from the ship's echo sounding system and from the DTU10 bathymetry data when no echo sounder depths were available. The reduction density was 1.64 g/cm³ and an infinite horizontal slab was assumed. A topographic reduction was not performed.

Fig. 24 shows the map of the Bouguer gravity anomalies together with the bathymetry. On the oceanic crust the anomalies are positive (up to +300 mGal in the north) with a clear north-south trending decrease of values towards Svalbard. Landward the values decrease as well rapidly. Low Bouguer gravity values (-10 mGal) are reached close to the Svalbard islands.

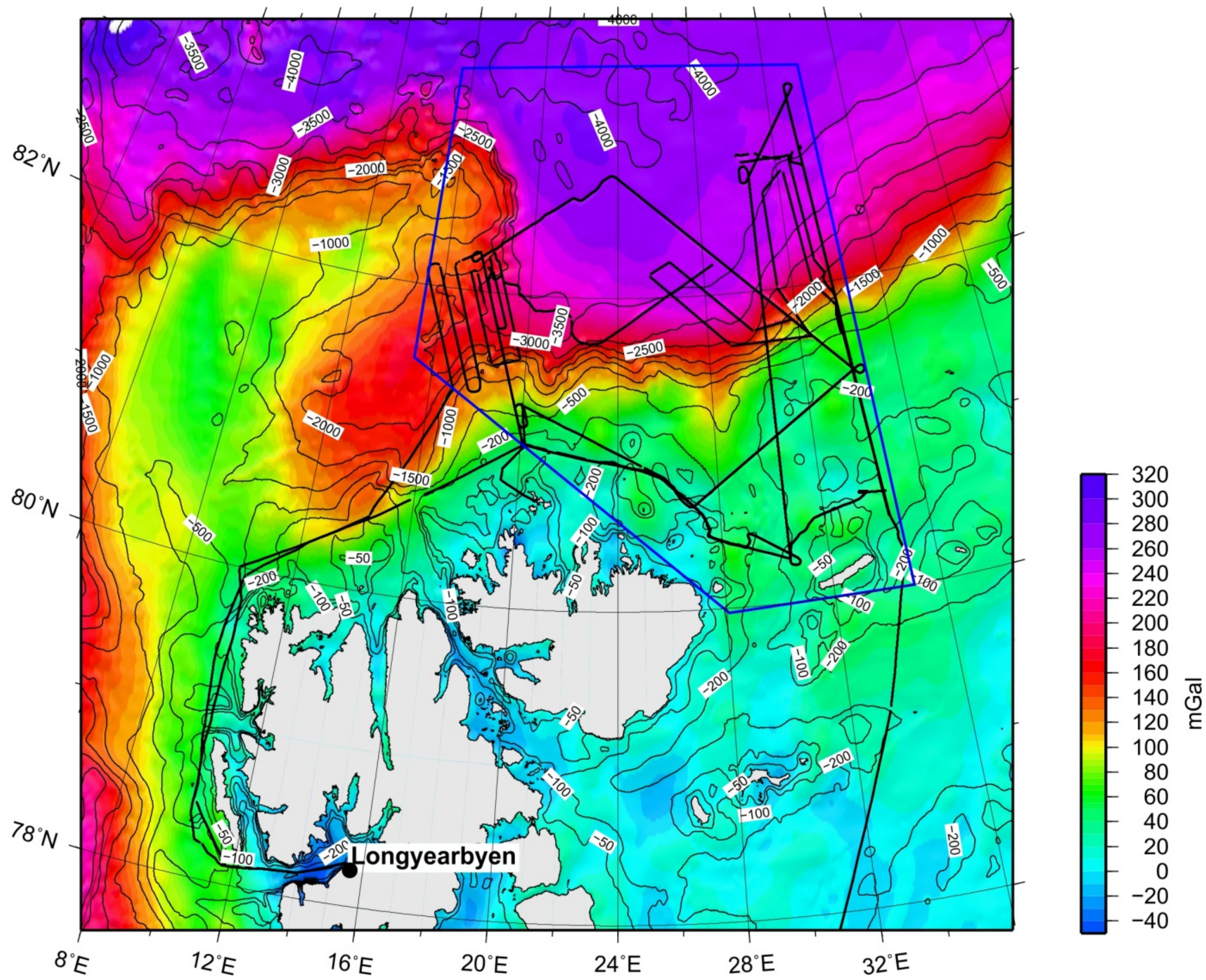


Fig. 24: Map of Bouguer gravity anomalies with no terrain corrections applied. The reduction density was 1.64 g/cm³. The map is underlain by the DTU10 bathymetry (Andersen, 2010).

8.5.4 Outlook

2D forward modeling of the free-air gravity anomalies along several profiles will be carried out with the software GM-SYS (Northwest Geophysical Associates, Inc.). The corresponding results of the MCS interpretation will be taken into account. The 2D models will represent first approaches to explain the observed free-air gravity and anomalies and form the basis of a comprehensive 3D density model which will be developed subsequently.

9. MAGNETICS

B. Schreckenberger, I. Heyde, U. Barckhausen and C. Gaina

9.1 Magnetometer systems and operation

9.1.1 Towed magnetometer system

The BGR SeaSpy™ gradient magnetometer system with two scalar Overhauser magnetometer sensors was used during cruise PANORAMA-1. It was manufactured by Marine Magnetics Corp. and consists of two proton precession magnetometers, enhanced with the Overhauser effect. Two equivalent magnetometer sensors are towed 150 meters apart as a longitudinal array about 550 meters astern of the ship (Fig. 25). Both sensors measure the total intensity of the magnetic field simultaneously. The difference between the two measurements is an approximation for the longitudinal gradient of the field in the direction of the profile line. Provided that the time variations are spatially homogeneous over the sensor spacing, the differences are free from temporal variations and their integration restores the variation-free total intensity or magnetic anomaly (apart from a constant value).

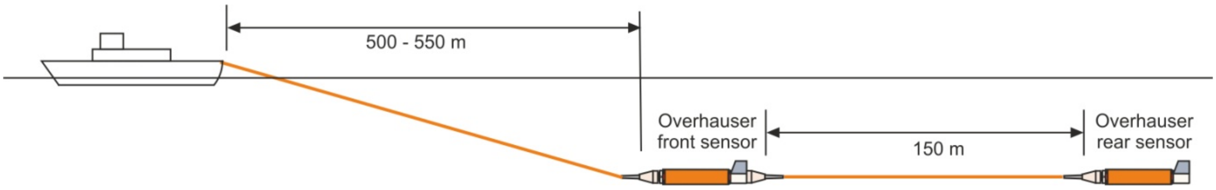


Fig. 25: Schematic sketch of the towed gradiometer system setup.

A standard proton precession magnetometer uses a strong DC magnetic field to polarize itself before a reading can be taken. Overhauser sensors work similar to proton magnetometers with the exception that the excitement of the proton spin (polarization) is done by radio waves which excite the spin of the electrons in an organic fluid within the sensors. The electrons then transfer their spin to the protons in the fluid via a quantum mechanical process called Overhauser effect. Similar to every other proton magnetometer the relaxation frequency of the protons is a measure for the magnitude of the ambient magnetic field. The polarization power required is much smaller than that needed by normal proton magnetometer systems and the AC field may be left active while the sensor is producing a valid output signal. This allows the sensor to cycle much faster and to produce more precise results than a standard proton magnetometer. As configured for this survey, the Overhauser sensors had a cycle time of one second. The sensors are specified with a noise level of 0.01 nT/√Hz, a resolution of 0.001 nT, and an absolute accuracy of 0.2 nT.

The towing arrangement was different between both Legs of the cruise. On Leg 1 the magnetometer array according to Fig. 25 was towed over an A-frame and an additional boom on the starboard side of the vessel in order to avoid interference with the reflection seismic equipment (Fig. 26a). On Leg 2 without seismics the magnetometers were deployed directly at the stern (Fig. 26b).

We used three different SeaSPY sensors during the cruise. On all profiles of Leg 1 and profiles BGR13-2M5 to -2M14 of Leg 2 the tow fishes with serial numbers 13140 (front) and 13546 (rear) were used. From line BGR13-2M15 on until to the end of the cruise the front sensor was replaced by s/n 13545 because s/n 13140 lost all its fins during ice contact. On all lines up to BGR13-2M8 the tow cable was 600 m long. During recovering the gradiometer after line BGR13-2M8 the tow cable was damaged near the winch and had to be shortened to appr. 550 m. The effective length of the cable behind the stern of the ship was appr. 550 m until line BGR13-2M8 and 500 m thereafter.

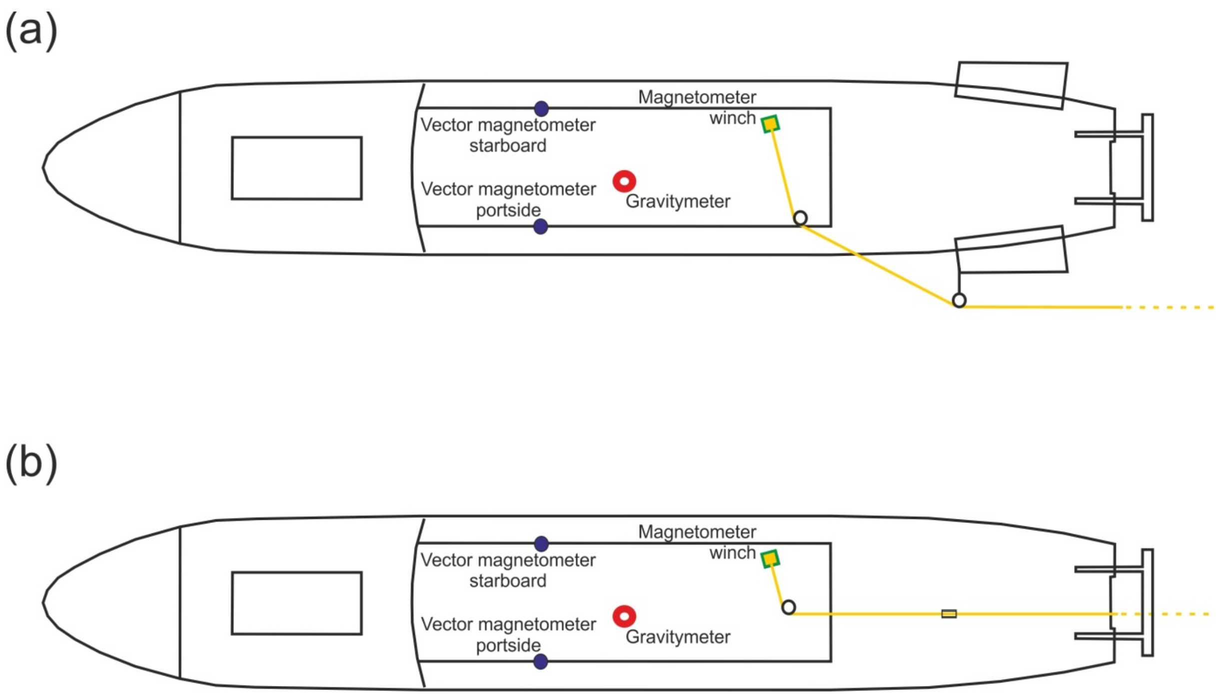


Fig. 26: Deployment configuration of the towed gradiometer array and installation locations of the ship-borne vector magnetometers on (a) Leg 1 and (b) Leg 2.

9.1.2 Shipboard vector magnetometer

A vector magnetometer system was installed on the observation deck of the vessel. It consists of two separate waterproof housings that contain orthogonal digital ring core fluxgate sensors and two-axis inclinometers, a data acquisition box and a GPS mouse. The system was built by MAGSON GmbH in Berlin for BGR as an onboard system for research vessels. The sensors have a dynamic range of +/- 100000 nT and a long-term stability of <10 nT/year and were fixed to the railing on the port and starboard sides of the observation deck (Fig. 7.2). The data are recorded internally on a CF memory card. Two different types of data files are stored separately for each hour. The first file type (file extension M60) contains the values of three orthogonal vector components and the inclination values together with UTC time marks. The sampling rate can be chosen between 1 and 20 Hz. On this cruise we used 10 Hz. The second file type (file extension S60) contains time marks and latitude and longitude from the GPS receiver and temperature values for both sensors. The sensors are internally heated to a selectable temperature, on our cruise to 30°C. Additionally we also recorded the values from the ship's motion reference units (heave, roll, pitch, and azimuth). Experience shows that roll and pitch values from the vessel sensors are more precise than the inclinometer values from the fluxgate sensors which notoriously suffer from errors due to dynamic accelerations.

Two dedicated vector magnetometer calibration loops were performed on September 3 (double loop from 22:36 to 22:51 UTC) and on September 10 (single loop at 17:00 UTC).

Using the data from the calibration loops and from additional loops and turns between seismic profile lines (Leg1) and coring and heatflow stations (Leg2) it will later be attempted to compensate for the ships magnetic field by estimating the compensation matrix during turns and to calculate total intensity values and magnetic anomalies from the vector components. Additionally it is intended to apply methods that were used by e.g. Seama et al. (1993), Korenaga (1995), Parker and O'Brien (1997) and Engels et al. (2008) to utilize the vector components for the determination of magnetic strike directions.

9.2 Data processing

Due to a malfunction of the computer which ran the SeaSPY data acquisition software during the cruise, the original files containing the gradiometer data are incomplete. The data were nevertheless recorded in the ship's data acquisition system. From here data files were extracted that contain all magnetic and position data. Oasis Montaj processing software was used to clean the data and to remove the IGRF 2010 reference field. Fig. 27 shows the IGRF corrected data for one Overhauser sensor without further data processing for each Leg separately.

Particularly during the first Leg, geomagnetic variations caused severe disturbances of the magnetic data. For the second Leg this is also true but to a much lesser extent. This observation corresponds to the recordings of the magnetic observatory Hornsund in the South of Svalbard that also shows a much quieter field for the time of the second Leg.

Only for two Lines (BGR13-202 and -204) from the first Leg we provisionally processed the gradient data but with great success. Especially the easternmost line of the whole survey (BGR13-202) was severely influenced by variations (Fig. 28a) that are now removed (Fig. 28b) to give a usable magnetic anomaly. On the other hand, line BGR13-204 obviously was only to a much lesser extent influenced by variations.

Fig. 30 finally shows the magnetic anomaly data after the first preliminary processing steps which here also include the removal of the linear anomaly trend of each single profile. This adhoc manipulation reduces the visually disturbing leveling problems (see some profiles e.g. from the first leg across the Sophia basin, Fig. 27) caused by magnetic variations. The magnetic color map in the background shows the CAMP-GM data set (Gaina et al., 2011).

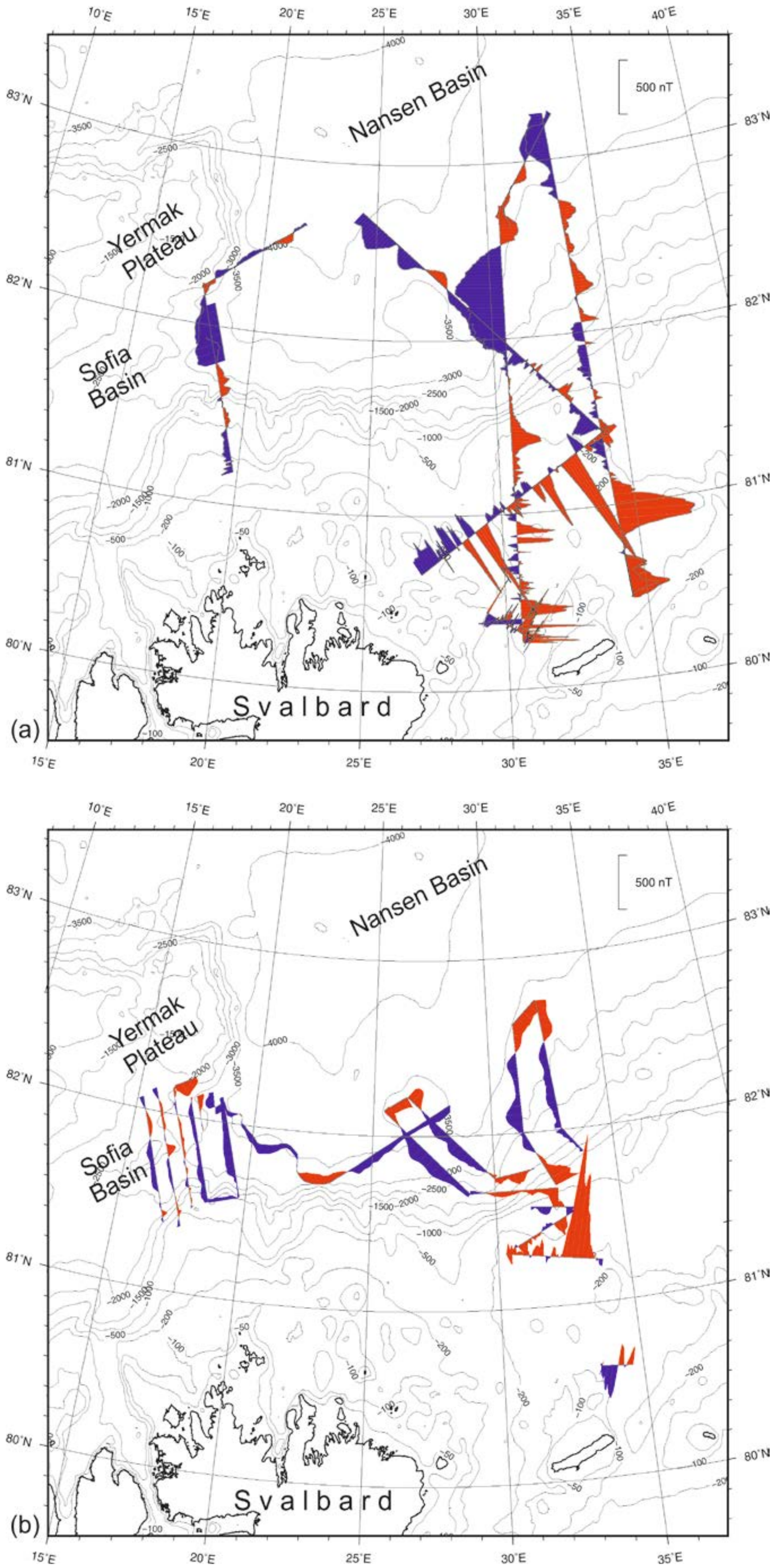


Fig. 27: IGRF corrected magnetic anomalies (red: positive, blue: negative) measured during cruise BGR13-2 (a) Leg1 and (b) Leg2.

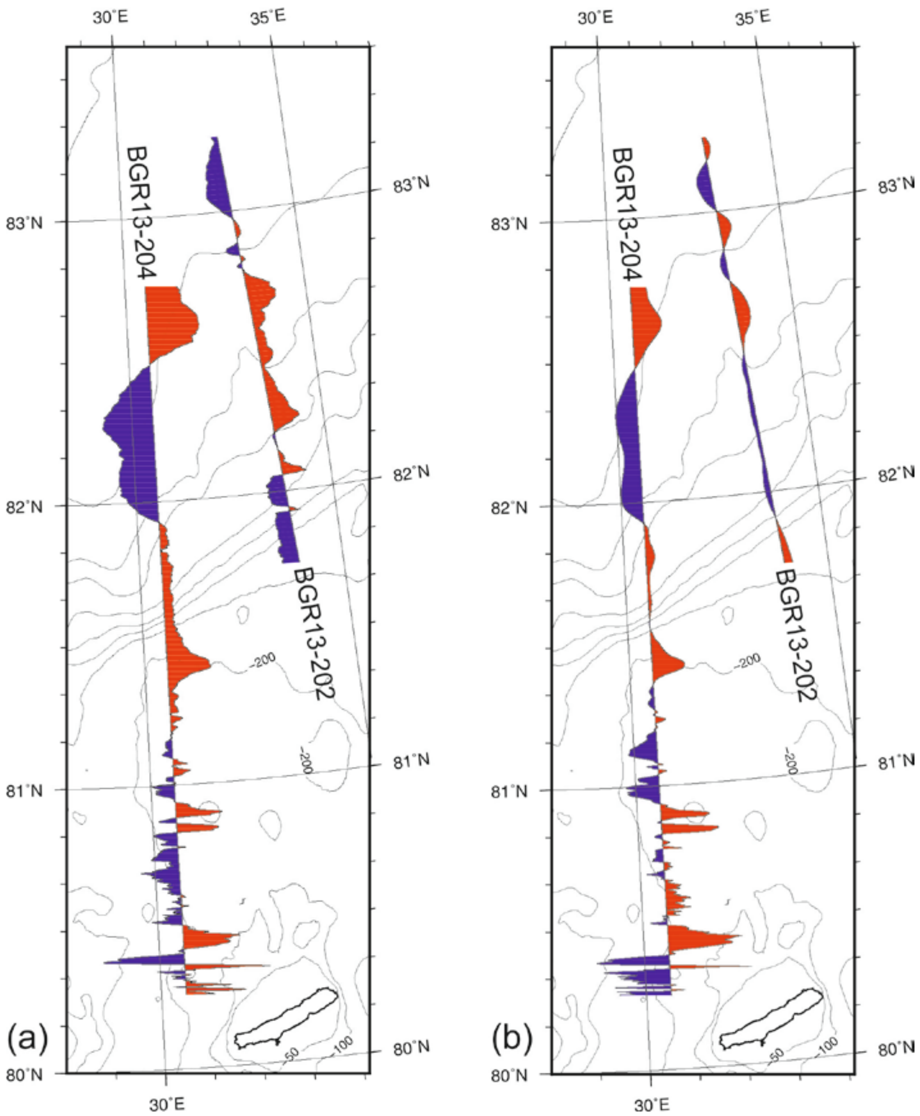


Fig. 28: Comparison of magnetic anomalies (red: positive; blue: negative) from (a) one sensor (front) and (b) reconstructed from the gradient magnetometer data. Version (a) contains strong magnetic variations, particularly on line BGR13-202 that are removed in version (b).

After the cruise the data will be converted into the BGR data acquisition and processing framework. Then, all routine and special processing methods for gradiometer and vector magnetometer data will be available. This includes a program package described by Eilers et al. (1994) and Roeser et al. (2002) that can be used to calculate the variation-free anomalies from the gradient. An alternative program suite (Engels et al., 2008) usually gives similar results for the reconstruction of the residual total magnetic field anomalies but is also able to process and calibrate the vector data.

9.3 Preliminary results

This short preliminary discussion refers to Fig. 29 and Fig. 30. The discussion can be divided into the western and the eastern survey area. The western profiles between 15°E and 23°E are grouped along two seismic lines (BGR13-206 and -207) that explore the southwestern tip of the Yermak Plateau. All profiles are located in the area of low to moderate amplitude anomalies. There are hardly any signs for extended or shallow volcanic basement rocks in the magnetic data as it is the case for the northwestern part of the plateau between 82° and 83°N. Also, the Svalbard and the Yermak Plateau margins of the Sophia Basin do not show a distinct or consistent magnetic signature. Particularly, there are no indications for lineations that could be correlated in the Sophia Basin.

The survey area east of 25°E can be divided into the shelf area and a deep water part. The shelf area is characterized by short wavelengths anomalies and locally high amplitudes, indicative for presumably volcanic basement rocks at shallow depths. The margin itself is magnetically inconspicuous suggesting that the margin to the Nansen Basin is of the non-volcanic type. The magnetic anomalies in the deep water area are generally consistent with the CAMP-GM anomaly map (Gaina et al., 2011). Magnetic lineations C23 and C24 according to the interpretation of Brozena et al. (2003) can clearly be identified but so far there are hardly any indications for C25 that was tentatively interpreted by Brozena et al. (2003) for this margin but can be seen somewhat clearer at the conjugated Amundsen Sea/Lomonossov Ridge margin.

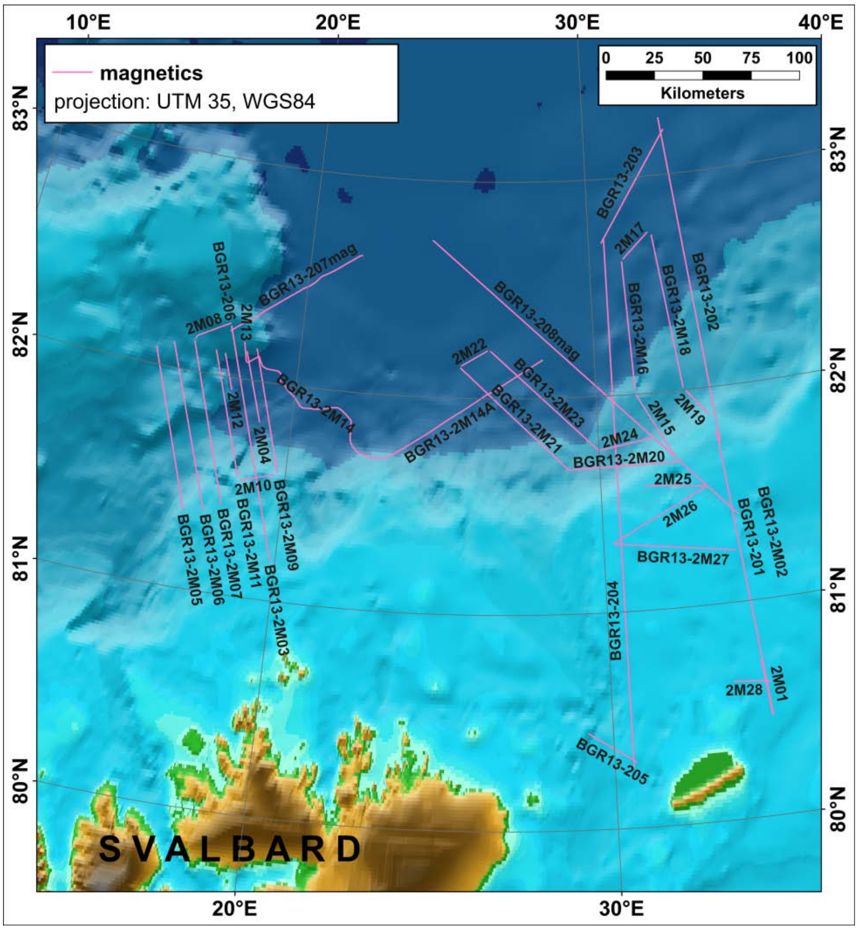


Fig. 29: Location of magnetic profiles acquired during cruise PANORAMA-1.

Fig. 30 also shows major differences between the CAMP-GM map and our new data for the shelf area between 82°N and 83°N. The CAMP_GM map shows a prominent magnetic maximum at 81.5°N/32°E which obviously does not exist and seems to be an interpolation artifact related to a gap in the original line coverage. Instead, short wavelength anomalies are present at that location that mimic the character of the anomalies in the volcanic area south of 81°S.

Further processing of the newly acquired data set will be necessary to ensure high data quality and a sound interpretation under consideration of other geophysical (reflection seismic, gravity and heatflow) and geological data.

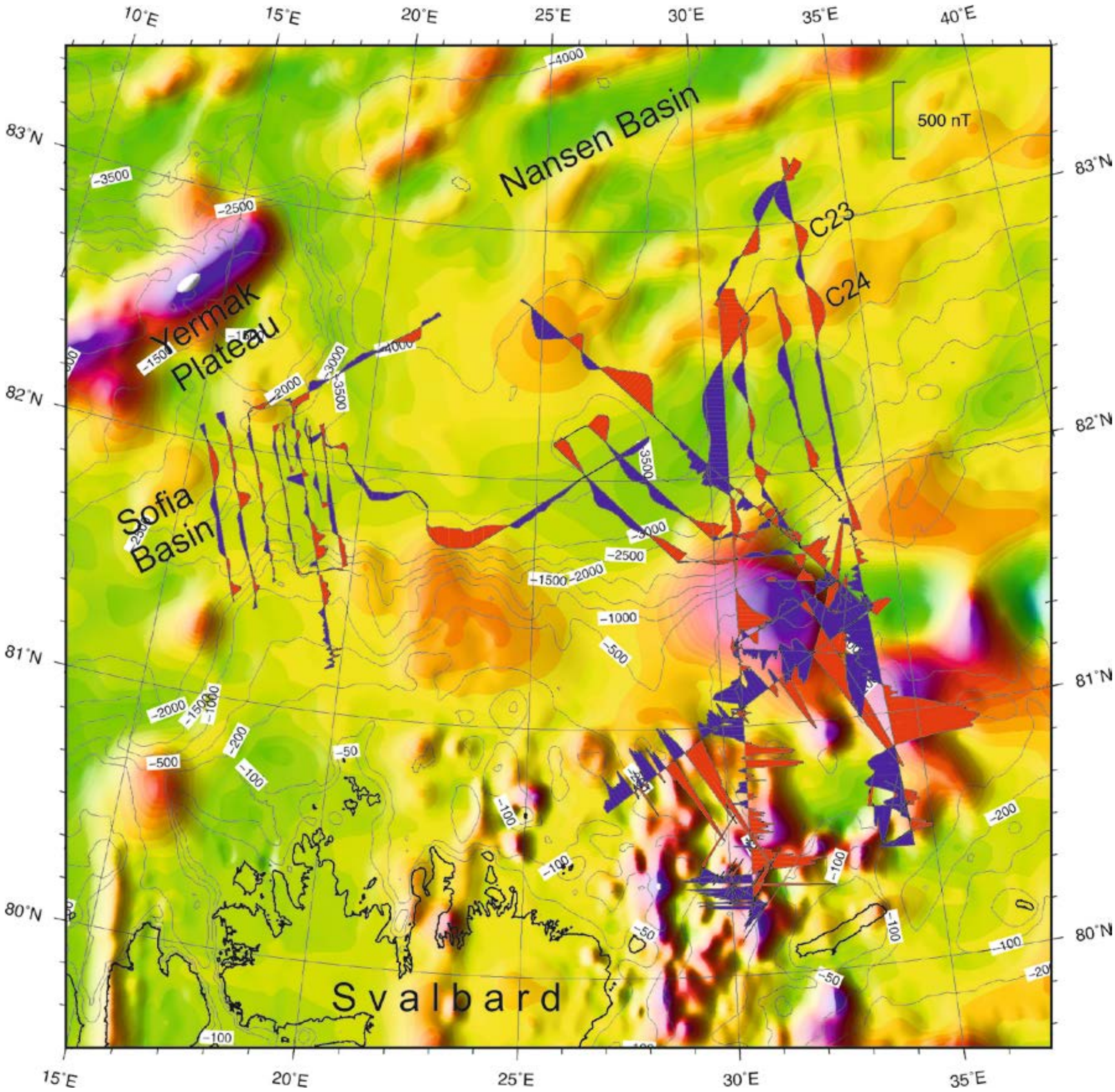


Fig. 30: Magnetic anomalies from cruise BGR13-2 (wiggle traces) and from magnetic anomaly compilation CAMP-GM (Gaina et al., 2011) (color map).

10. MULTI-CHANNEL SEISMIC REFLECTION (MCS) RECORDING SYSTEM

Axel Ehrhardt, Volkmar Damm, Ümit Demir, Timo Ebert, Thomas Behrens, Günter Kallaus, Kai Berglar

10.1 Methods

Two different types of seismic investigations were applied during the cruise in order to match the scientific tasks (Fig. 31). The imaging and identification of the sedimentary pattern and the uppermost crustal structure was carried out with multi-channel seismics (MCS) (see chapter 10.3.2). For a better control on the seismic velocities, the MCS method was expanded by sonobuoy wide angle and refraction measurements (see chapter 10.3.3).

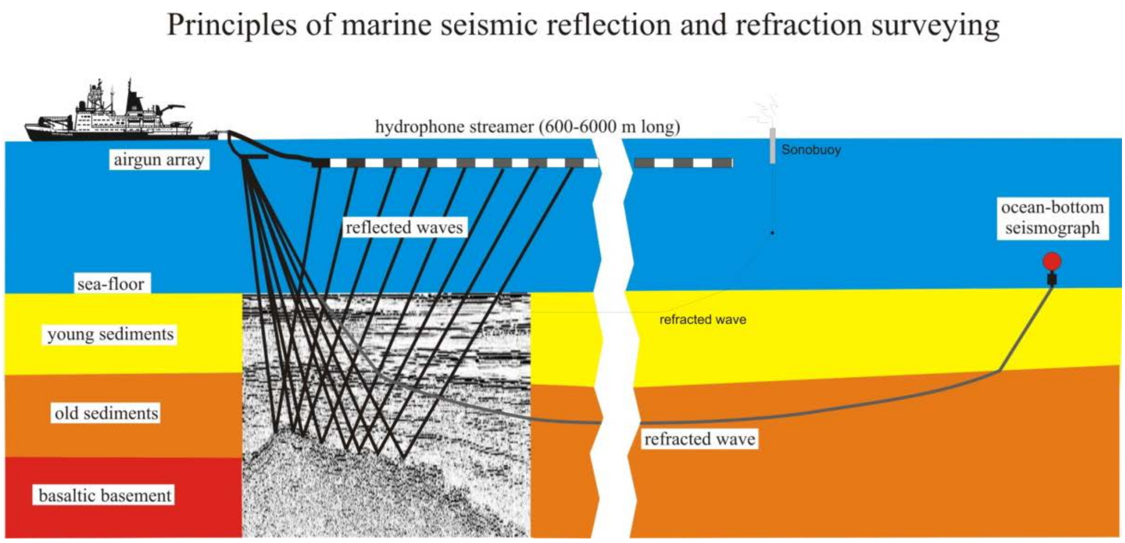


Fig. 31: Marine seismic methods: Multi-channel seismic (MCS) for recording of reflected waves, sonobuoy measurements for refracted waves.

All seismic operations were conducted in a way to minimize the acoustic impact and a possible disturbance of marine life as much as possible and to reduce operation times to the lowest practicable and necessary for the scientific goals. This follows best practice rules of BGR for using marine seismic methods within all own research activities. To meet this mitigation measures an external marine mammal observer was contracted.

10.2 Marine mammal observation to comply with environmental best practice standards

Nathan Griggs, Volkmar Damm

The Norwegian Government did not require that marine mammal observers (MMOs) are carried aboard seismic survey vessels. However, in the adoption of best practice to international standards, BGR implemented a MMO regime aboard the OGS Explora for the portion of the survey involving the use of a noise source array.

The Guidelines set down in August 2010 by the UK's Joint Nature Conservation Committee (JNCC, at www.jncc.gov.uk/marine) were adopted for, and adapted to use on this survey. The purpose of the JNCC Guidelines is to minimise the risk of possible injury from seismic survey source operation to marine mammals including seals, whales, polar bears and walruses.

There was one certified MMO, contracted through RPS Energy in UK, to fulfill the obligations in mitigating for seismic survey operations in the sea area to the north-east of the Svalbard archipelago during BGR–Cruise PANORAMA -1.

The role of the trained MMO was to:

- advise on the use of the JNCC Guidelines in all seismic survey activities and;
- suggest modifications to the Guidelines for the special circumstances of the survey,
- and conduct visual searches for marine mammals prior to the use of the source array.

The MMO was assisted in his work by three members of the BGR team who had previously completed a training course, recognised by JNCC, in marine mammal observation techniques and procedures.

The specific mitigation measures adopted by the operator should be appropriate to minimise the risk of causing harm to marine mammals and should implement the following best practice measures. The roles of the MMOs were as follows:

- Conduct 60 minute (for waters over 200m deep) pre-shooting watches of a 500m exclusion zone around the source array to ensure the absence of marine mammals before the commencement of soft-starts.
- To monitor soft-starts of the seismic array to ensure a minimum of 20 minutes in (and no greater than 40 minutes) in duration.
- To ensure that marine mammals have the opportunity to leave the survey area and request a delay to the soft-start if a marine mammal is sighted within the exclusion zone.
- To advise the crew on the procedures set out in the JNCC Guidelines and to provide advice to ensure that the survey programme is undertaken in accordance with those Guidelines.
- To conduct watches in daylight hours, and so document any marine mammal sightings.
- To document and report all source array use hours, observation effort hours, mammal sightings and mitigation and compliance issues.

MMOs kept a full watch nearly all daylight hours – at this latitude it was daylight 24 hours each day. Limitation on personnel numbers precluded the period of midnight to 2 a.m. from being covered. The lead observer worked, or was on call, from (local) 6 a.m. to 10 p.m. The other trained BGR observers worked 2 hour shifts in turn, to cover the remaining periods.
The JNCC Guidelines were modified in the following ways:

- Mitigation guns -
  due to the problem with icing up of the source array in frigid waters, it was determined that in turns between survey lines the airguns would be left running (where there was no need to remove them from the sea for maintenance/ repair) at low power.
- The use of (part only of) the source array in the turn phase proved advisable overall, given the prevalence of fast-developing fog (occurring on most days) in the survey area – the resulting restricted visibility meant a mitigation airgun was appropriate for warning and warding off nearby marine mammals.

- Pre-watch duration -
  in order to keep the administration of the watch duties simple for all concerned, it was decided to maintain a 60 minute pre-shoot watch on all occasions when the source array was to be started afresh (by the soft-start procedure).
- The detailed final MMO report, by week, is attached in the Appendix A10

The following procedure was employed to conduct the seismic data acquisition following the above guidelines of JNCC:

1. 1.5 hours (appr. 6 nm) before reaching the first dedicated shot point on the line NavLab informs MMO (call bridge) to start mitigation observation
2. In case of the event, that mammals are sighted within the mitigation radius in this period, MMO calls Party Chief/Deputy to decide whether to slow down speed / make a turn/keep going while observation period has to start again.
3. After completion of observation period MMO calls Gun Shack to start soft start. Ramp-up is done by shooting with 20 sec intervals for 3 minutes one gun by the other. Gun Shack gives notice to NavLab and SeisLab before starting ramp-up.
4. NavLab informs SeisLab about remaining time until first shot point on line to prepare for data acquisition.
5. After completion of soft start Gun Shack calls NavLab.
6. NavLab checks remaining time until start of line and informs SeisLab.
7. SeisLab starts recording (note: recording might be started before reaching the preset first shotpoint!)
8. 15 min before completion of line NavLab informs SeisLab and Gun Shack.
9. After end of line and run out SeisLab informs Gun Shack to stop shooting during line change (in case of bad visibility/darkness 1 gun is fired every 2 minutes)
10. NavLab calculates the expected time till the next start of line and procedure has to follow starting at point 1.

10.3 Seismic equipment and survey setup

The survey area in the North Barents Sea can be subdivided into the shallow part that is characterized by highly compacted sediments directly beneath the seafloor and unknown basement nature. The deeper part north of the slope to the Nansen Basin consists out of normal sediments covering a sheared or passive continental margin and probably oceanic crust, however, unpredictable sea ice and ice berg conditions handicapped continuous seismic data acquisition. The target was to ensure deep signal penetration in order to identify and map the basement structure. Owing to these preconditions we decided to use a streamer with a maximum length of 24 ALS-Sections. The active length of the streamer was 3600m.

In general the streamer was towed in a depth of 12 m, for the enhancement of low frequencies and in order to avoid ice contact.

A powerful source of eigth 250 in³ G-Guns was fixed in 2 rows with 4 guns each. The distance between the two arrays was 14 m. These two gun arrays were towed close to the stern of the vessel (approx. 25 m behind the stern) in order to protect the guns and umbilicals from drifting ice bergs and growlers.

The streamer consisted of 24 fluid sections (ALS, channel 1 – 288). No tail buoy was used, also because of the unpredictable ice conditions. The streamer winch was placed middle of the working deck and deployed by use of the A-frame at the stern.

10.3.1 Seismic sources, triggering and timing

Airgun system

On Board of OGS Explora we used the OGS GI-Gun hanger system with four 250 in³ G-Guns. The G-Gun array is subdivided into two sub-arrays. Each sub-Array consists of two two-gun clusters. The volume of each gun was 250 in³ (4,1l). The total volume of the starboard and portside array was 2000 in³ (32,8l) in use. The compressed air was produced by three LMF-Type 240HB Compressors. Each was capable to produce 24.000 m³/min at 140 bar working pressure. Every LMF-Compressor was powered by a 362Kw MAN Diesel engine.

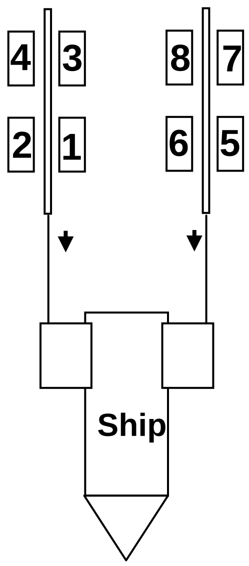


Fig. 32: Sketch of the airgun setup used on OGS Explora. The distance of the center of each array was 25 m behind the stern of the vessel.

The towing depth of the airguns was 6m troughout the survey. The center of each sub-array was 25 m behind the stern of the vessel. The lateral distance between the arrays was 14m. The nominal working pressure of the guns is 2.100psi (145bar). Triggering and synchronization was controlled by a BigShot Gunsystem from “Real Time Systems”. The triggering Signal came from the Shipnavigation laboratory. Before stating the measurements we enlarged the airgun power stepwise during a soft-start phase (ramp-up). The ramp-up was done by shooting with 20 sec. intervals. During this soft-start period we enabled for 3–minutes on each Gun. The complete Airgun volume was in use by 24 minutes. For details see the observer logs.

Fig. 33: Starboard G-Gun-Line consisting of two clusters hanging from the A-Frame close before deployment. In background and lower left corner the two buoys (orange) carrying the Gun-Line are to be seen.

10.3.2 Multi-channel seismic reflection (MCS) recording system

BGR’s SEAL seismic recording system and a digital cable with an activ length of 3600 m were used to record the seismic data. The bird controlling system (DigiCOURSE System3) and the streamer control system are interfaced with the Master PC. The system start trigger was generated by OGS-Navigation. The data for the external header, e.g. from the DigiCOURSE System3, navigation system, GPS-clock, pressure, etc., are received and the external header was generated, stored and sent via an interface to the SEAL system and to the navigation system (Fig. 36). An AGC with a 1000 ms window length was applied to the data.

The DigiCOURSE System 3 was used to control the vertical streamer position (depth) and to measure the heading and temperature. DigiCOURSE System 3 is a hardware and software package that controls and collects data from a network of acoustic sensors and streamer positioning devices (Fig. 34). The system has online command, diagnostic, and performance-monitoring capability. System 3 employs a modular architecture which provides for a variety of configurations and levels of functionality. The minimum system equipment configuration includes two real-time processors: an Operator Interface (OI) and a Data Management Unit (DMU), a Line Interface Unit (LIU), and cable-mounted measuring devices: birds with compass. It is suggested to get the full equipped streaming device self buoyant. To produce more buoyancy we mounted at each bird position a floatation tube or instead that a recovery system which has a self triggering mechanism at a depth of 50 m. We operated the cable at a depth of 12m.

Fig. 34: DigiCOURSE System 3 bird with compass

Streamer system

BGR's SEAL streamer consists of 24 seismic sections (24*ALS) with 288 channels (Fig. 35). It has a flexible architecture with redundant data transmission modes, i.e. data transmission may be reconfigurated on line failure. Each channel has an individual 24 bit, Sigma Delta A/D converter. The active streamer sections have a diameter of 50 mm.

The SEAL recording system is capable to handle a maximum recording capacity of 2000 channels (@ 12.5 m; 2 ms) per streamer, a maximum record length of 99 s, and a maximum number of 20.000 seismic channels and 60 AUX channels. The sampling rate may vary from 1/4 ms, 1/2 ms, 1 ms, 2 ms to 4 ms. During the cruise we sampled the data at 2 ms.

Up to 6 tape drives may be operated either simultaneously or in alternating modes. We operated two SDLT 320 and simultaneously one NAS system during the cruise. Data format is 4byte - SEG-D revision 2, demultiplexed 32 bit IEEE, Code 8058.

Fahrt PANORAMA 1 mit OSG EXPLORA

Profil BGR13-101

Slip Ring 12992-1006

	Lead In (200m) 50m	SHS	HAU	HESE (CB1)	HESE (CB2 WB)	HESA
		6m		50m	50m	10m
	118431	4803	878	1435	2692	4394

CB3	CB4/R1			CB5/R2				CB6				CB7/R3		
ALS 1	ALS 2	ALS 3	ALS 4	ALS 5	LAUM	ALS 6	ALS 7	ALS 8	ALS 9	ALS 10	LAUM	ALS 11	ALS 12	ALS 13
1 - 12	13 - 24	25 - 36	37 - 48	49 - 60	1	61 - 72	73 - 84	85 - 96	97 - 108	109 - 120	2	121 - 132	133 - 144	145 - 156
7024	7021	8633	7020	8628	**480**	8637	7030	8640	7027	8630	**557**	7026	7023	8617

CB8				CB9/R4			CB10			CB11/R5		CB12/R6		
ALS 14	ALS 15	LAUM	ALS 16	ALS 17	ALS 18	ALS 19	ALS 20	LAUM	ALS 21	ALS 22	ALS 23	ALS 24	TAPU	TES
157 - 168	169 - 180	3	181 - 192	193 - 204	205 - 216	217 - 228	229 - 240	4	241 - 252	253 - 264	265 - 276	277 - 288		50m
8634	8636	**5030**	7016	8631	7015	8638	5421B	**5035**	7022	7018	5942B	8639	**186**	4670

STIC	TS
25m	
168	4451

Gesamtlänge (Heck - Tail TES): 3.842m

Dst to stern	Bird No	S/N	
104	CB1 :	36056	
154m	CB2 :	36194	
307m	CB3 :	36464	Flotation Tube
457m	CB4 :	36707	Recovery 1
907m	CB5 :	36914	Recovery 2
1357m	CB6 :	42461	Flotation Tube
1807m	CB7 :	42778	Recovery 3
2257m	CB8 :	58797	Flotation Tube
2707m	CB9 :	58871	Recovery 4
3157m	CB10 :	59042	Flotation Tube
3457m	CB11 :	59524	Recovery 5
3757m	CB12 :	59560	Recovery 6

Blaue Spule für CB: Abstand von Headkupplung 140,6m (ALS), 47,5m (HESE)

CB: Compassbird R: Streamer Recovery Device 500 / 500S

Fahrt PANORAMA 1 mit OSG EXPLORA

Profil BGR13-101

Slip Ring 12992-1006

	Lead In (200m) 50m	SHS	HAU	HESE (CB1)	HESE (CB2 WB)	HESA
		6m		50m	50m	10m
	118431	4803	878	1435	2692	4394

CB3	CB4/R1			CB5/R2				CB6				CB7/R3		
ALS 1	ALS 2	ALS 3	ALS 4	ALS 5	LAUM	ALS 6	ALS 7	ALS 8	ALS 9	ALS 10	LAUM	ALS 11	ALS 12	ALS 13
1 - 12	13 - 24	25 - 36	37 - 48	49 - 60	1	61 - 72	73 - 84	85 - 96	97 - 108	109 - 120	2	121 - 132	133 - 144	145 - 156
7024	7021	8633	7020	8628	**480**	8637	7030	8640	7027	8630	**557**	7026	7023	8617

CB8				CB9/R4			CB10			CB11/R5		CB12/R6		
ALS 14	ALS 15	LAUM	ALS 16	ALS 17	ALS 18	ALS 19	ALS 20	LAUM	ALS 21	ALS 22	ALS 23	ALS 24	TAPU	TES
157 - 168	169 - 180	3	181 - 192	193 - 204	205 - 216	217 - 228	229 - 240	4	241 - 252	253 - 264	265 - 276	277 - 288		50m
8634	8636	**5030**	7016	8631	7015	8638	5421B	**5035**	7022	7018	5942B	8639	**186**	4670

STIC	TS
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2707m	CB9 :	58871	Recovery 4
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3757m	CB12 :	59560	Recovery 6

Blaue Spule für CB: Abstand von Headkupplung 140,6m (ALS), 47,5m (HESE)

CB: Compassbird R: Streamer Recovery Device 500 / 500S

Fig. 35: Streamer configuration used.

In-water equipment

The seismic data are amplified, filtered, and analogue-digital converted within the SEAL streamer by using the following main modules installed in the streamer: 1 LCI, 1 DCXU, 4 LAUM, 1 TAPU, 1 AXCU and 1 HAU.

ALS Acquisition Line Section
SSAS Solid State Acquisition Section
Both with a length of 150 m, an ALS/SSAS acquire data from 12 channels with an equal spacing of 12.5 m. Each channel receives data from a group of 16 hydrophones, with a capacity of 256 nF (@ 20°C), a sensitivity of 20 V/bar open circuit, and 17.4 V/bar, with electronics included.
HAU Head Auxiliary Unit
The HAU assures power supply for the TLFOI and measures the tensile strength value between the cable and the vessel. During cruise Panorama1 the stress was about 0.7 t.
HESE Head Elastic Section Extension
LAUM Line Acquisition Unit, Marine
TAPU Tail Acquisition and Power Unit

Onboard equipment

AXCU Auxiliary Channel Unit
The AXCU box contains FDU2M (Field Digitizer Unit 2 Marine). It is used to convert analogue data coming from the airgun array and the waterbreak-section.
5 auxiliary channels (AUX) are recorded (max. 6): Aux1= WB (waterbreak), Aux2 - Aux5 were not used according the AWI-Gun-frame was not prepared for.
CM408XL Control Module eXtra Large
DCXU Deck Cable Cross Unit & Line Acquisition Unit, Cross line, Marine
LAUXM The Deck Cable Unit, housing a Deck Cable Interface (DCI) and a Line
PWM2 PoWer Module generates a +175/-175 VDC voltage
PWMC PoWer Module Controller
HCI Human Computer Interface
The HCI is the control unit for the operator. Script files can be saved to and/or loaded from another computer and an online help is available.

The QC software running on a ‘SunBlade 150’ workstation enables the control of the following functions and settings via a permanent graphic display:

- Operation and function control of the different units (PWMC, PRM, QC) with automatic central control unit acceptance tests
- Concise display of system activity
- Automatic log of observer report data
- Display of power status
- Acquisition sequence controlled by external shooting system
- On-line real-time signal graphic analyser
- Printout of all parameters

PRM Processing Module

The PRM is a processor software module that is used for transferring the data to and from the cartridge drive, the NAS-Servers, to the plotter and the SeaProQC system. It is installed on a separate 'SunBlade 2500' workstation.

SeaProQC Sea Processing Quality Control

Continuous online seismic data quality control is performed using a SeaProQC workstation 'SunBlade 2500' connected directly to the PRM without slowing down the acquisition. Three main windows are used for quality control:

- The History display window with bar graphs shows a summary of errors and source attributes for the successive shots processed by the SeaProQC. It displays the attributes of the data from the previous shots.
- The Normal display window shows the latest incoming SEGD shot record. The traces are displayed in the time/distance range with the noise of each trace on top of the display.
- The Single Trace window shows the data of one selected channel from the streamer. With each new shot the display is updated with the new acquired trace added to the window. Four single trace windows may be opened simultaneously.

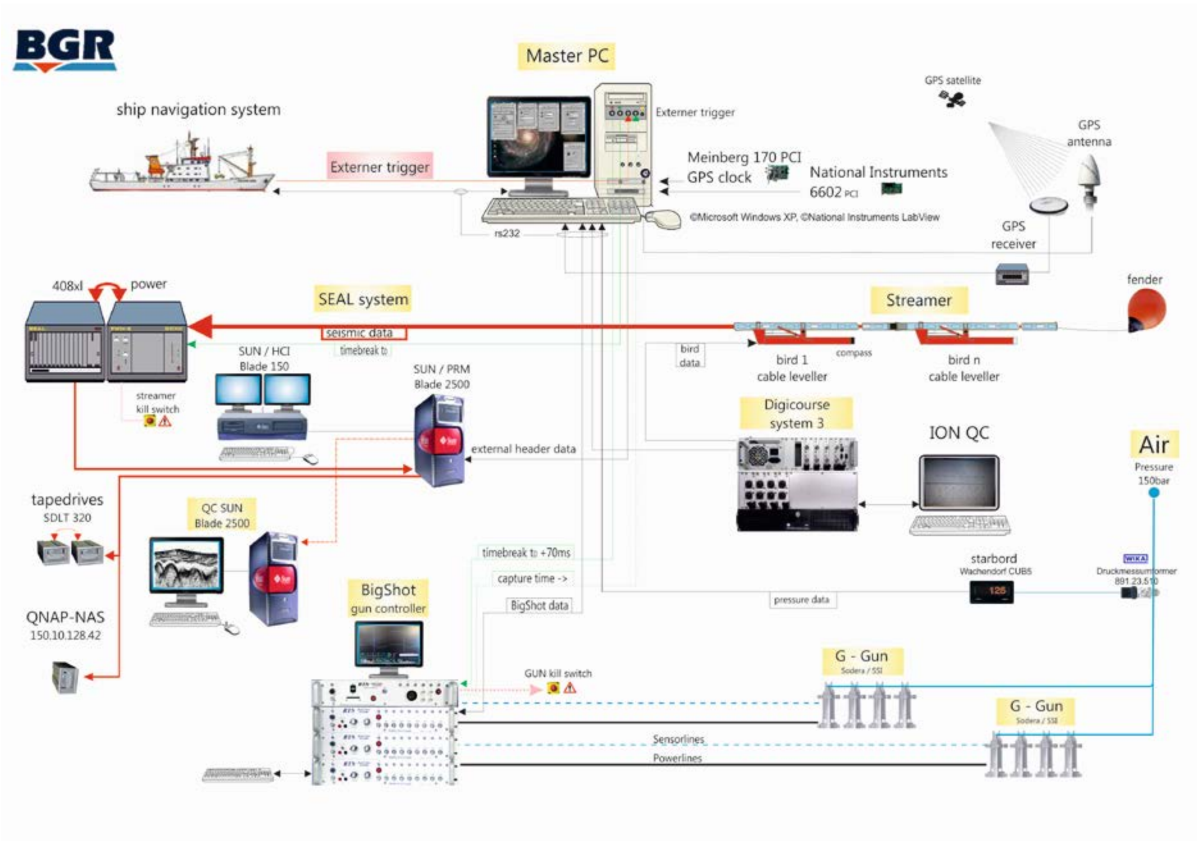


Fig. 36: Signal flow diagram for BGR's reflection seismic data acquisition system.

Shot triggering

Before starting data acquisition a soft-start procedure of the airguns was completed. During this procedure we operated 3 minutes with one gun, shooting all 20 seconds. After 3 minutes a second gun was added and two guns together were shooting every 20 seconds. So each 3 Minutes one gun was added and after 21 minutes the soft-start procedure was finished. After that the regular shooting began for production of seismic lines. Between two profiles, after EOL of the current line and before reaching SOL of the following profile, four guns went on shooting every 30 seconds and another 4 guns were inactive. Approximately 6 minutes before SOL every 2 minutes one additional gun was activated and at SOL all 8 guns are active.

The triggering of the guns during production was performed by OGS equipment. The shots were triggered by the OGS- Navigation System PDS2000 from Reson B.V. The intended shot distance of 25 m was achieved at a speed of approx. 4.0 knots. The shot trigger was sent to the RTS BigShot and to the Master PC simultaneously. After receiving the trigger the Master PC simultaneously starts the data acquisition cycle at the Seal system 50ms before shoting and waits for the timebreak signal received from Bigshot after shoting before transferring the external header data to the Seal-System. The Seal system recorded the data with a record length of 10 sec. The Master PC is running under Microsoft Windows XP and the Software is LabView Ver.8.6 from National Instruments.

Shot triggering for Sonobuoy-profile SB01

The shots for the **Sonobuoy** line BGR13-SB01 were triggered in time intervals of 30 seconds synchronized with GPS-Time over Meinberg GPS 166 clock. The shot time interval was generated by the OGS- Navigation System PDS2000 from Reson B.V. and sent to the RTS BigShot trigger device.

Quality control

Quality control during acquisition comprised:

- Continuous control of the airgun pressure
- Observation of the hydrophone signals within the arrays and adjustment of the trigger delays for an optimum signal.
- Checking and recording the streamer depth and position (heading) every shot via the control screen of the DigiCOURSE System 3. These data are stored in the header and are written on the field tapes.
- Continuous checks whether all sections of the streamer are free of abnormal noise and give about the same signal amplitude. This was done for every shot via the QC Graphics display of the SeaProQC system.
- Continuous observation of the single resp. near trace records.

10.3.3 Sonobuoy instruments for wide-angle seismic data acquisition

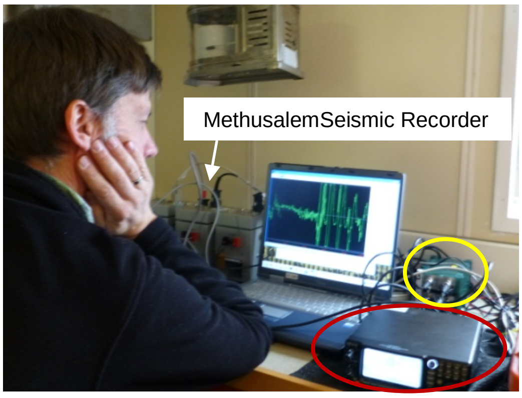


Fig. 37: Launching a sonobuoy from the stern of the vessel – Quality control of the received sonobuoy signal on the bridge deck. Red circle: Yaseo Radio Receiver; Yellow circle: Win-Radio Receiver

Marine sonobuoys (Fig. 37) were deployed to acquire wide angle reflection and refraction data to better determine the velocity structure of the sub-surface. Sonobuoys are recording the seismic energy released by the air guns and radio the information back to the seismic vessel. After entering the seawater, a salt water battery activates the sonobuoy. A surface unit (which contains the VHF-FM antenna) is inflated. After that, a cable pack pays out to a predefined length. At the lower end of the cable, a hydrophone is situated. A hole is burned in the plastic material of the float after a predefined time and cause the system to scuttle.

We used sonobuoys manufactured by Ultra Electronics, Type AN/SSQ-53D(3). These instruments were modified to be suitable for the amplitude and frequency response of acoustic seismic refraction measurements. The frequency response was increased in the 5-60 Hz band of interest. Before deployment, the sonobuoy was programmed to the desired life time, hydrophone depth and radio frequency. The life time can been chosen between 0.5 and 8 hours, the hydrophone depth may be in a range of 30 to 300 m and the signals can be transmitted between 136.0 and 173.5 MHz.

On the rear side of R/V OGS Explora funnel, a tuned and stacked Yaggi antenna was installed. Two Win-radios and one radio-receiver (Yaesu VR-5000) were set up in front of the radio office. The signals were recorded on a METHUSALEM-MBS recorder (SEND GmbH, Hamburg).

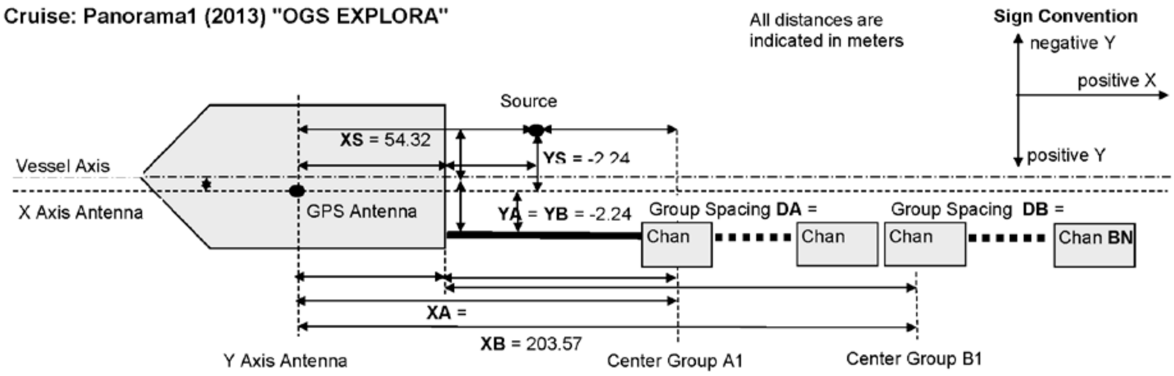
10.4 Processing of multi-channel reflection data

Seismic data processing was done using a Linux workstation with ProMAX™ 2D, Version 5000.0.1 licenses. The workstation has two Quadcore AMD CPUs, a RAM of 32 GB and a 170 GB system hard drive. The operating system is CentOS Linux 5.0. Data was stored on two internal hard drives. Backup was carried out on to an attached NAS system.

Onboard processing was done for all acquired MCS data including the following steps: geometry setup, data and geometry input, prestack processing to enhance signal quality including multiple reduction, data stacking and Kirchhoff migration. The ProMAX™ processing flows for these steps are attached as appendix A.5A to this cruise report.

Geometry setup

The streamer – airgun setup that was used during the OGS Explora cruise is summarized in Fig. 38.



Patterns Spreadsheet for 2D Marine Geometry Assignment in ProMAX from line BGR13-201 to BGR13-209

Mark Block	Min Chan	Max Chan	Chan Inc	Src Pattern	Grp Int	X Offset	Y Offset	
1	**A1** =1	**AN** = 288	1		**DA** =12.5	**XA** =203.37	**YA** = -2.24	Streamer Patterns
2	**B1**=	**BN**=			**DB** =	**XB** =	**YB** =	
3								
M								
M+1				1 **)		**XS** = 54.32	**YS** = -2.24	Source Patterns
...								

*) -1 if A1 > AN, 1 if A1 < AN **) The Src Pattern numbers has to be indicated in the SIN Ordered Parameter File

Depth of Source Arrays = 6 m
Streamer Depth = 12 m

Fig. 38: Sketch of the streamer and airgun geometry aboard of RV OGS Explora.

The geometry of the source and the receivers was set up in relation to the GPS antenna position. The active streamer length was set to 3.600 m with 288 channels for seismic lines. In ProMAX the 2D Marine Geometry Spreadsheet was used. It includes the following steps which have to be carried out in the geometry setup sequence:

File. UKOAA Import:

The navigation data were transformed by the navigation group into rectangular UTM coordinates and saved in the format “STANDARD UKOOA 90 Marine 2D”.

Setup:

All lines were acquired with 12.5 m nominal receiver spacing and 25 m nominal source station interval. The other parameters changed and are reported in the acquisition logs. All units are given in meters.

Sources:

The following columns in the spreadsheet have to be filled using the “Edit” option: “Source” and “Station”, beginning with 1 and incrementing with 1. The streamer azimuth has to be calculated using “auto azimuth”. The algorithm used for this by ProMAX is very crude. It is based only on the first and last source point, the calculated azimuth is assigned to all source positions. The column “Src Pattern” has to be filled with the number of the pattern defined in the next step. Shotpoint interval and error were checked by the QC tool.

Patterns:

The streamer and source patterns have to be defined according to the spreadsheet in Fig. 38 and the configuration of the used sources.

Bin:

The binning consists of three steps:

1. Assign Midpoint.
2. Binning. Source station tie to CDP number: This is usually shot number 1. In some cases the shots were already recorded when the ramp up was applied and the vessel still turned. In these cases the first shot on the line was noted in the acquisition logs and this shot should be entered as station tie to CDP number;
   CDP Number tie to source station: 10000. This tie fulfils BGRs standard for CDP numbering: The first station with full coverage is tied approximately to CDP 10000. Distance between CDPs: 6.25. This implies a nominal CDP coverage of 72 (for 288 channels) in case of a shot increment of 25 m. Binning was done for CDP locations and receivers (channel number decrease in shot direction).
3. Finalize Database.

TraceQC:

Quality control of the binning. Here two checks are undertaken:

a) Checking the computed offsets with the offsets given in the streamer plan by comparing the values for the last hydrophone group (channel 288) and nearest hydrophone group (channel 1).
b) Checking if the source and receiver locations (in UTM coordinates) are behind the vessel in relation to the sense of direction.

A further quality control was done by using the graphical display tools of the database application:

c) CDP fold map (Database => View => Predefined => CDP fold map). X_COORD and Y_COORD – Axes; FOLD: Color coded and as histogram.
d) CDP fold table (Database => View => Tabular => CDP): List of CDP Number, FOLD, X_COORD and Y_COORD.

SEG-D input from NAS and geometry application

Data were loaded from NAS hard drive using the ProMAX module SEG-D Input. The SEG-D Input module fails, if the path name to the segd files is too long. An acceptable work-around is to create a soft-link in the root directory to the segd-file directory.
The shot-ordered data consists of 288 data channels and 5 auxiliary channels sampled at 2 ms with a recording length of 10000 ms. The auxiliary channels record data from the waterbreak hydrophone; the remaining 4 aux channels were void. With the "Display ensemble information" set to YES a summary of all imported shot is written to the log-file. This is helpful in case that there are problems during acquisition and the FFID does not resemble the correct shotpoint. In case that there are FFIDs duplicated on the records the data may be read in SOURCE order with the unwanted FFIDs excluded (e.g. 1-1249, 1251-2400).

Resampling (Resample/Desample)

The seismic data has been acquired at 2 ms sampling rate. To speed up the onboard processing, the data has been re-sampled to 4 ms applying a high-fidelity anti-alias filter.

SOD time correction (Header Statics)

The Sercel acquisition system starts registration 50 ms before triggering of the airguns occurs. This time delay has been verified on the auxiliary channel containing the signal from the waterbreak hydrophone at AUX CHAN -1 and on the direct water wave on the groups near to the source.

Geometry Apply (Inline Geometry Header Load)

With this ProMAX module, the geometry information from the database were written into the trace headers.

Finally, the *Trace Header Math* module inserted an entry for the line number header word.

The altered data was written to hard disk as new prestack data set (*Disk Data Output*).

Prestack processing (for detail of individual steps see appendix A.5A)

Bad Trace Editing

The shot gathers were checked for bad traces. If present, these can be killed and thus been excluded from further processing. Anyway, the data recorded was of very good quality with no bad traces, which had to be deleted.

Bandpass Filter

After the examination of the interactive spectral analysis a zero phase Ormsby bandpass filter of 4-8-80-160 Hz was applied to the data.

Prestack Deconvolution

In order to reduce ringing within the dataset and to shorten the seismic wavelet, a single trace predictive deconvolution was applied. In general, the input ensemble can be a shot record, or a CDP or receiver gather. The deconvolution design gates were picked on CDP gathers.
One deconvolution design gate was specified for each location along the seismic section. The gate was picked within the uppermost part of the sediments, excluding the seafloor reflection which had to be adjusted according to the seafloor and subsurface morphology.
A single trace predictive deconvolution with an operator length of 170 to 220 ms and was applied with a prediction length of 32 ms. White noise level was 0.1. (For detail of usage see appendix A.5A.)

Velocity analysis

Two different velocity analysis tools were applied for onboard processing. A) the classic velocity analysis with supergathers at a regular CDP interval. B) the new SeisSpace Java Constant Velocity Analysis tool using a java environment.

A) Velocities were picked at regular intervals of 480 CDPs (equivalent to 3.000 m CDP spacing) along the lines. In case of large variations in seafloor topography and/or sub bottom structures the spacing was reduced to get an appropriate number of representative locations. Velocity analysis and QC were done in several steps.

B) SeisSpace Java Constant Velocity Analysis tool:
   1. Picking of velocity analysis stations. The spacing between individual velocity stations was adjusted to the variations in seafloor morphology.
   2. Sorting into supergathers (each supergather was built out of 9 to 11 CDPs) and calculation of semblance values and CVS panels (*Velocity Analysis Precompute*).
   3. Interactive *Velocity Analysis* using semblance velocity spectrum, animated reflection hyperbolas and constant velocity stack panels (CVS).
   4. QC and smoothing the velocity field with *Velocity Viewer/Point Editor*.
   5. Optional QC with *Volume Viewer* in interaction with *Velocity Analysis*. The *Volume Viewer* displays a poststack section with an overlay of the colour coded velocity field (RMS or interval velocity). Velocity stations and picks are shown on the section and could interact with the *Velocity Analysis*.

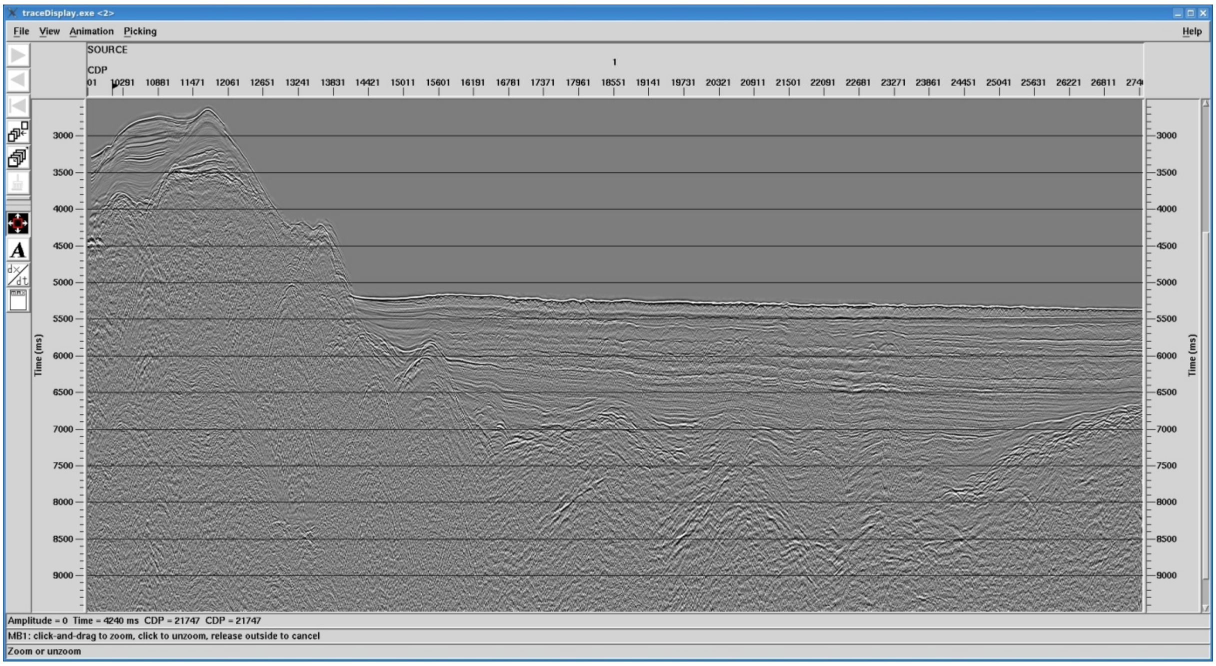
The various tools, namely to use QC during interactive velocity analysis, allow for careful estimation of stacking velocities. This was of special importance because of very high interval velocities right below the seafloor. The ProMAX velocity picking module included a semblance display with an interval velocity graph, a CDP supergather which could have NMO applied instantly, a series of constant velocity stack panels, and a dynamic stack panel.

RMS stacking velocities were picked by examining the information of the semblance spectrum (left panel), supergather CDP (center, left), dynamic stack (center, right) and constant velocity stacks (right panel). For improving the signal to noise ratio, supergathers were formed by combining 11 adjacent CDP gathers, and these CDP gathers also made up the stack panels. Amplitudes were corrected roughly by using True Amplitude Recovery with manually given TAR velocity function (e.g. 0-1500, 9000-4000, 13000-6000).

To speed up the on screen velocity picking procedure, the velocity analysis displays were pre-computed. After velocity picking, RMS stacking velocities were viewed and QC`d on screen using the ProMAX velocity viewer module. This module was most useful for editing any unreasonable velocity picks and finally to smooth the velocity field for the further processing. Furthermore, the viewer module was used to compare the interval velocity field with a brute stack version of the line. Based on this QC subsequently the velocity field could be further adjusted during an additional velocity analysis.

Radon Velocity Filter

The *Radon Velocity Filter* was applied to CDP gathers after NMO correction. Since multiple reflections have an approximately parabolic moveout after NMO they can be imaged in the tau-P domain. The filter will reject all data within a certain velocity bandwidth around the picked velocities (-15%, +20%). The other data will be treated as multiple energy and re-transformed into x-t domain and subtracted from the input CDP gather. Because this technique models and subtracts multiple energy, the near offset traces should be attenuated in the same manner as far offsets. In general the Radon Velocity Filter works well. However, in areas with high velocity gradients the Radon Velocity Filter produces high frequency noise, most likely because of the NMO stretch mute. Thus, the Radon Velocity Filter was applied only on selected lines



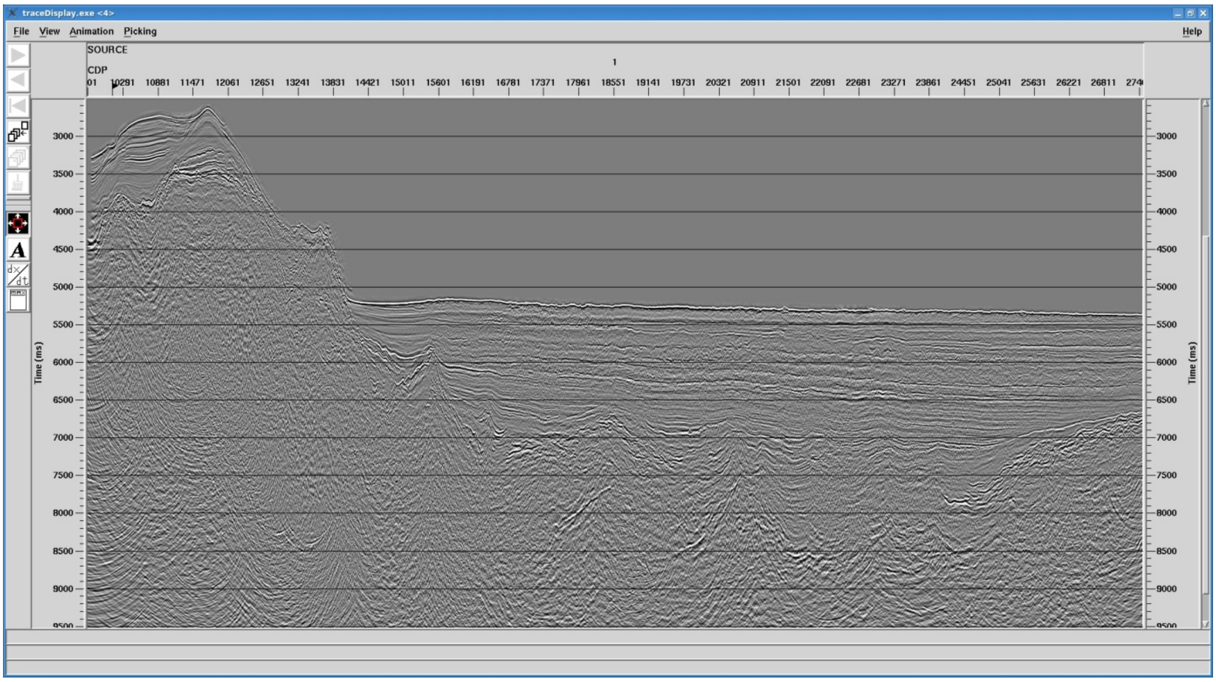


Fig. 39: Comparison between a stacked and Poststack Kirchoff migrated section BGR13-208.

Stacking

Before NMO correction of the CDP gathers a true amplitude recovery (TAR) has been applied using the smoothed RMS stacking velocity field to compensate for spherical divergence (1/(time*vel^2)). A radon velocity filter as described above was applied to suppress multiples on selected seismic lines prior to stacking. After stacking (mean stack) the traces in the CDP gathers, the stacked sections were written to disk.

Migration

All processed data are Kirchhoff time migrated. The migration velocities were calculated during the velocity analysis and had to be adjusted carefully sometimes. The stacking velocities (rms velocities) were scaled by about 90% for Kirchhoff migration. Migration aperture was set to 6000 m, the maximum migration dip was 30°.

Outlook

Whereas the reflection seismic lines from the deep Nansen Basin and the eastern Yermak Plateau are straightforward to process the lines from the shallow Barents Sea area are challenging. Please compare Fig. 39 and Fig. 40. Both lines were acquired with the same seismic setup. The very shallow and high impedance contrast seafloor in the Barents Sea makes a special processing regarding the de-multiple process necessary, in order to uncover the geologic structure.

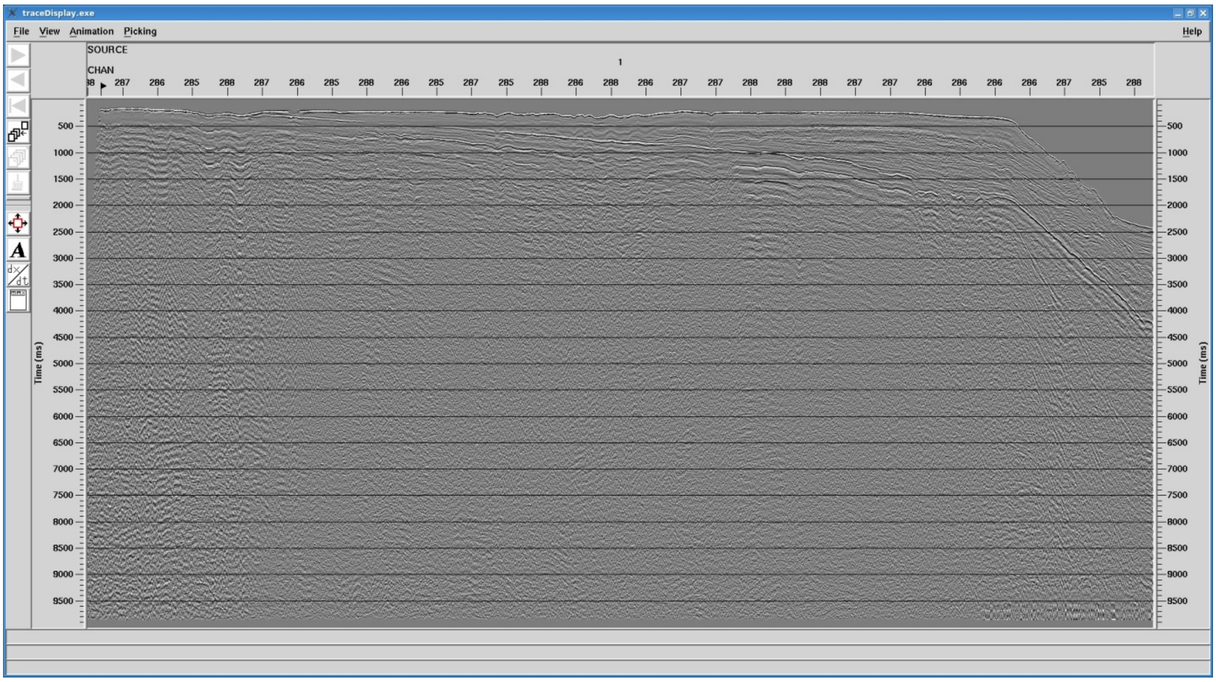


Fig. 40: Stacked section of BGR2013-201 running from the Barents Sea towards north into the Nansen Basin. The high impedance contrast from the seafloor reflects much of the seismic energy and the ringing of multiple echoes mask geologic structures. Standard de-multiple tools do not have the desired success. Special emphasis on the reduction of multiple energy is needed in order to image the Barents Sea sub-seafloor structure.

10.5 Description of seismic profiles

Volkmar Damm

The geophysical profiles represent three different structural provinces:

- The platform province in the North Barents Sea (seismic lines BGR13-201, -205 and parts of lines BGR13-204 and -208)
- The continental margin and transition to the Nansen Basin (seismic lines BGR 13-202, -203, parts of BGR 13-204, -208)
- The SE Yermak Plateau and transition to the Sophia Basin in the south and Nansen Basin in the east (lines BGR 13-206, -207)

Platform province

Line BGR13-201 (Fig. 41) runs from northeast of Kvitoya Island in parallel to the maritime border to Russia and perpendicular to the shelf edge. Water depth ranges from 100 to 400 m on the shelf. The high reflectivity of the sea bottom causing strong first multiple reflections in the vintage data and widely removed during pre-processing is originated by high consolidated sediments which experienced a strong compression due to glacier surcharge and glacial erosion. At the southern end of lines 201 and 204 the basement which is probably build up by Devonian to Early Cretaceous sequences (Grogran et al., 1999) crop out directly at the seafloor. The gentle northward dipping basement top is covered by prograding sedimentary sequences.

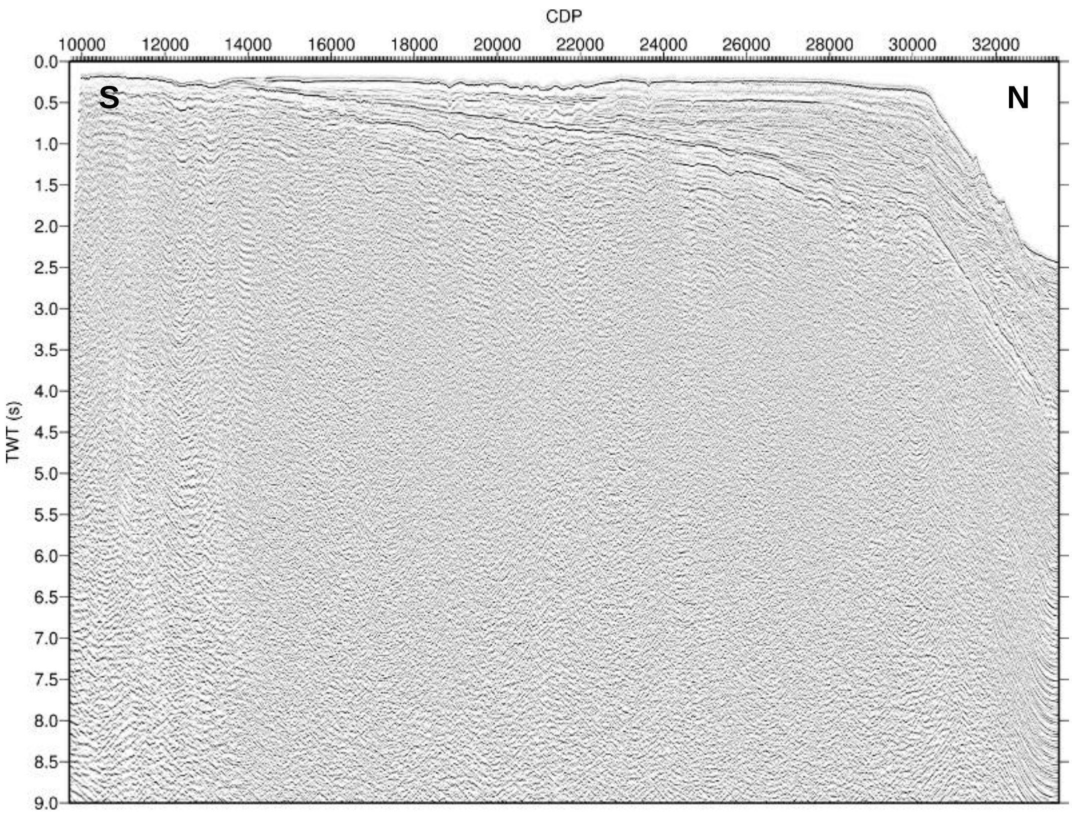


Fig. 41: Seismic line BGR13-201, running from the North Barents platform to the slope.

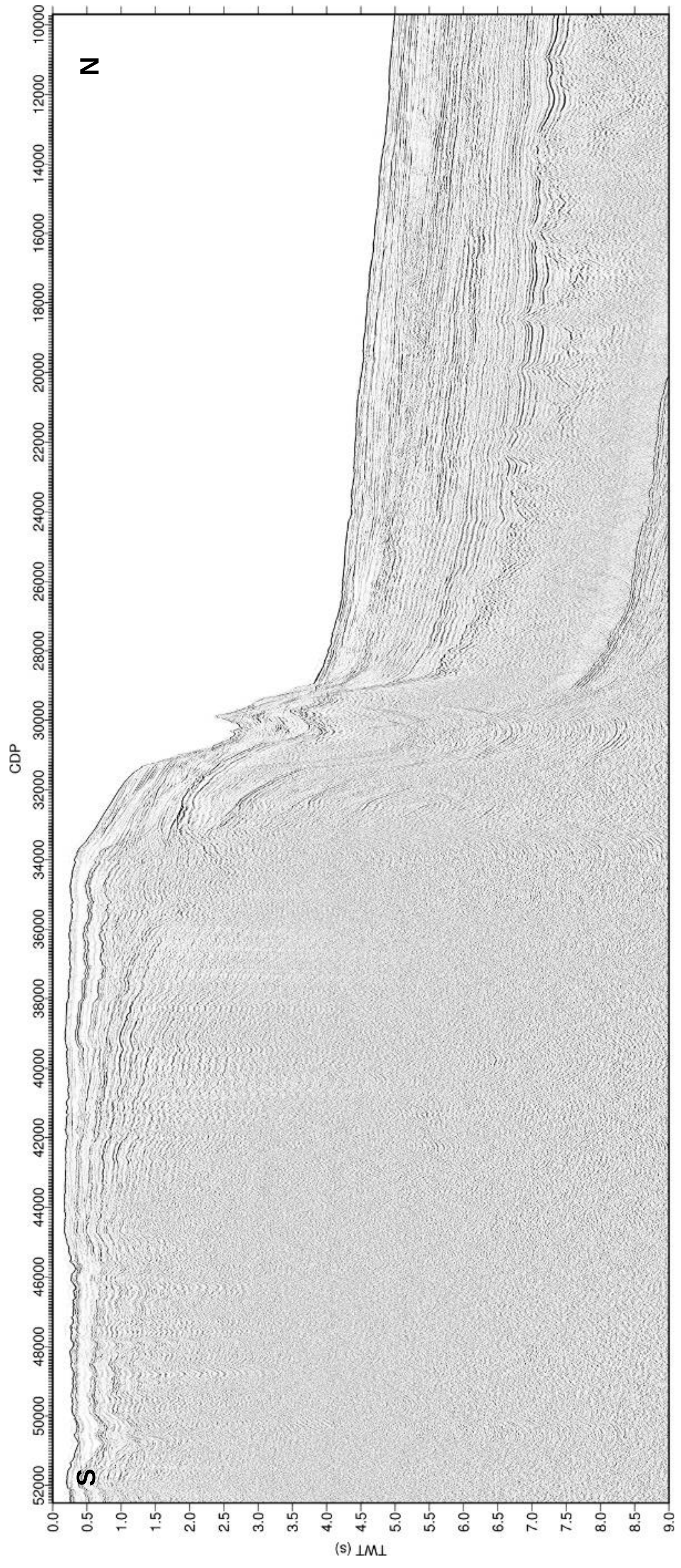


Fig. 42: Seismic line BGR13-204, running from the North Barents platform into the Nansen Basin.

Line BGR13-204 (Fig. 42) is located 50 km to the west. Multiple suppression was not incorporated in the processing flow during this pre-processing, therefore multiple reflections are more prominent in this profile. On both lines the inner shelf is only partly covered by thin sediment layers, which are strongly consolidated Palaeozoic/Mesozoic basement structures showing rough topography are exposed at the southern end of the line. The basinward dipping of the basement is probably caused by subsidence during early rifting. Thickness of sediment structures increases at the outer shelf to about 1.5 sec TWT. Close to the shelf break an outlier appears where the basement top is masked by opaque overburden.

Continental margin and transition to the Nansen Basin

Water depth rapidly increases from 200 m to 3000 m at the shelf break (line BGR13-204 –Fig. 42) and 3750 m in the basin centre. Since lines BGR13-201, -202 (Fig. 41, Fig. 43) cross the shelf edge oblique, water depth along these lines increases more gently than in lines BGR13-204 (Fig. 42) and -208 (Fig. 45). Fault blocks are developed along boundary faults during the Paleocene rifting process. Massive slumps and debris flows are documented at several locations at the slope. The sediment thickness in the Nansen basin varies between 2.0 and 2.5 sec TWT (line BGR13-203 – Fig. 44), locally ranging 3 sec TWT close to the hinge zone (Fig. 43). Sediments are mostly well stratified and show onlaps at the slope. Whereas the lowermost sediment layers do not show much thickness variation, the overlying younger strata thin out with increasing distance from the slope. The younger sediments are more influenced by slumping than the older strata. A hummocky topography of the basement, underlying the sediments in the Nansen basin indicates the oceanic nature of the crust. The ocean-continent border is clearly identifiable.

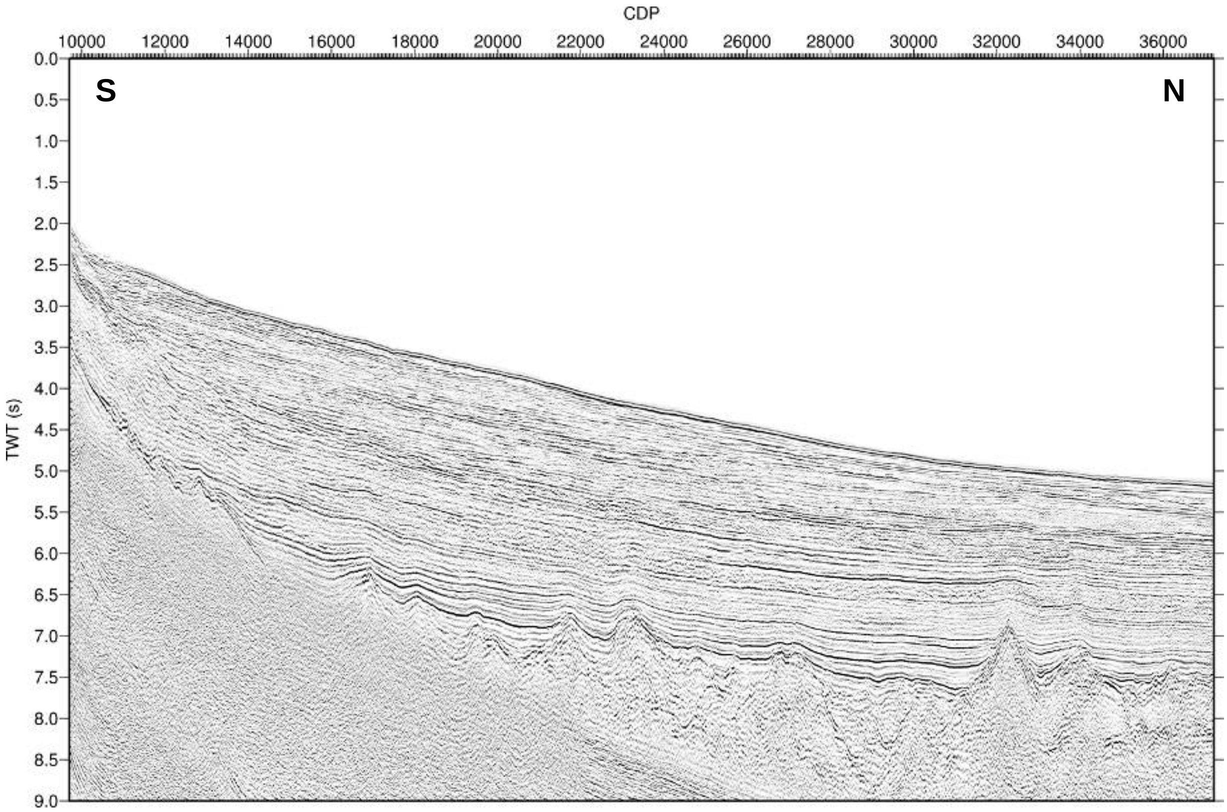


Fig. 43: Seismic line BGR13-202, running from the North Barents slope into the Nansen Basin.

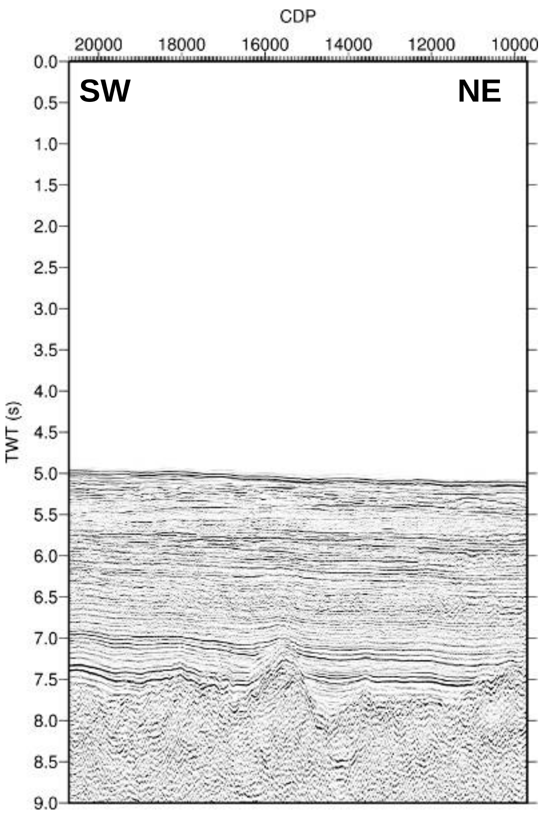


Fig. 44: Seismic line BGR13-203, oceanic domain in the Nansen Basin.

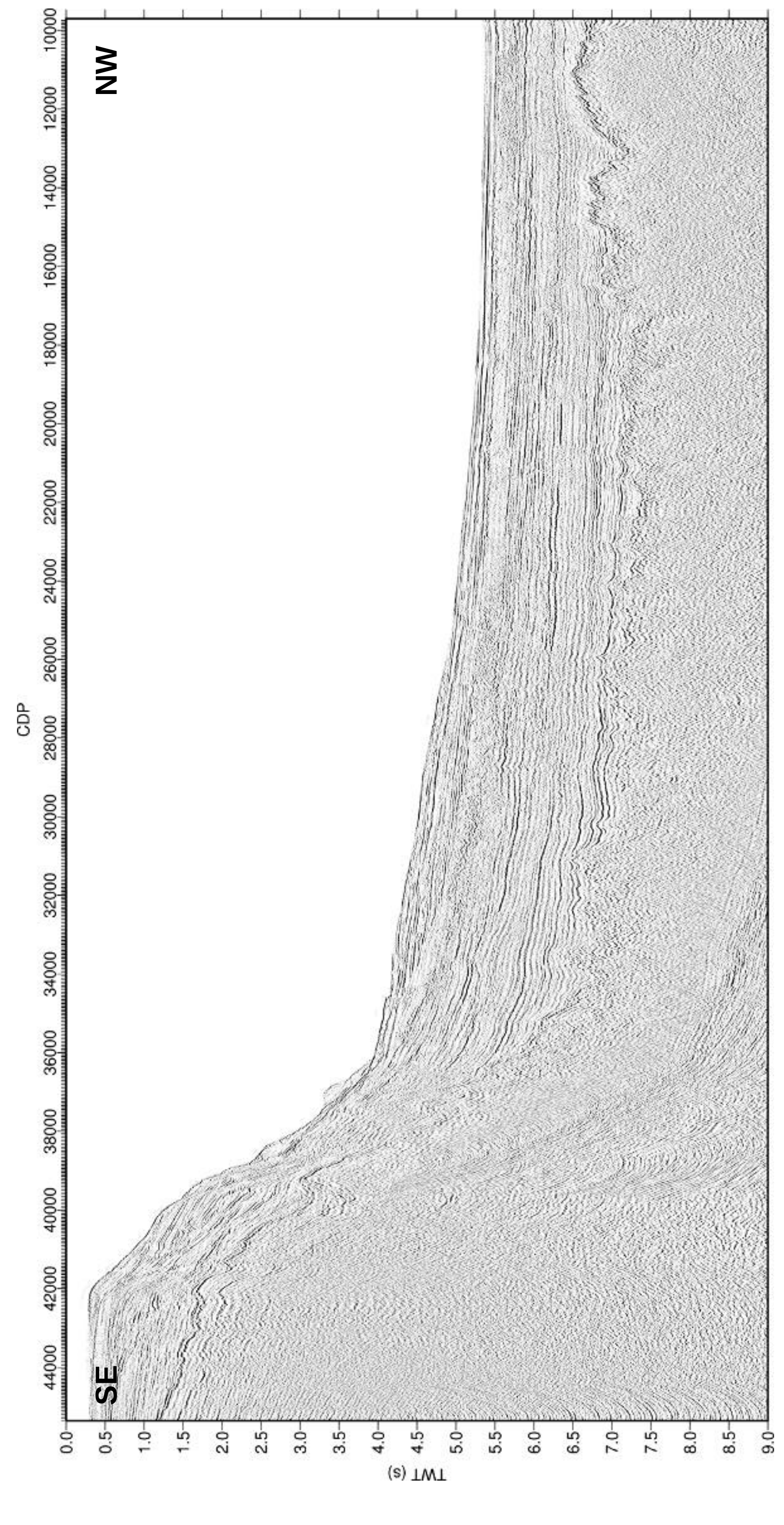


Fig. 45: Seismic line BGR13-208, running from the North Barents platform into the Nansen Basin.

SE Yermak Plateau and transition to the Sophia Basin and Nansen Basin

Due to bad ice and weather conditions seismic operations in this area was highly restricted. Seismic line BGR13-206 (Fig. 46) covers only the northernmost margin of the Sophia Basin.

Water depth along this line decreases from 3300 m in the Sophia Basin to 1800 m over the south-eastern part of the Yermak Plateau. Sediments are well stratified with lower transparency in the older strata. Sediment layers may be well correlated along the line and does not show much variation in thickness over the slope. At the lower slope the sediment sequences are dislocated by a massive slump event probably connected to subsidence in the Sophia Basin. Slumping is also obvious in younger sediments uphill the Yermak Plateau.

The eastern slope of the Yermak Plateau demonstrates different features (line BGR13-207 – Fig. 47). The transition to the Nansen Basin is built up of a steep shoulder and shows eastward block faulting. This infers crustal thinning and rifting along an axes perpendicular to the modern rift axes. The well stratified sediments in the Nansen Basin clearly show onlaps at the eastern flank of the Yermak Plateau. Provence of sediments in this part of the Nansen Basin is located in the south. This preliminary interpretation has to be verified by additional data and will be subject to subsequent studies.

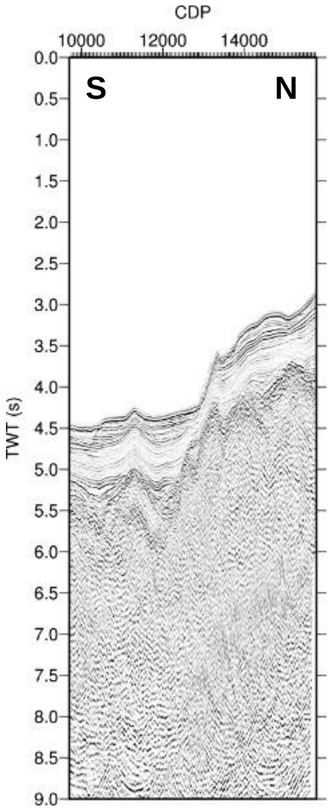


Fig. 46: Seismic line BGR13-206, running from the Sophia Basin to the SE Yermak Plateau.

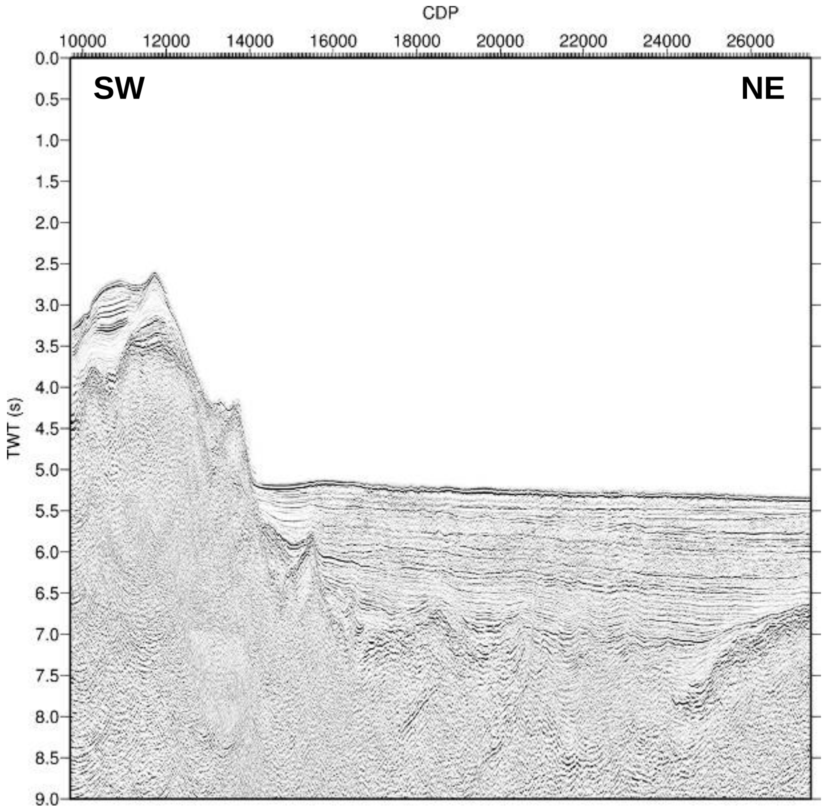


Fig. 47: Seismic line BGR13-207, running from the SE Yermak Plateau into the Nansen Basin.

11. HEAT FLOW MEASUREMENTS

Ingo Heyde, Michael Zeibig and Udo Barckhausen

11.1 Method and instrument

Since tectonic processes in the oceans are primarily heat-driven, measurements of geothermal flux provide important boundary conditions for models that seek to explain how the ocean basins and their margins have evolved through time. Regional variations in the depth of the deep-sea floor are found to be linked closely to thermal processes. The knowledge of surface heat flow constrains mechanisms for subsidence and elevation arising from changes in heat balance. The heat flow through continental margins is also important because Paleo-temperatures and geothermal gradients affect the maturation of organic sequences. Basin modelling is based on sediment thicknesses and paleo-temperatures for assessment of the hydrocarbon potential of sedimentary basins.

It is possible to use shallow probes in the deep ocean because the seabed is generally in thermal equilibrium. On the continental slope and shelf, access to deep boreholes is essential since short-term variations in bottom water temperature and sediment movements disturb thermal gradients near the seabed so shallow coring does not yield values that reflect heat transfer at depth. If the bottom water temperature increases, the thermal gradient just below the sea floor is reduced and so heat flow decreases, and vice versa.

Equipment

BGR employs currently two different types of marine heat flow probes – a conventional probe, built after the so-called violin-bow concept and a second probe, specially designed for employment in hard ground situations. It was assumed that the sediments in the Northern Barents Sea are characterized by rather hard top sediments (drop-stones, relatively coarse, ice-rafted debris), which excluded the use of the conventional type marine heat flow probe. Additionally with RV OGS EXPLORA it would have been not possible to deploy this 5 m long instrument. For this reason the BGR-“hard ground” heat flow probe (Fig. 48) was used during this cruise. The “hard ground” heat flow probe features a 2.2 m long sensor rod made of steel with a diameter of 2 cm mounted along the long axis of a cage and held in position by a special mechanism to prevent bending during penetration of hard ground sediments. It contains 7 thermistors with a spacing of 28 cm. The necessary force to press the sensor rod into the sediments is provided by a cylinder, which houses lead plates with a total weight of 600 kg and an electronic unit within a pressure vessel with a total weight of additional 144 kg. The purpose of the electronic unit housed in the pressure vessel is to control the data transfer and the measurements. All measured data are transferred via the ship’s coax cable in real time online to a laptop PC on board. The coax cable had a diameter of 11.43 mm and a working load of 17.8 kN. Taking into account the weight of the probe and the cable the water depth until which the probe could be deployed safely was limited to about 1950 m.

All measured data are recorded, stored, digitized and monitored by so-called “intelligent sensor modules” (ISM) installed in the pressure vessel. This technology relies on immediate digitization and downloads of measured values in the memory and enables us to improve the accuracy of measurement to ~0.002K. All recorded values are sent to an analogue-multiplexer and then to a 16bit-A/D-converter. The high accuracy and linearity during A/D-transformation is achieved by the application of the sigma delta method. To further improve the accuracy of the measurements, an arithmetic mean of 20 consecutive measurements per sensor is formed and then accepted as one single measured value.

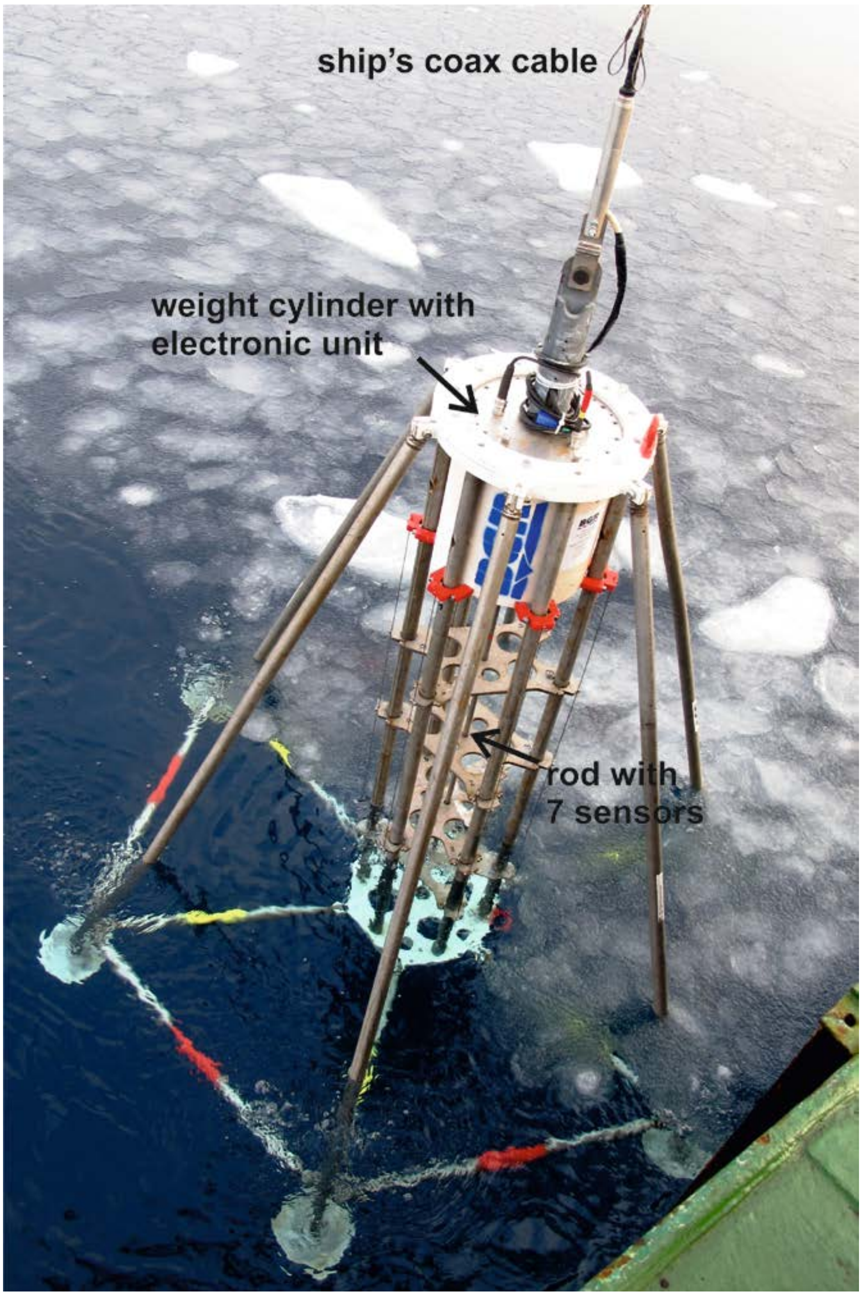


Fig. 48: BGR - hard ground heat flow probe.

All specific modules, which control the configuration, linearization and scaling data in the ISM-module, are stored in an EPROM. Storage and display of the measured data is done via a special computer code, stored on PC. A patent has been issued for this particular design.

Fig. 49 shows a typical heat flow measurement with the temperature graphs of 7 sensors from deployment to the seafloor until hoisting back through the water column. To achieve optimum thermistor calibration, the heat flow probe is stopped slightly above the seafloor on the down trip. A horizontal tilt meter (in the two perpendicular directions) in the recording device allows verifying when the probe stopped swinging. After a time period of typically less than 2 minutes, thermal stabilization within ~0.001K is obtained at all thermistors. It is assumed that the thermistors measure identical seawater temperatures. Recalibration of all thermistors is achieved by using one thermistor as the master sensor, whose measured value is used to calibrate the data measured by the other thermistors.

Following this procedure, the probe is lowered with a velocity of 0.1 m/s, until penetration of the seafloor by the sensor rod is achieved. The tilt meter again gives information about the inclination of the probe. The thermal gradient in the sediments is measured continuously for a time period of typically 6 minutes. After this period, the frictional heat component caused by the penetration of the rod into the sediments has decayed to negligible values.

Thereafter, a constant electric current of about 1 A (@ 10 V) is sent through the heating wire (about 4 m long) for the measurement of the in-situ thermal conductivity (λ). The temperature increase in the metallic rod is inversely proportional to the in-situ thermal conductivity of the adjacent sediments. We have measured the linear T-increase after initial heat-up of the assemblage and will derive λ from this curve for all stations.

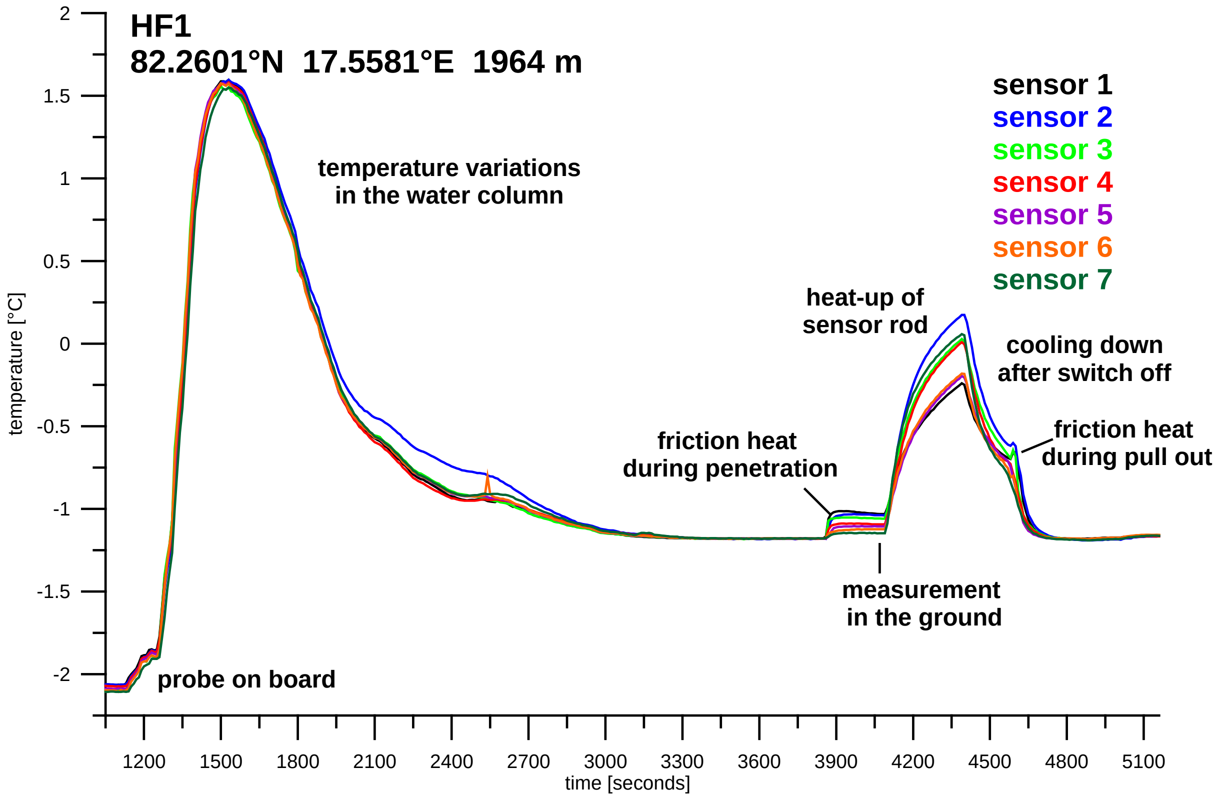


Fig. 49: Heat flow measurement HF1 with the temperature of the 7 sensors from the deployment to the seafloor, penetration into the ground, heating and beginning hoisting back through the water column.

11.2 Station work and preliminary results

All heat flow measurements were conducted in areas where seismic lines give us information on the sediment thickness and a rough estimate on likely sedimentation rates. This way the true heat flow value, corrected for sedimentation effects, can be determined. However the measurements were restricted to areas with water depths between of 1750 to 1970 m. Measurements with shallower water depths of about 1200 m were cancelled due to the limited time and to make sure to receive reliable heat flow values at all stations.

Altogether at 7 stations heat flow measurements were conducted (Tab. 9). Visual inspections after recovery showed that the probe penetrated at all stations the sediments till the maximum depth of 2.2 m. For all measurements the same sensor rod was used. Based on the stabilised ground temperature values at the different positions of the rod the temperature gradient was calculated by linear regression. Fig. 50, Fig. 51 and Fig. 52 show the temperature gradients at all stations.

At stations HF4, HF5 and HF6 the upper 3 to 4 temperature sensors did not show a reliable gradient. Obviously a slightly increased ground water temperature compared to the annual mean value disturbed the temperature field in the upper 0.8 to 1 m of the seabed. However the gradient of the lower 3 to 4 sensors at these stations seems to be reliable.

Fig. 53 shows a map of the stations with the measured temperature gradients. Additional data from the Data Base, compiled by Pollack et al. (1993) and initiated by the International Heat Flow Commission of the International Association of Seismology and Physics of the Earth's Interior (IASPEI) could not be accessed due to the US governmental shutdown.

The temperature gradient at the southeastern is very homogeneous with values of about 70 mK/m. The gradients in the Nansen Basin vary between 56 and 87 mK/m. The derivation of the in-situ thermal conductivity of the adjacent sediments from the heat-up of the sensor rod will be calculated precisely back in the labs.Thus also heat flow values will be determined only after the cruise. In combination with the results of the seismic measurements we expect to resolve the influence of high sedimentation rates which may reduce the heat flow.

Tab. 9: List of heat flow stations with position, water depth and temperature gradient

Station	Station-no.	Date/Time	Latitude	Longitude	Depth [m]	Comments	Heaflow [mW/m²] T. Gradient [mK/m]
HF1	SE Yermak Plateau	08.09. 11:51 13:30	82.2601°N	17.5581°E	1954		64.9 72.1
HF2	SE Yermak Plateau	08.09./14:30 15:45	82.2434°N	17.8463°E	1970		59.8 66.5
HF3	SE Yermak Plateau	08.09./16:00 17:44	82.2691°N	18.1198°E	1897 2058cable	Probe fell down during pullout	62.7 69.6
HF4	S-Central Nansen B.	10.09./15:00 16:30	81.6932°N	32.4560°E	1821	2 gradients	52.5 / 78.4 (4 deep) 58.3 / 87.1 (4 deep)
HF5	S-East Nansen B.	11.09./06:11 07:30	81.8348°N	33.8772°E	1910	2 gradients	15.2 / 77.1 (3 deep) 16.8 / 85.7 (3 deep)
HF6	S-East Nansen B.	11.09./09:00 10:25	81.7766°N	33.9042°E	1750	2 gradients	17.2 / 50.1 (4 deep) 19.1 / 55.7 (4 deep)
HF7	S-West Nansen B.	12.09./15:30 17:20	81.6209°N	30.5363°E	1737 1900 ?	Several attempts due to rough topography	50.6 56.3

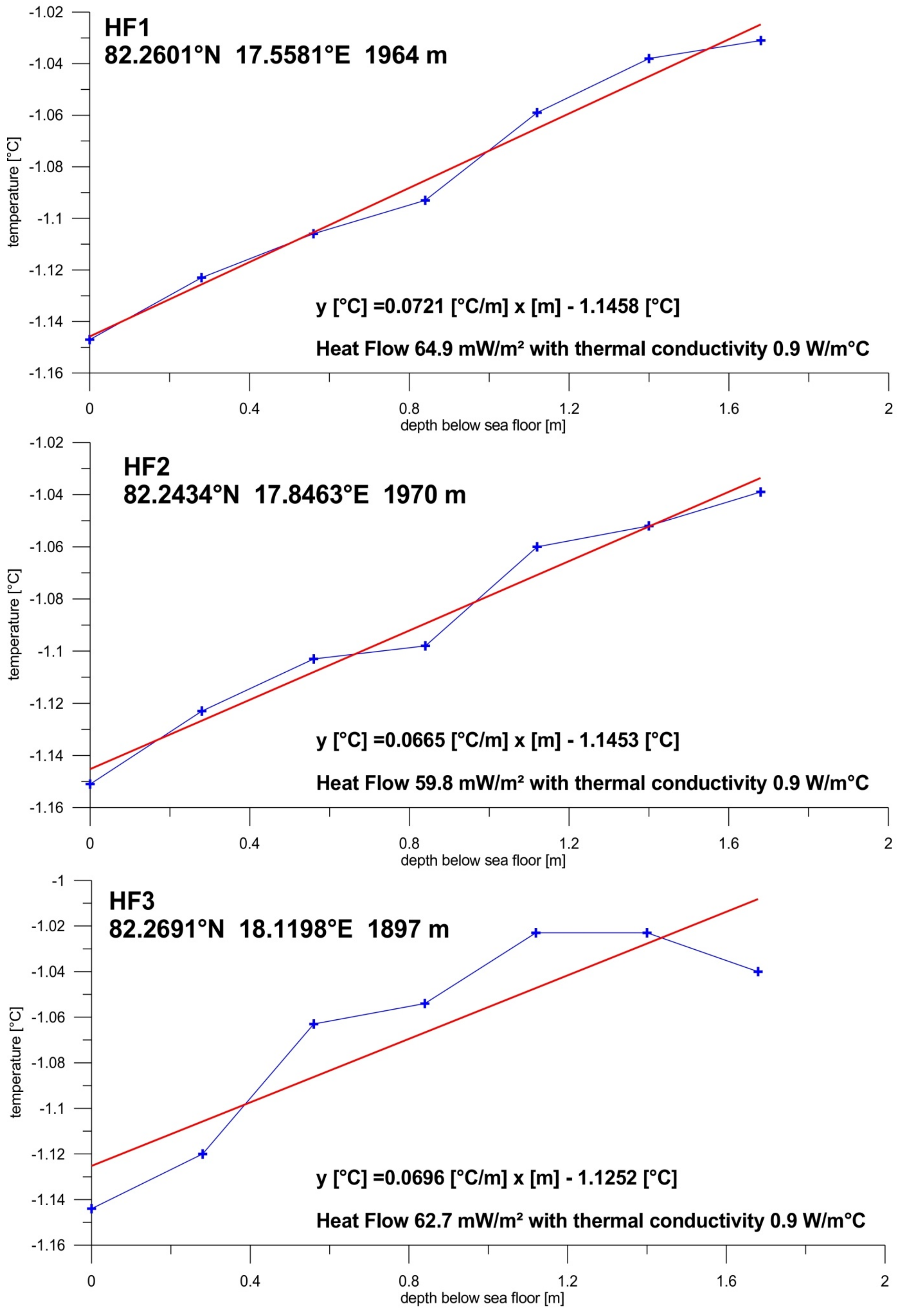


Fig. 50: Determination of the temperature gradient by linear regression for stations HF1, HF2 and HF3.

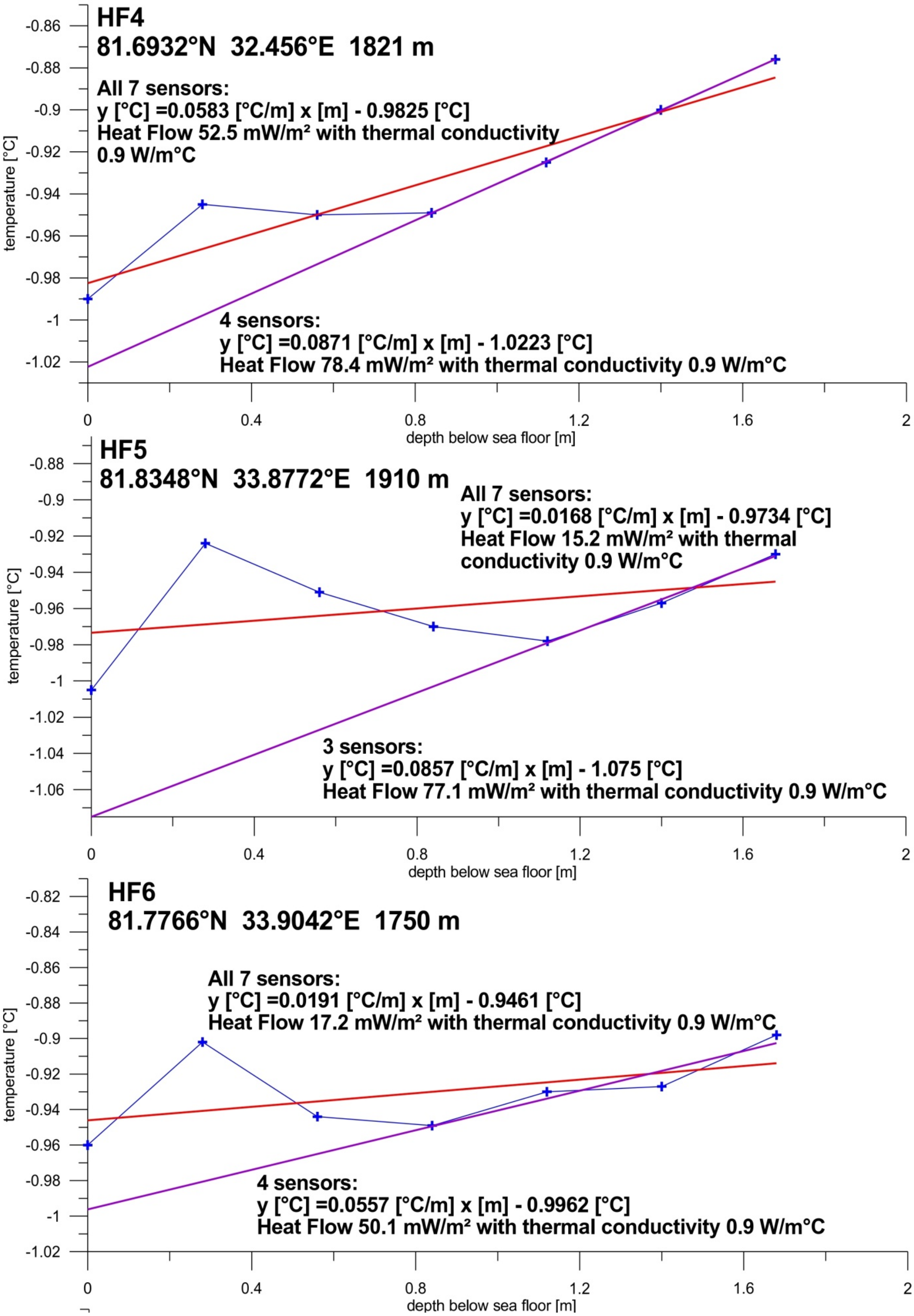


Fig. 51: Determination of the temperature gradient by linear regression for stations HF4, HF5 and HF6.

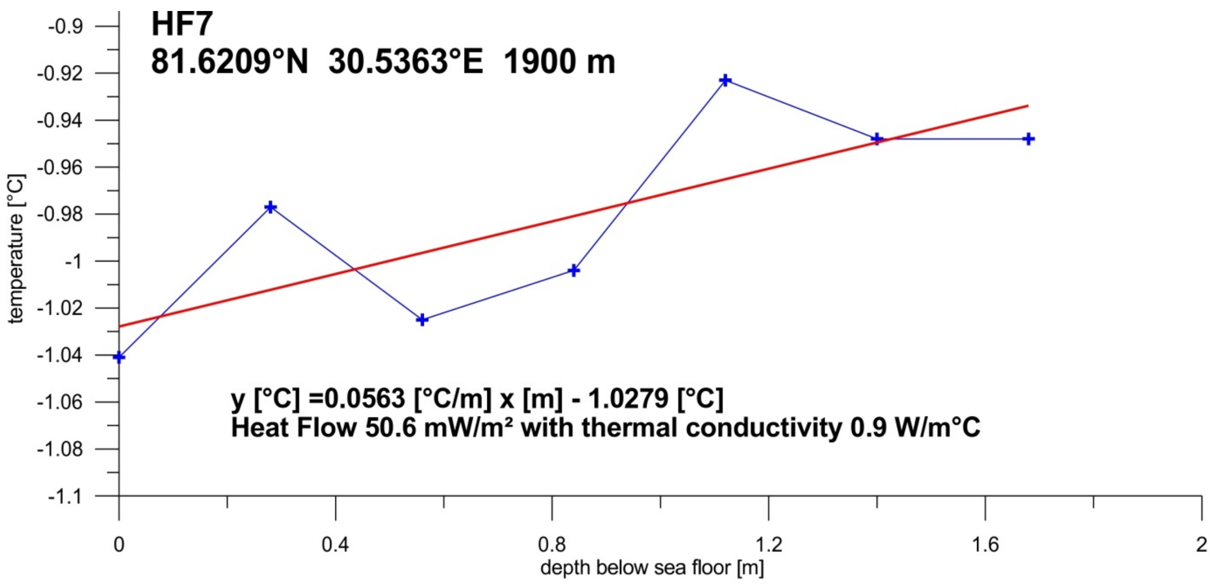


Fig. 52: Determination of the temperature gradient by linear regression for station HF7.

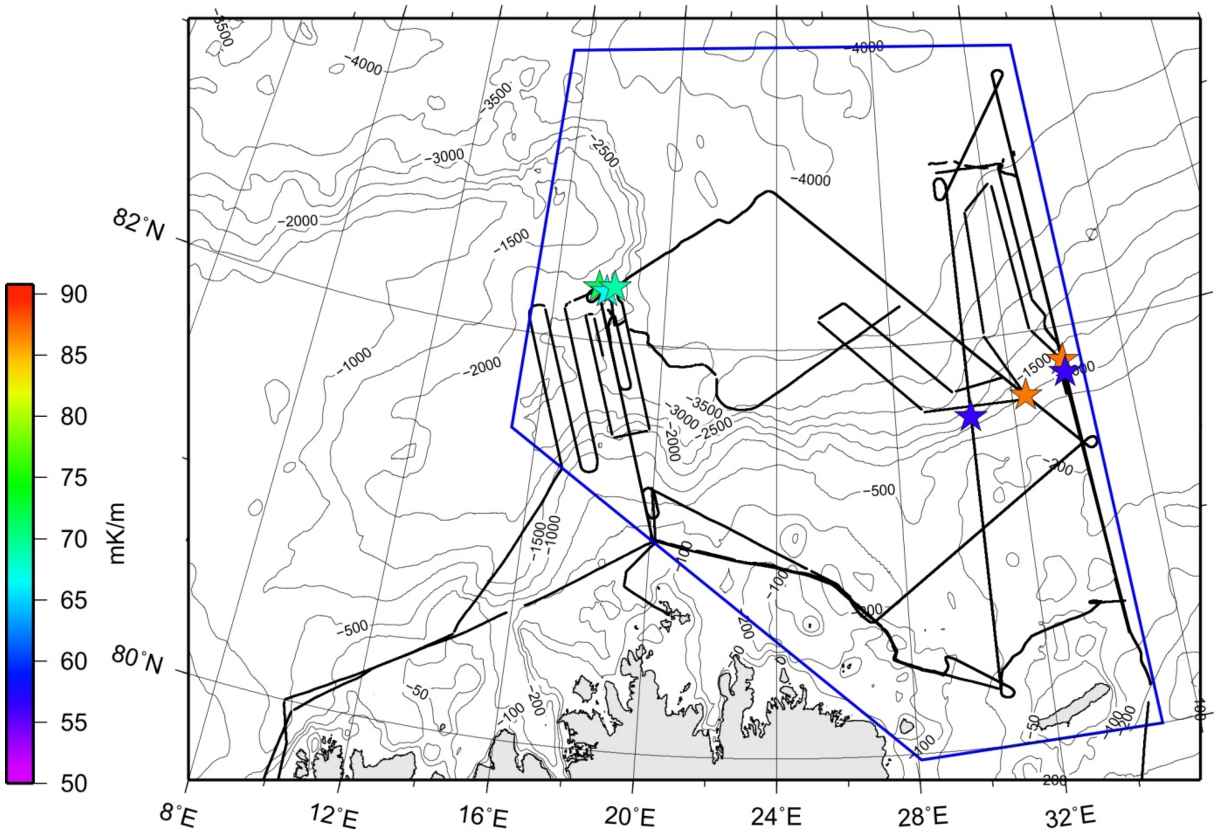


Fig. 53: Map of the stations with measured temperature gradients in mK/m.

12. BIOGEOCHEMISTRY AND GEOMICROBIOLOGY

Daniela Zoch, Nontje Straaten, Martin Krüger

Objectives

Together with echosounder and gas geochemical investigations in the water column, knowledge on the geochemistry and geomicrobiology of the northern Barents Sea can support modelling and exploration for the hydrocarbon potential. Geochemical characterisation of the sedimentary environments can aid in the identification of very low-intensity gaseous or oily hydrocarbon seepage as indicators of possible subsurface reservoirs. Microbiological investigations of the hydrocarbon degradation potential of the indigenous microbial communities by molecularbiological analysis together with the cultivation of such microorganisms can give additional useful data on the potential of the microbial communities in this area to react to natural or man-made accidental oil spills.

Additionally, this study contributes to the understanding of one of the least known and most extreme ecosystems in these permanently cold and presumably nutrient-limited marine sediments. In fact, very little is known about the nature and activity of life in remote Arctic marine sediments. The phylogenetic and physiological diversity of marine Arctic sediment communities of the northern Barents Sea is largely unknown.

Sediment Coring

Gravity cores where taken at 11 stations to make sediment samples available for gas geochemical and microbiologic analyses (Coring list – see Appendix). A gravity corer with a three meter core barrel was used at all stations. The filled part of the liner was cut into one-meter sections using a commercial tube cutting tool and a clean masonry spatula. Before splitting the one-meter core sections they were sampled for gas analyses (see below).

After the gas sampling was completed, sections were laterally opened using two sledge-mounted vibrational saws. The end caps were cut with a conventional cutting blade. When the liner and the end caps were separated, a simple, hand-held device with a thin stainless steel thread was used to separate the two halves of the section. The two halves were split by hitting the separated section on two wooden supports. Splitting was sometimes incomplete and required the additional help of a masonry spatula. All masonry spatulas, the saw blades, the cutter and steel thread were surgically cleaned between the cutting processes.

A total number of 11 short piston cores (70 to 230 cm length) were taken at selected locations along the refraction seismic profiles, covering three sampling areas in the western, eastern and southern parts of the working area (Fig. 54). The sampling material will be used to study the quantity, the chemical and the isotopic composition of gases in the porewater and adsorbed to the surface sediments. These compositional data will be integrated into a model of hydrocarbon generation and migration. Additionally, the sampling material will be used to analyse in great detail geochemical, mineralogical and geomicrobiological sedimentary features and hydrocarbon degradation potential of indigenous microbial communities. Furthermore, samples for molecular biological studies of the quantitative and qualitative microbial community composition were collected, processed on board and preserved for subsequent analysis.

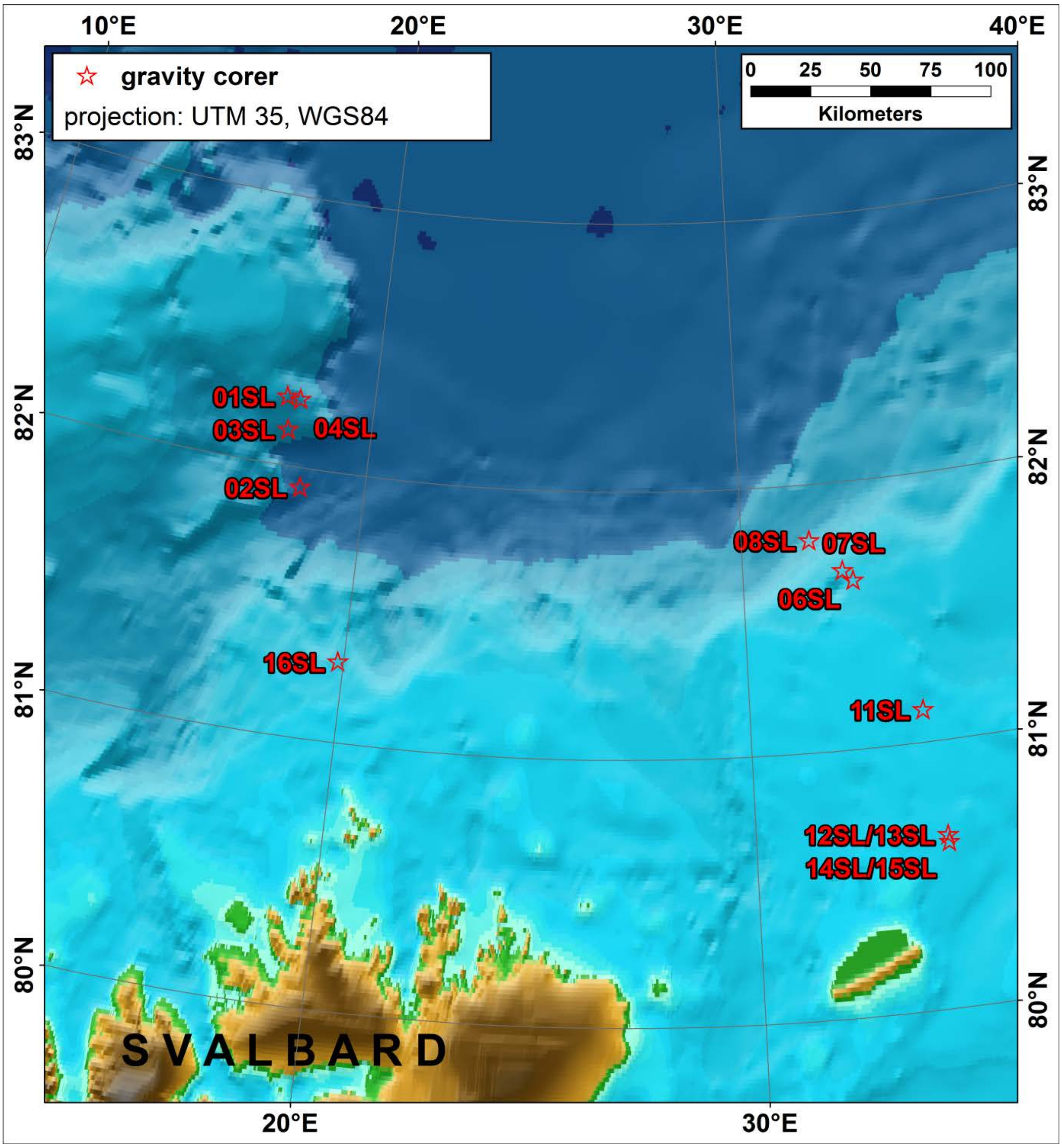


Fig. 54: Gravity corer locations.

12.1 Methods and instruments

12.1.1 Biogeochemistry

Gas geochemical profiles along the cores

The gravity core was quickly cut into 1 m sections. For the gas analysis, and to avoid degassing, holes (2 cm diameter) were drilled into the liner at short intervals starting at 10 cm below the sediment surface/top of the core. Five ml of sediment were sampled with a cut 5 ml syringe. Holes were immediately sealed with tape after sample retrieval. Extracted sediment samples were placed in glass serum vials (50 ml of volume), suspended in 5 ml of HgCL solution (400 mg/l) and after sealing with butyl septa and crimp caps vigorously mixed. 100 µl from the headspace from each serum vial are measured onshore for methane and carbon dioxide concentration with a modified Gas Chromatograph (Shimadzu GC-14A/B). Later analyses involve depth profiles of stable C- and H-isotope ratios to decipher the biogenic or thermogenic origin of the gases present.

Samples for adsorbed gases and hydrocarbons

To study the quantity, the chemical and the isotopic compositions of gases adsorbed to surface sediments on the bottom of the study area, we took samples from the gravity cores that were frozen for later laboratory analysis of adsorbed hydrocarbons (methane, ethane and propane) and other parameters (e.g. carbonate content, total organic carbon) These compositional data shall be interpreted in the context of the measured basin geometry and heat flow to be integrated into a model of hydrocarbon generation and migration.

Large samples (ca. 200 g) were taken for adsorbed gas analyses from the top and bottom of each core immediately after the core had been retrieved from the seafloor and subsampled for porewater and molecular biological studies. The samples were placed in conventional polyethylene bags, and stored and transported at -20° C.

Porewater samples for geochemical analysis along the cores

For further processing, the 1 m section was subsequently split in half-core sections. Since the diameter of the core was less than 90 mm, both half-core sections had to be used for geochemical and microbiological analysis. The samples were taken at selected depth intervals. During sampling, the outer surface of the core was carefully left in place to avoid contamination with seawater.

Interstitial water samples were extracted from sediments with a pore water press designed by the BGR. Compact PTFE sample vessels with a maximum volume of 125 ccm were used to collect the samples. Tefzel LUER LOCK outlets for the sample water and self-locking sea-waterproof V4A-stainless steel intergas-valves guaranteed a contamination-free sample preparation procedure. Also a specially designed quick lock support and a miniaturised pressure gas distribution-block improved the handling of multiple samples.

The selected sediment slices were then transferred to a sample vessel using metal-free spoons or spatulas. After covering the sample with parafilm and NBR-rubber mat the vessels were mounted in the pore water press stand. Extraction time was usually about 10-15 minutes and a pressure of 3 to 8 bar (argon gas) was applied. Depending on the composition of the sediment 10 mL to 40 mL of pore water was gained. Each sample was filtered through a ‘Sartorius’ cellulose nitrate filter 0.45 µm type 11306-100-K and directly collected in a 25 mL PE Roth vial. The sampled pore water was then transferred into a 30 mL slip tip syringe and filtered with a ‘Sartorius’ Minisart High-Flow single use syringe filter (0.2 µm, polyethersulfone) to remove particles and microorganisms. With the syringe, subsamples were directly filled into different sample vials for shore-based laboratory analyses:

Subsamples were taken for:

- Metal ion analyses with ICP-OES (5 mL sample volume acidified with 50 µL HNO3 in 25 mL PP Roth vials)
- Anion analysis with ion chromatography (5 mL sample volume in 8 mL glass vials)
- Analysis of sulphide after fixation with ZnCL2 (20%) solution.
- Analysis of d13C of porewater DIC after fixation with saturated HgCL2 solution.
- d13C from TOC and biomarker analyses (from frozen squeeze cakes)
- Total C, total N, total S and CaCO3 analyses (from squeeze cakes)

12.1.2 Geomicrobiology

Microbiological samples for the qualitative and quantitative description of the microbial populations within the sediment and cultivation of specific microorganisms were taken from the uncontaminated centre of the sediment core immediately after the splicing in two halves. These samples were prepared for the subsequent laboratory analysis:

Numbers of living Bacteria and Archaea by CARD-FISH (Catalyzed Reporter Deposition-Fluorescence In Situ Hybridisation) by fluorescence microscopy.

For this purpose, 0.5 g of sediment from selected depths was placed in sterile 2ml-Eppendorf tubes and fixed in 1 ml of a cold 4% formaldehyde-PBS solution (phosphate buffered saline, 130 mmol Sodium chloride, 7 mmol di-Sodium hydrogen phosphate, 3 mmol Sodium di-hydrogen phosphate, sterile filtered 0.2 µm) for 2 hours at room temperature (20°C), washed twice with cold PBS using an Eppendorf centrifuge at 13000 rpm for 10 min and finally stored at -20°C in 1 ml PBS-ethanol (1:1). All samples were frozen at -20ºC until analysis in the shore-based laboratory.

Qualitative and quantitative description of microbial community inhabiting the sediments

Around 15 ml of sediment was sampled in duplicates with a cut sterile 2 ml/ 5 ml syringe and placed in Falcon screw capped vials. All samples were immediately frozen at -80°C until analyzed. Further analysis involves DNA extraction, quantification of specific Prokaryote groups with Q-PCR and clone libraries.

Determination of microbial activities

The selected sampling areas will allow investigating a broad range of different environmental and geological settings. Main topics are (1) the investigation of composition biodiversity and metabolic potentials of indigenous microbial communities by geochemical, and micro- and molecular biological analyses of porewater and sediment samples; (2) the quantification of the ability of the indigenous microbial communities to react to naturally or accidentally spilled hydrocarbons; and (3) the identification of hydrocarbon seepage as indicators of subsurface reservoirs and thus the potential presence of adapted microbial communities by means of geochemical analysis of the sedimentary environments in this region.

Microbiological samples for the quantification of related microbial activities and communities have been collected roughly from the same depths as the geochemistry samples. Sediment microcosms will be set-up onshore to measure on site rates of important microbial processes, i.e. sulfate reduction, methane and carbon dioxide formation and consumption, as well as the degradation of different higher hydrocarbons. The geochemical and geomicrobiological results will increase the up to date very scarce database on Arctic sediments / seafloor environments. Besides a detailed characterisation of the present microbial biodiversity and its environmental controls, a special focus will be on the potential of the indigenous microbial communities to degrade hydrocarbons. This will help to estimate consequences of a potential oil spill.

13. ACKNOWLEDGEMENTS

Volkmar Damm

After a 25 years break BGR Hannover again got the opportunity to use this vessel for a marine research project. We experienced an excellent cooperation with the ship's master and crew, were perfectly assisted during all our research operations and made use of an exemplary service.

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ANNEX

A.1 Teilnehmende Institute / participating institutions

	Address
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe Stilleweg 2 30655 Hannover Germany
ARGO	Argo Srl – Ship Management & Services Via Campi Flegrei 34 80078 Pozzuoli (Napoli) Italy
DIAMAR	DIAMAR S.r.l. Via G. Porzio n°4 Centro Direzionale Isola G.2 – int. 44 80143 Napoli Italy
OGS	OGS Trieste Istituto Nazionale di Oceanografia e di Geofisica Spermintale Borgo Grotta Gigante 42/c 34010 Sgonico (Trieste) Italy
RPS	RPS Energy Nelson House, Coombe Lane Axminster, Devon, EX 13 5 AX United Kingdom
University Oslo	University of Oslo Centre for Earth Evolution and Dynamics Department of Geosciences University of Oslo P.O. Box 1047 Blindern 0316 Oslo Norway

A.2 Fahrtteilnehmer / cruise participants

Leg 1

	Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**
1.	Damm	Volkmar	BGR	Geophysicist, Chief Scientist
2.	Behrens	Thomas	BGR	Technician
3.	Berglar	Kai	BGR	Geologist
4.	Demir	Ümit	BGR	Technician
5.	Ebert	Timo	BGR	Technician
6.	Ehrhardt	Axel	BGR	Geophysicist
7.	Facchin	Lorenzo	OGS	Geophysicist
8.	Gricks	Nathan	RPS	Ecologist
9.	Heyde	Ingo	BGR	Geophysicist
10.	Kallaus	Günter	BGR	Technician
11.	Tomini	Isabelle	OGS	Technician
12.	Visnovic	Gianpaolo	OGS	Technician

Leg 2

	Name/ Last name	**Vorname/ First name**	**Institut/ Institute**	**Beruf/ Profession**
1.	Damm	Volkmar	BGR	Geophysicist, Chief Scientist
2.	Barckhausen	Udo	BGR	Geophysicist
3.	Berglar	Kai	BGR	Geologist
4.	Facchin	Lorenzo	OGS	Geophysicist
5.	Gaina	Carmen	University Oslo	Geophysicist
6.	Heyde	Ingo	BGR	Geophysicist
7.	Krüger	Martin	BGR	Geomicrobiologist
8.	Schreckenberger	Bernd	BGR	Geophysicist
9.	Straaten	Nontje	BGR	Geomicrobiologist
10.	Visnovic	Gianpaolo	OGS	Technician
11.	Zeibig	Michael	BGR	Technician
12.	Zoch	Daniela	BGR	Technician

A.3 Schiffsbesatzung / ship's crew

	Name	Rank
1.	Sedmak, Franco	Master
2.	Festivo, Lazzaro	1. Offc.
3.	Filipovic, Ljubinko	Ch. Eng.
4.	Scotto di Perta, Andrea	2. Offc.
5.	Scotto d’Apollonia, Valentino	3. Offc.
6.	Bastiani, Dario	Doctor
7.	Zubcic, Damir	2. Eng.
8.	Marchelli, Marcello	3. Eng.
9.	Nucic, Jadranko	Elec. Eng.
10.	Genzo, Gianfranco	A.B.
11.	Franco, Gerardo	A.B.
12.	Guaiana, Antonio	A.B.
13.	Caruso, Rosario	O.S.
14.	Talarico, Diego	Mot-man
15.	Calvanico, Catello	Eng-boy
16.	Guida, Aldo	Cook
17.	Merone, Pasquale	Cooksmate
18.	De Vivo, Salvatore	1. Steward
19.	Franco, Salvatore	2. Steward

A.4 Geophysical profile list

line number	shot point start/ end	date	time UTC	latitude	longitude	course	S=MCS Rx-seis. SB=sonobuoy wide-angle seis. M=magnetics G=gravity B=bathymetrie SE=sediment echosounding	length (km)
BGR13-201	1	18.08.13	13:03:34	80°28.56’ N	34°29.550’ E		S, G, B, SE	
	5865	19.08.13	09:06:47	81°47.40’ N	33°50.670’ E	356°		147.15
BGR13-2R1	1	20.08.13	13:28:06	82°45.618'N	33°15.660'E		SB, G, B, SE	
	3910	21.08.13	22:28:27	80°47.010'N	34°20.964'E	176°		221.43
BGR13-2M1		21.08.13	23:17:48	80°43.526'N	34°21.310'E		M, G, B, SE	
		22.08.13	01:01:56	80°27.944'N	34°28.421'E	176°		29.08
BGR13-2M2		22.08.13	01:18:27	80°27.660'N	34°29.889'E		M, G, B, SE	
		22.08.13	09:27:30	81°51.214'N	33°49.905'E	356°		155.92
BGR13-202	2	22.08.13	15:20:36	81°44.658'N	33°55.386'E		S, M, G, B, SE	
	6863	23.08.13	14:48:47	83°15.960'N	32°59.928'E	356°		170.46
BGR13-203	1	23.08.13	16:39:06	83°12.498'N	33° 8.754'E		S, M, G, B, SE	
	2690	24.08.13	01:30:29	82°42.360'N	30°27.768'E	213°		67.05
BGR13-204	1	24.08.13	04:30:40	82°43.908'N	30°33.756'E		S, M, G, B, SE	
	10952	25.08.13	16:50:00	80°16.890'N	30°30.966'E	180°		273.62
BGR13-205	1	25.08.13	18:56:10	80°18.210'N	30°36.618'E		S, M, G, B, SE	
	1169	25.08.13	22:45:06	80°26.778'N	29°18.048'E	303°		29.19
BGR13-2M3		30.08.13	17:46:00	81°10.936'N	19°51.392'E		M, G, B, SE	
		31.08.13	04:25:00	81°59.042'N	18° 9.713'E	343°		93.71
BGR13-2M4		31.08.13	08:46:33	82° 7.820'N	18°12.687'E		M, G, B, SE	
		31.08.13	10:51:00	81°48.809'N	18°57.748'E	162°		37.27
BGR13-206	1	31.08.13	14:04:10	81°55.542'N	18°17.766'E		S, M, G, B, SE	
	1448	31.08.13	18:51:10	82°14.034'N	17°33.540'E	342°		36.24
BGR13-207	1	31.08.13	20:55:40	82°12.570'N	17°33.432'E		S, G, B, SE	
	4508	01.09.13	11:39:00	82°46.686'N	23°41.976'E	55°		109.80
BGR13-207mag		31.08.13	20:56:00	82°12.588'N	17°33.529'E		M	
		01.09.13	07:16:06	82°37.909'N	21°50.174'E	53°		78.67
BGR13-208	1	01.09.13	11:43:44	82°46.626'N	23°44.388'E		S, G, B, SE	
	8900	02.09.13	17:04:28	81°24.192'N	34°12.924'E	134°		222.11
BGR13-208mag		01.09.13	13:04:42	82°43.511'N	24°19.679'E		M	

		02.09.13	17:14:00	81°23.660'N	34°16.569'E	134°		213.39
BGR13-209	1	02.09.13	19:20:35	81°24.606'N	33°59.478'E		S, M, G, B, SE	
	5891	03.09.13	14:42:52	80°39.984'N	27° 1.410'E	236°		146.89
BGR13-2M5		07.09.13	13:33:00	81°21.621'N	16°59.155'E		M, G, B, SE	
		07.09.13	18:03:33	82° 4.816'N	15°11.983'E	340°		85.37
BGR-13-1M6		07.09.13	18:43:20	82° 7.153'N	15°43.855'E		M, G, B, SE	
		07.09.13	23:17:23	81°22.368'N	17°37.039'E	160°		88.66
BGR13-2M7		08.09.13	00:00:39	81°24.698'N	18° 6.975'E		M, G, B, SE	
		08.09.13	04:35:14	82° 8.228'N	16°24.898'E	341.5°		85.45
BGR13-2M8		08.09.13	04:39:58	82° 8.983'N	16°26.164'E		M, G, B, SE	
		08.09.13	06:09:09	82°14.821'N	17°32.675'E	57°		20.01
BGR13-2M9		08.09.13	20:07:00	82° 8.994'N	18°32.092'E		M, G, B, SE	
		08.09.13	23:27:47	81°35.477'N	19°44.415'E	163°		65.22
BGR13-2M10		08.09.13	23:33:19	81°34.946'N	19°39.788'E		M, G, B, SE	
		09.09.13	00:30:23	81°32.191'N	18°35.916'E	254°		18.19
BGR13-2M11		09.09.13	00:36:40	81°32.927'N	18°31.158'E		M, G, B, SE	
		09.09.13	04:05:57	82° 6.976'N	17°11.264'E	342°		66.80
BGR13-2M12		09.09.13	04:26:42	82° 6.364'N	17°30.103'E		M, G, B, SE	
		09.09.13	05:24:02	81°56.587'N	17°54.250'E	161°		19.24
BGR13-2M13		09.09.13	17:28:00	82°10.267'N	18° 5.323'E		M, G, B, SE	
		09.09.13	18:05:00	82° 4.960'N	18°14.532'E	167°		10.15
BGR13-2M14		09.09.13	18:05:00	82° 4.960'N	18°14.532'E		M, G, B, SE	Direct dist.
		10.09.13	01:55:13	81°43.061'N	23°14.492'E	various		88.59
BGR13-2M14A		10.09.13	01:55:18	81°43.066'N	23°14.566'E		M, G, B, SE	
		10.09.13	06:33:01	82°10.722'N	28°15.663'E	57°		93.86
BGR13-2M15		10.09.13	17:59:11	81°41.470'N	32°26.991'E		M, G, B, SE	
		10.09.13	19:55:23	82° 0.204'N	31°18.534'E	333°		39.27
BGR13-2M16		10.09.13	20:00:54	82° 1.182'N	31°18.408'E		M, G, B, SE	
		10.09.13	23:17:34	82°36.985'N	31° 9.762'E	358°		66.67
BGR13-2M17		10.09.13	23:21:42	82°37.581'N	31°12.774'E		M, G, B, SE	
		11.09.13	00:17:32	82°44.528'N	32°10.490'E	47°		18.82
BGR13-2M18		11.09.13	00:28:19	82°43.695'N	32°18.831'E		M, G, B, SE	
		11.09.13	04:26:10	82° 0.730'N	32°54.514'E	174°		80.45
BGR13-2M19		11.09.13	04:31:52	81°59.886'N	32°58.943'E		M, G, B, SE	
		11.09.13	05:22:28	81°52.445'N	33°39.974'E	142°		17.51

BGR13-2M20		11.09.13	18:05:33	81°40.327'N	32°32.307'E		M, G, B, SE	
		11.09.13	20:57:29	81°39.999'N	29° 1.110'E	269°		56.96
BGR13-2M21		11.09.13	20:58:09	81°40.004'N	29° 0.294'E		M, G, B, SE	
		12.09.13	00:50:47	82° 8.572'N	25°27.693'E	314°		77.01
BGR13-2M22		12.09.13	00:53:23	82° 8.918'N	25°28.819'E		M, G, B, SE	
		12.09.13	01:48:40	82°13.287'N	26°22.583'E	59°		15.85
BGR13-2M23		12.09.13	01:53:00	82°13.159'N	26°27.068'E		M, G, B, SE	
		12.09.13	06:29:15	81°45.031'N	30° 0.489'E	133°		76.21
BGR13-2M24		12.09.13	06:30:16	81°45.049'N	30° 1.471'E		M, G, B, SE	
		12.09.13	08:17:15	81°47.591'N	31°43.717'E	80°		27.65
BGR13-2M25		12.09.13	19:16:16	81°34.584'N	31°23.794'E		M, G, B, SE	
		12.09.13	21:50:07	81°33.025'N	33°16.016'E	95°		30.79
BGR13-2M26		12.09.13	22:03:07	81°32.922'N	33°19.639'E		M, G, B, SE	
		13.09.13	02:23:38	81°19.071'N	30°18.294'E	243°		56.50
BGR13-2M27		13.09.13	02:25:38	81°18.910'N	30°18.884'E		M, G, B, SE	
		13.09.13	07:18:19	81°14.417'N	33°59.815'E	98°		62.92
BGR13-2M28		13.09.13	18:38:13	80°37.236'N	34°33.286'E		M, G, B, SE	
		13.09.13	20:07:57	80°38.290'N	33°29.443'E	276°		19.45
						Total	MCS	1055.62
						Total	Wide angle seismics	221.43
						Total	Magnetics	2658.78

A.5 Sonobuoy station list

Station	Profile	Channel	Duration	Depth (m)	Lat. (N)	Long. (E)	Shot number	Date	Time (UTC)
SB01	1R1		4 h	3394 m	82° 43.9904’	033° 21.7186’	34	20.08.2013	13:58
SB02	1R1		4 h	3287 m	82° 39.3871’	033° 24.6687’	204	20.08.2013	15:23
SB03	1R1		4 h	3173 m	82° 34.1542’	033° 27.9218’	390	20.08.2013	16:56
SB04	1R1		4 h	3058 m	82° 28.7629’	033° 31.1623’	572	20.08.2013	18:27
SB05	1R1		4 h	2896 m	82° 22.7220’	033° 34.7488’	770	20.08.2013	20:06
SB06	1R1		4 h	2758 m	82° 17.3176’	033° 37.8949’	947	20.08.2013	21:34
SB07	1R1		4 h	2633 m	82° 12.6751’	033° 40.5302’	1105	20.08.2013	22:53
SB08	1R1		4 h	2499 m	82° 07.2727’	033° 43.5110’	1304	21.08.2013	00:34
SB09	1R1		4 h	2351 m	82° 01.8459’	033° 46.4856’	1499	21.08.2013	02:11
SB10	1R1		4 h	2183 m	81° 56.5496’	033° 49.02860’	1676	21.08.2013	03:39
SB11	1R1		4 h	1953 m	81° 50.9814’	033° 52.2155’	1851	21.08.2013	05:07
SB12	1R1		4 h	1730 m	81° 45.7326’	033° 57.8747’	2045	21.08.2013	06:44
SB13	1R1		4 h	802 m	81° 40.4230’	033° 57.5090’	2235	21.08.2013	08:19
SB14	1R1		4 h	250 m	81° 34.4867’	034° 00.3475’	2446	21.08.2013	10:04
SB15	1R1		4 h	198 m	81° 29.5378’	034° 02.7349’	2609	21.08.2013	11:25
SB16	1R1		4 h	178 m	81° 23.5414’	034° 05.5167’	2801	21.08.2013	13:01
SB17	1R1		4 h	181 m	81° 18.9908’	034° 07.5988’	2934	21.08.2013	14:07
SB18	1R1		8 h	176 m	81° 13.2997’	034° 10.1590’	3097	21.08.2013	15:30
SB19	1R1		8 h	248 m	81° 07.8111’	034° 12.5440’	3262	21.08.2013	16:52
SB20	1R1		8 h	211 m	81° 02.7499’	034° 14.7802’	3415	21.08.2013	18:08

A.6 Heat flow station list

Station	Date/Time	Position [°]	Depth [m]	T. Gradient [mK/m]
HF1	08.09. / 11:51 - 13:30	82.2601°N 17.5581°E	1954	72.1
HF2	08.09. / 14:30 - 15:45	82.2434°N 17.8463°E	1970	66.5
HF3	08.09. / 16:00 - 17:44	82.2691°N 18.1198°E	1897	69.6
HF4	10.09. / 15:00 - 16:30	81.6932°N 32.4560°E	1821	58.3 87.1 (4 deep sensors)
HF5	11.09./ 06:11 - 07:30	81.8348°N 33.8772°E	1910	16.8 85.7 (3 deep sensors)
HF6	11.09./ 09:00 - 10:25	81.7766°N 33.9042°E	1750	19.1 55.7 (4 deep))
HF7	12.09./ 15:30 -17:20	81.6209°N 30.5363°E	1900	56.3

A.7 Coring station list

Core label	Site	Latitude	Longitude	Water Depth (m)	Recovery (cm)	Coring date (dd:mm:yyyy)	on deck (hh:mm)	Remarks
01SL	Core01	82.243182°N	17.484586°E	2024	190	08.09.2013	09:45	Winch problems
02SL	Core02	81.929493°N	18.287814°E	3284	187	09.09.2013	09:30	
03SL	Core04	82.136274°N	17.737374°E	2398	212	09.09.2013	13:25	
04SL	Core05	82.254585°N	17.946056°E	2006	210	09.09.2013	16:15	
---	C44	82.217598°N	28.731679°E	3600	---	10.09.2013	10:40	Liners empty
06SL	C48	81.632644°N	32.825319°E	900	166	11.09.2013	14:55	
07SL	C47	81.671682°N	32.574744°E	1450	173	11.09.2013	16:50	
08SL	C45	81.793767°N	31.783250°E	2891	213	12.09.2013	11:40	
---	C6	81.236667°N	34.139167°E	210	---	13.09.2013	08:22	Liners empty
11SL	C5	81.123167°N	34.195000°E	250	74	13.09.2013	11:55	
12SL	C3	80.649368°N	34.415378°E	215	30	13.09.2013	15:42	
13SL	C3	80.649334°N	34.415551°E	215	132	13.09.2013	16:22	
14SL	C2	80.623407°N	34.426756°E	212	70	13.09.2013	16:55	
15SL	C2	80.623053°N	34.424950°E	212	80	13.09.2013	17:24	
16SL	C99	81.303746°N	19.862518°E	561	232	14.09.2013	22:55	

A.8 Weekly marine mammal observation report

BGR

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)
EOM1527 BGR Norway MMO

WEEKLY MMO REPORT **Week Starting 11 August 2013**

Week 1 of Project

PROJECT DETAILS

Client	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	**Streamers**	1	**No. sources**	1
Survey	EOM1527 BGR Norway MMO	**Streamer length**	4200	**Source volume**	2000
Vessel	R/V OGS Explora	**Streamer sep**		**Source separation**	
Contractor		**Streamer depth Source depth**	6m	**Shot interval**	
Mobilisation	15/08/2013	**Sample rate**		**Record length**	
Contractor project #		**Group interval**		**Nominal source-near trace offset**	

CONTACT INFORMATION

MMO Company	RPS Energy		
MMO Personnel	Nathan Gricks	nathangricks@yahoo.co.uk	+44 (0) 1297 34656
Client contact	Susanne Wrobel	susanne.wrobel@bgr.de	+49 (0)511 643 2271
Party Chief	Party Chief		

DAILY MMO DIARY

Sighting #	Date	**Species**	**Start**	**End**	**Action taken**	**Vessel Activity**	**Source status when detected**	**Estimated loss of production**
1	16/08/2013	Fin whale [Balaenoptera physalus]	06:39	07:01	No Action	Other	No source	
2	16/08/2013	Unidentifiable dolphin [n/a]	13:44	13:51	No Action	Other	No source	
3	16/08/2013	White-beaked dolphin [Lagenorhynchus albirostris]	14:51	15:24	No Action	Other	No source	
4	16/08/2013	Sperm whale [Physeter macrocephalus]	16:07	16:15	No Action	Other	No source	
5	16/08/2013	White-beaked dolphin [Lagenorhynchus albirostris]	18:02	18:33	No Action	Other	No source	

RPS

WEEKLY MMO REPORT

Week Starting 11 August 2013

SUMMARY OF ACTION TAKEN

Action	Weekly	Project
No Action	5	5
Power Down	0	0
Shut Down	0	0
Delayed Soft Start	0	0

Bundesanstalt für
Geowissenschaften und Rohstoffe
(BGR)
EOM1527 BGR Norway MMO

WEEKLY MMO REPORT

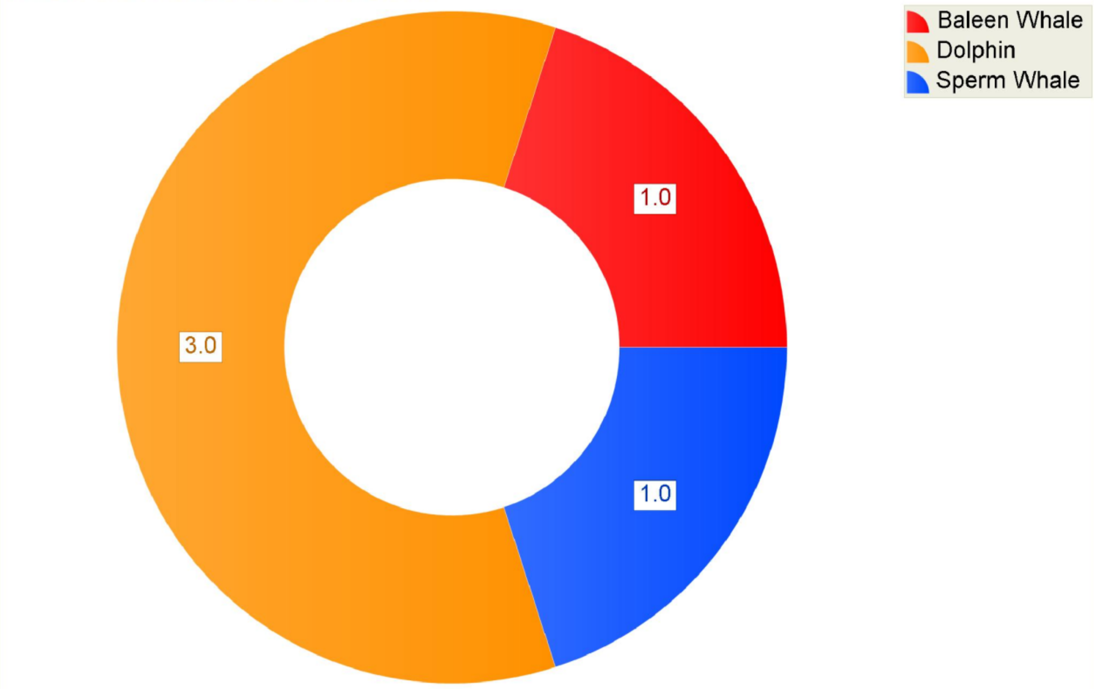
Week Starting 11 August 2013

PROJECT SIGHTINGS

SIGHTINGS BY CATEGORY

Category	Weekly	Project
Baleen Whale	1	1
Dolphin	3	3
Sperm Whale	1	1

WEEK SIGHTINGS BY CATEGORY



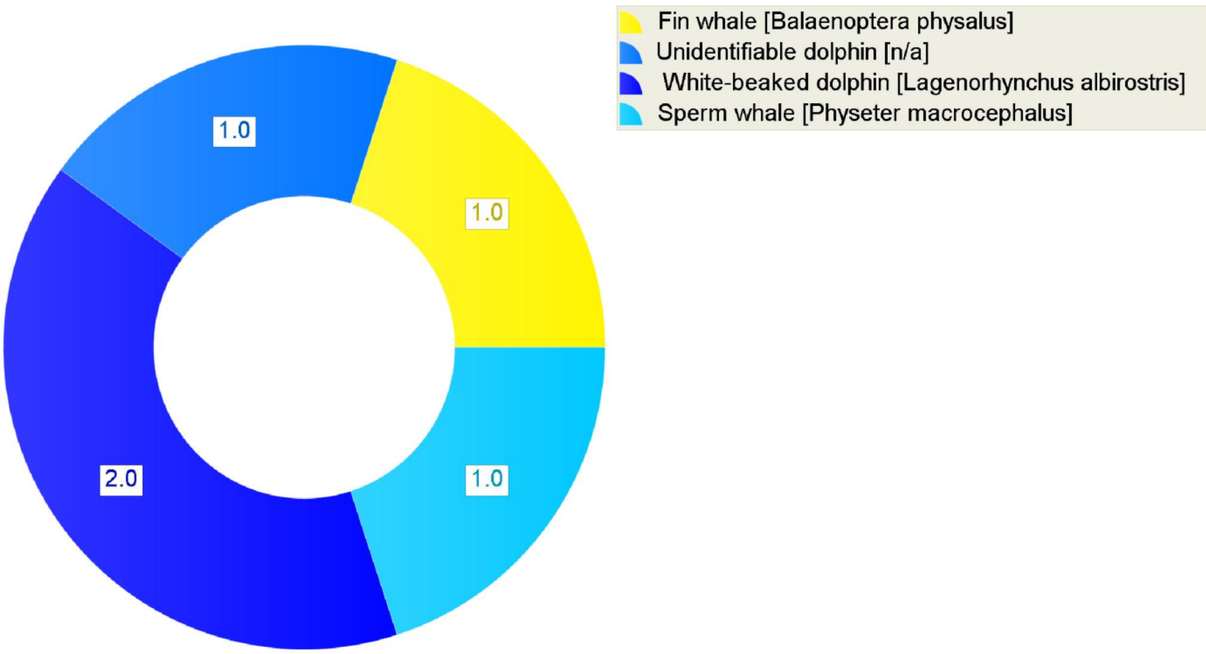
WEEKLY MMO REPORT

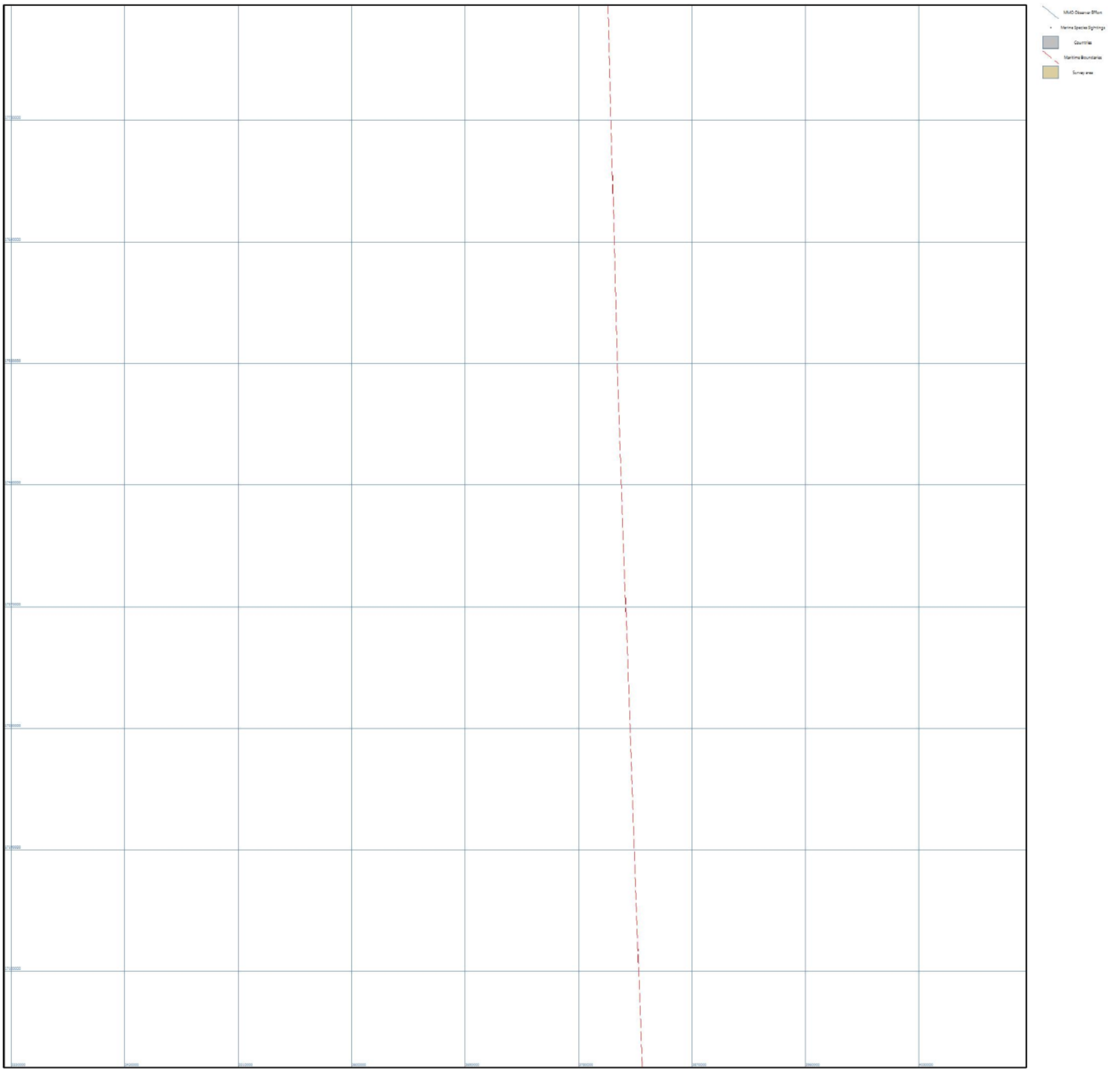
Week Starting 11 August 2013

SIGHTINGS BY SPECIES

Species	Weekly	Project
Fin whale [Balaenoptera physalus]	1	1
White-beaked dolphin [Lagenorhynchus albirostris]	2	2
Unidentifiable dolphin [n/a]	1	1
Sperm whale [Physeter macrocephalus]	1	1

WEEK SIGHTINGS BY SPECIES





Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)
EOM1527 BGR Norway MMO

WEEKLY MMO REPORT

Week Starting 18 August 2013

Week 2 of Project

PROJECT DETAILS

Client	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	**Streamers**	1	**No. sources**	1
Survey	EOM1527 BGR Norway MMO	**Streamer length**	4200	**Source volume**	2000
Vessel	R/V OGS Explora	**Streamer sep**		**Source separation**	
Contractor		**Streamer depth Source depth**	6m	**Shot interval**	
Mobilisation	15/08/2013	**Sample rate**		**Record length**	
Contractor project #		**Group interval**		**Nominal source-near trace offset**	

CONTACT INFORMATION

MMO Company	RPS Energy		
MMO Personnel	Nathan Gricks	nathangricks@yahoo.co.uk	+44 (0) 1297 34656
Client contact	Susanne Wrobel	susanne.wrobel@bgr.de	+49 (0)511 643 2271
Party Chief	Party Chief		

DAILY MMO DIARY

Sighting #	Date	Species	Start	End	Action taken	Vessel Activity	Source status when detected	Estimated loss of production
6	22/08/2013	Unidentifiable seal [n/a]	06:30	06:30	No Action	Line change or turn	No source	
7	22/08/2013	Unidentifiable baleen whale [n/a]	07:57	07:57	No Action	Line change or turn	No source	
8	22/08/2013	Unidentifiable seal [n/a]	09:48	09:48	No Action	Line change or turn	No source	
9	23/08/2013	Unidentifiable seal [n/a]	01:30	01:35	No Action	Online - acquiring data	Full power	
10	23/08/2013	Ringed seal [Phoca hispida]	06:30	06:32	No Action	Online - acquiring data	Full power	
11	23/08/2013	Unidentifiable seal [n/a]	07:10	07:10	No Action	Online - acquiring data	Full power	
12	23/08/2013	Unidentifiable seal [n/a]	07:42	07:42	No Action	Online - acquiring data	Full power	

WEEKLY MMO REPORT

Week Starting 18 August 2013

13	23/08/2013	Ringed seal [Phoca hispida]	07:52	07:57	No Action	Online - acquiring data	Full power	
14	24/08/2013	Unidentifiable seal [n/a]	07:11	07:13	No Action	Online - acquiring data	Full power	
15	24/08/2013	Unidentifiable seal [n/a]	14:33	14:34	No Action	Online - acquiring data	Full power	
16	24/08/2013	Harp seal [Phoca groenlandica]	15:45	15:52	No Action	Online - acquiring data	Full power	0
17	24/08/2013	Unidentifiable seal [n/a]	16:28	16:28	No Action	Online - acquiring data	Full power	0
18	24/08/2013	Harp seal [Phoca groenlandica]	16:39	16:54	No Action	Online - acquiring data	Full power	0
19	24/08/2013	Unidentifiable seal [n/a]	16:42	16:42	No Action	Online - acquiring data	Full power	0

SUMMARY OF ACTION TAKEN

Action	Weekly	Project
No Action	14	19
Power Down	0	0
Shut Down	0	0
Delayed Soft Start	0	0

WEEKLY MMO REPORT

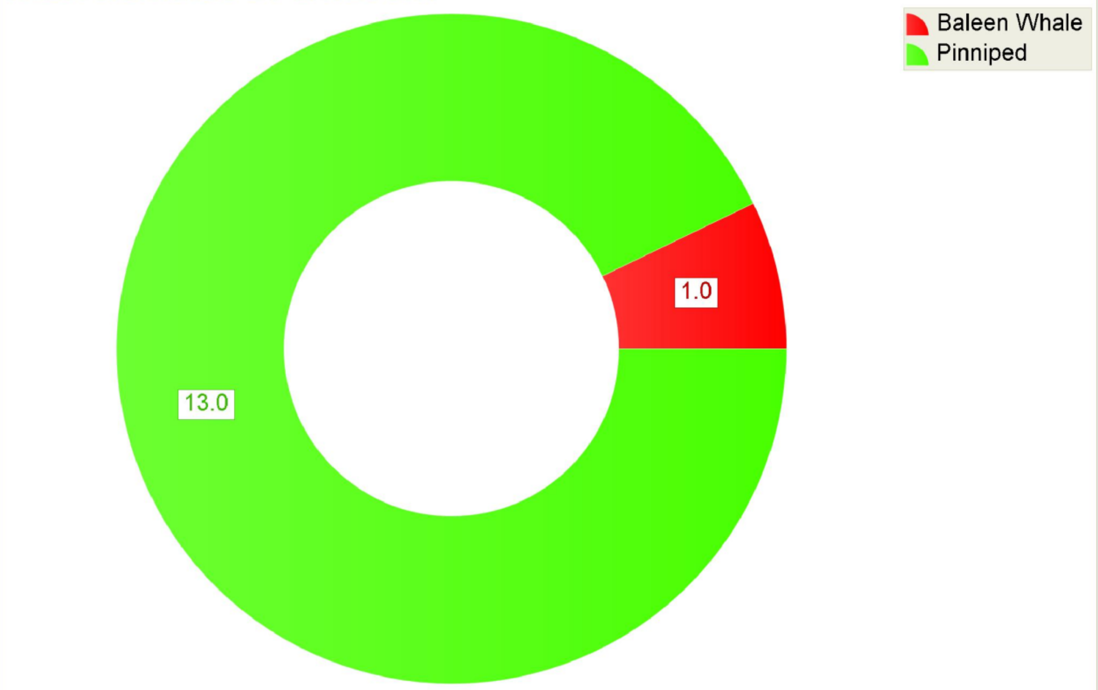
Week Starting 18 August 2013

PROJECT SIGHTINGS

SIGHTINGS BY CATEGORY

Category	Weekly	Project
Baleen Whale	1	2
Dolphin	0	3
Pinniped	13	13
Sperm Whale	0	1

WEEK SIGHTINGS BY CATEGORY



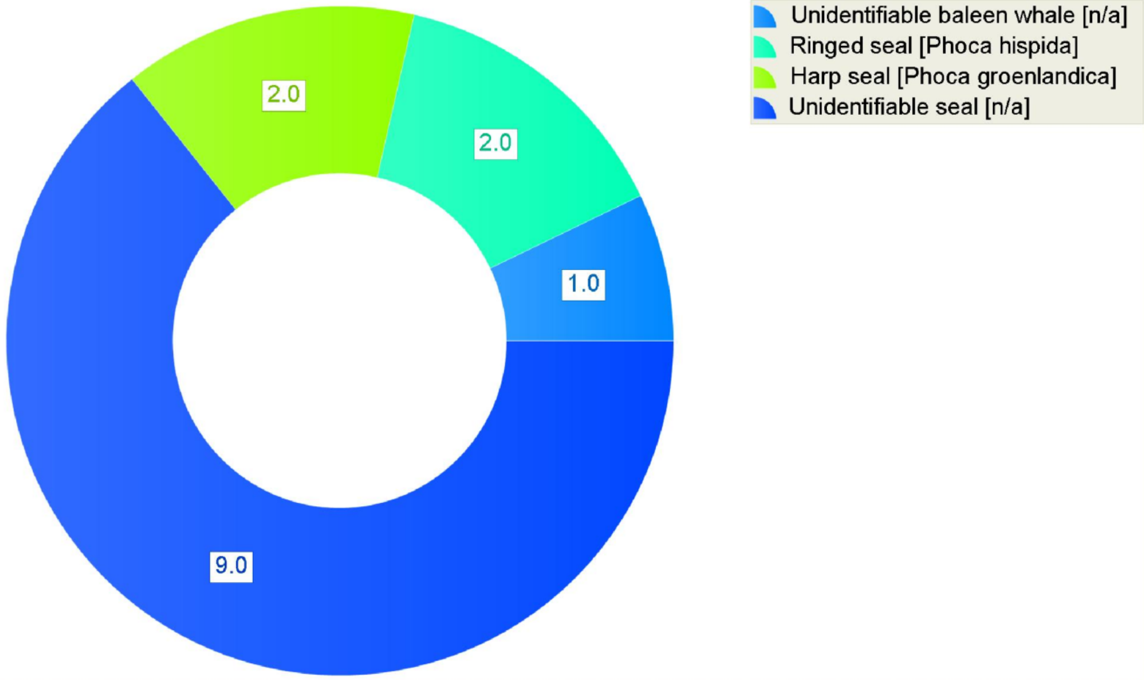
WEEKLY MMO REPORT

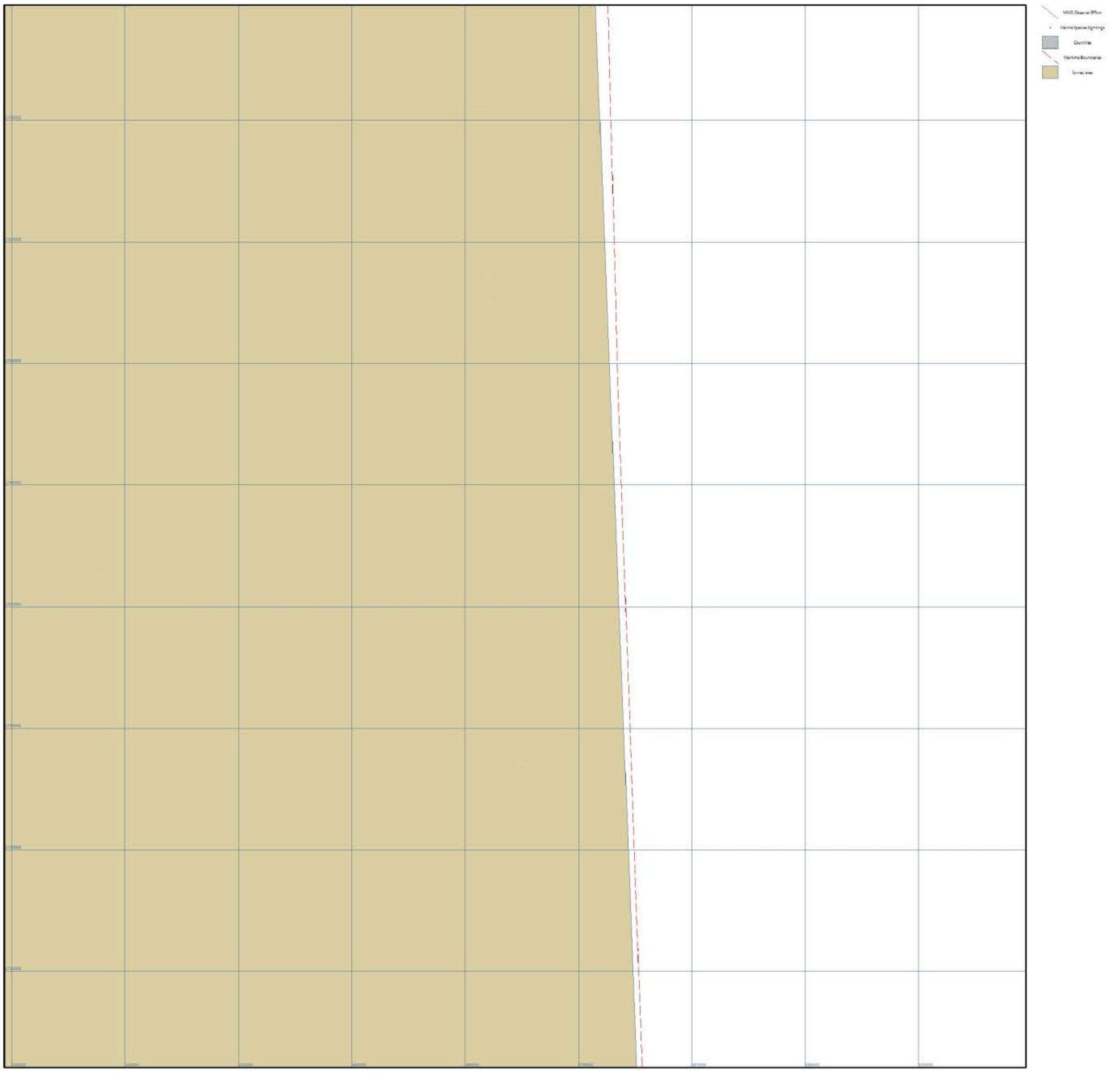
Week Starting 18 August 2013

SIGHTINGS BY SPECIES

Species	Weekly	Project
Fin whale [Balaenoptera physalus]	0	1
Unidentifiable baleen whale [n/a]	1	1
White-beaked dolphin [Lagenorhynchus albirostris]	0	2
Unidentifiable dolphin [n/a]	0	1
Harp seal [Phoca groenlandica]	2	2
Ringed seal [Phoca hispida]	2	2
Unidentifiable seal [n/a]	9	9
Sperm whale [Physeter macrocephalus]	0	1

WEEK SIGHTINGS BY SPECIES





Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)
EOM1527 BGR Norway MMO

WEEKLY MMO REPORT

Week Starting 25 August 2013

Week 3 of Project

PROJECT DETAILS

Client	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	**Streamers**	1	**No. sources**	1
Survey	EOM1527 BGR Norway MMO	**Streamer length**	4200	**Source volume**	2000
Vessel	R/V OGS Explora	**Streamer sep**		**Source separation**	
Contractor		**Streamer depth** **Source depth**	6m	**Shot interval**	
Mobilisation	15/08/2013	**Sample rate**		**Record length**	
Contractor project #		**Group interval**		**Nominal source-near trace offset**	

CONTACT INFORMATION

MMO Company	RPS Energy		
MMO Personnel	Nathan Gricks	nathangricks@yahoo.co.uk	+44 (0) 1297 34656
Client contact	Susanne Wrobel	susanne.wrobel@bgr.de	+49 (0)511 643 2271
Party Chief	Party Chief		

DAILY MMO DIARY

Sighting #	Date	Species	Start	End	Action taken	Vessel Activity	Source status when detected	Estimated loss of production
20	25/08/2013	Unidentifiable seal [n/a]	04:05	04:05	No Action	Online - acquiring data	Full power	0
21	25/08/2013	Unidentifiable seal [n/a]	07:59	07:59	No Action	Online - acquiring data	Full power	0
22	25/08/2013	Unidentifiable seal [n/a]	08:05	08:05	No Action	Online - acquiring data	Full power	0
23	26/08/2013	Unidentifiable baleen whale [n/a]	15:13	15:55	No Action	Other	No source	0
24	29/08/2013	Walrus [Odobenus rosmarus]	07:15	07:20	No Action	Other	No source	0
25	31/08/2013	Unidentifiable seal [n/a]	18:46	18:46	No Action	Online - acquiring data	Full power	0
26	31/08/2013	Harp seal [Phoca groenlandica]	19:25	19:25	No Action	Online - acquiring data	Full power	0

WEEKLY MMO REPORT

Week Starting 25 August 2013

SUMMARY OF ACTION TAKEN

Action	Weekly	Project
No Action	7	26
Power Down	0	0
Shut Down	0	0
Delayed Soft Start	0	0

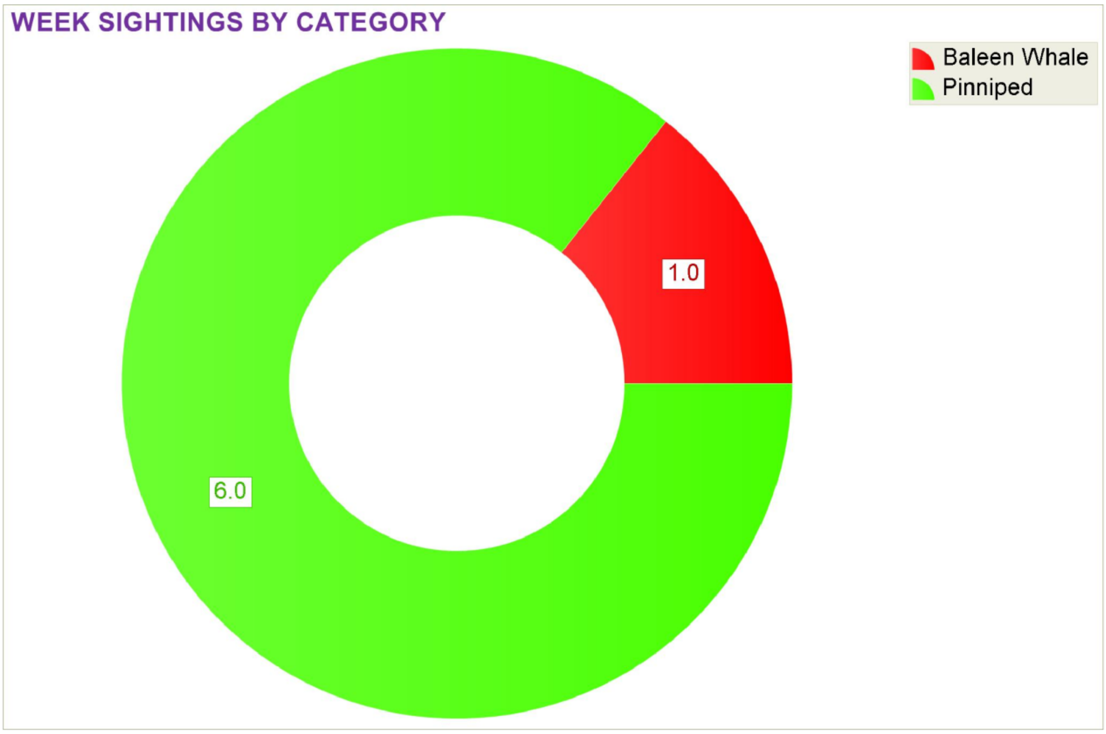
WEEKLY MMO REPORT

Week Starting 25 August 2013

PROJECT SIGHTINGS

SIGHTINGS BY CATEGORY

Category	Weekly	Project
Baleen Whale	1	3
Dolphin	0	3
Pinniped	6	19
Sperm Whale	0	1



Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)
EOM1527 BGR Norway MMO

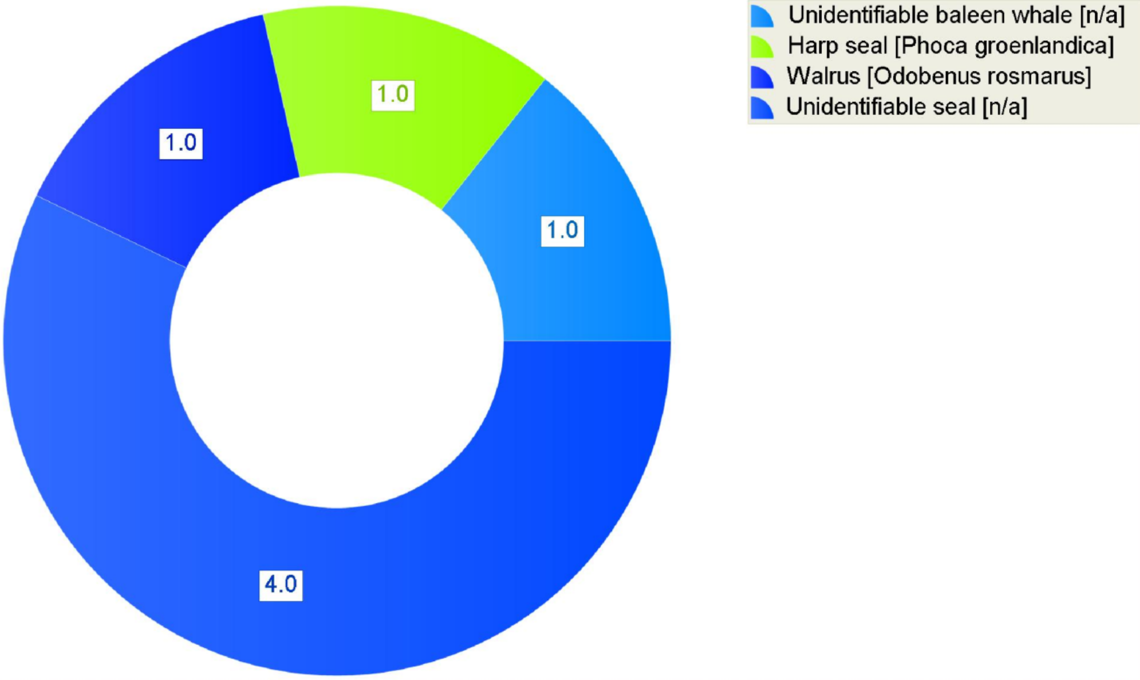
WEEKLY MMO REPORT

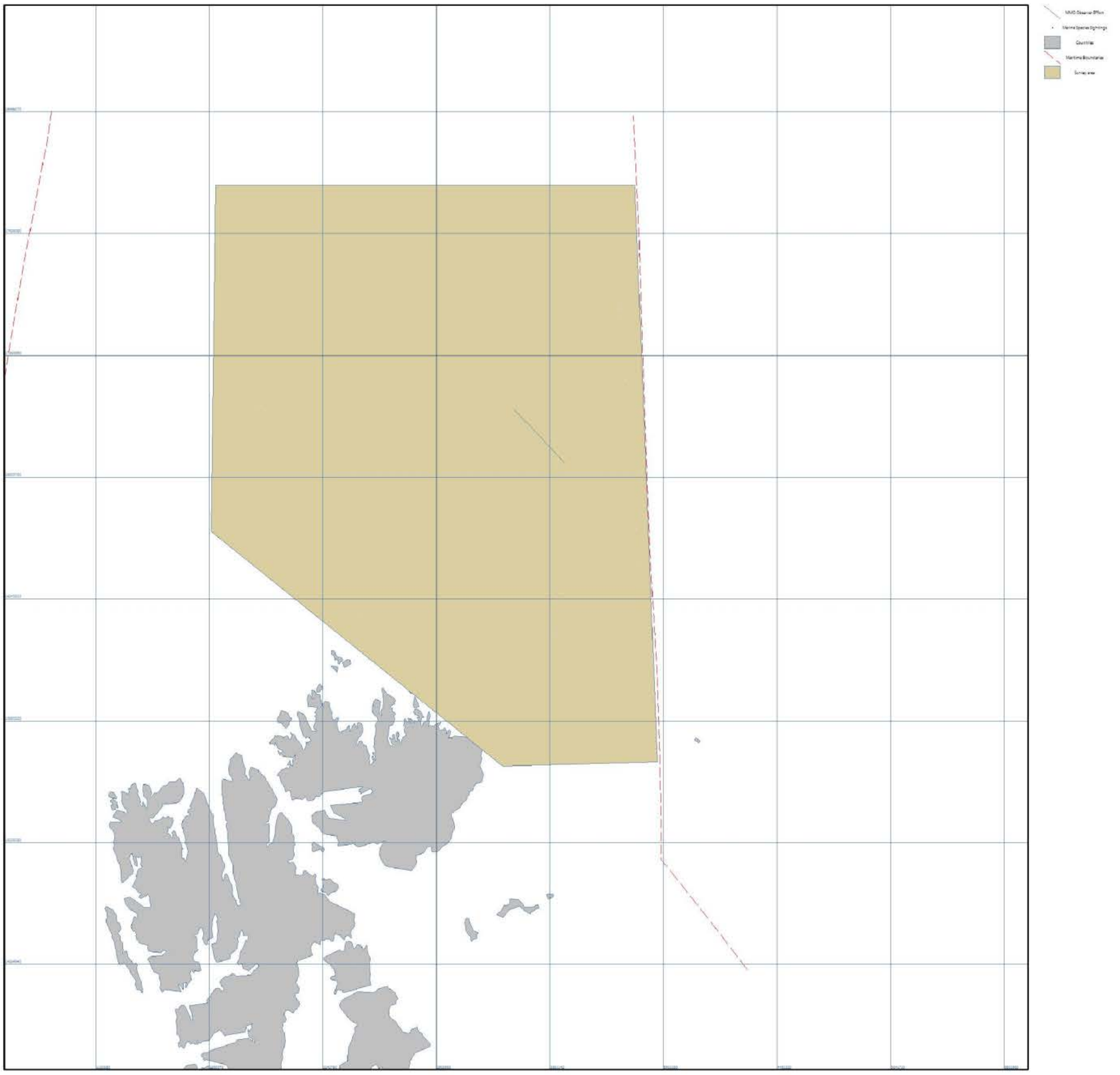
Week Starting 25 August 2013

SIGHTINGS BY SPECIES

Species	Weekly	Project
Fin whale [Balaenoptera physalus]	0	1
Unidentifiable baleen whale [n/a]	1	2
White-beaked dolphin [Lagenorhynchus albirostris]	0	2
Unidentifiable dolphin [n/a]	0	1
Walrus [Odobenus rosmarus]	1	1
Harp seal [Phoca groenlandica]	1	3
Ringed seal [Phoca hispida]	0	2
Unidentifiable seal [n/a]	4	13
Sperm whale [Physeter macrocephalus]	0	1

WEEK SIGHTINGS BY SPECIES





WEEKLY MMO REPORT

Week Starting 1 September 2013

Week 4 of Project

PROJECT DETAILS

Client	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	Streamers	1	No. sources	1
Survey	EOM1527 BGR Norway MMO	Streamer length	4200	Source volume	2000
Vessel	R/V OGS Explora	Streamer sep		Source separation	
Contractor		Streamer depth Source depth	6m	Shot interval	
Mobilisation	15/08/2013	Sample rate		Record length	
Contractor project #		Group interval		Nominal source-near trace offset	

CONTACT INFORMATION

MMO Company	RPS Energy		
MMO Personnel	Nathan Gricks	nathangricks@yahoo.co.uk	+44 (0) 1297 34656
Client contact	Susanne Wrobel	susanne.wrobel@bgr.de	+49 (0)511 643 2271
Party Chief	Party Chief		

DAILY MMO DIARY

Sighting #	Date	Species	Start	End	Action taken	Vessel Activity	Source status when detected	Estimated loss of production
27	01/09/2013	Unidentifiable seal [n/a]	06:56	06:56	No Action	Online - acquiring data	Full power	0
28	01/09/2013	Harp seal [Phoca groenlandica]	09:23	09:23	No Action	Online - acquiring data	Full power	0
29	03/09/2013	Unidentifiable seal [n/a]	12:35	12:35	No Action	Online - acquiring data	Full power	0
30	03/09/2013	Unidentifiable seal [n/a]	12:44	12:44	No Action	Online - acquiring data	Full power	0
31	03/09/2013	Unidentifiable seal [n/a]	12:48	12:48	No Action	Online - acquiring data	Full power	0
32	03/09/2013	Unidentifiable seal [n/a]	12:59	12:59	No Action	Online - acquiring data	Full power	0
33	03/09/2013	Unidentifiable seal [n/a]	13:07	13:07	No Action	Online - acquiring data	Full power	0

WEEKLY MMO REPORT

Week Starting 1 September 2013

SUMMARY OF ACTION TAKEN

Action	Weekly	Project
No Action	7	33
Power Down	0	0
Shut Down	0	0
Delayed Soft Start	0	0

WEEKLY MMO REPORT

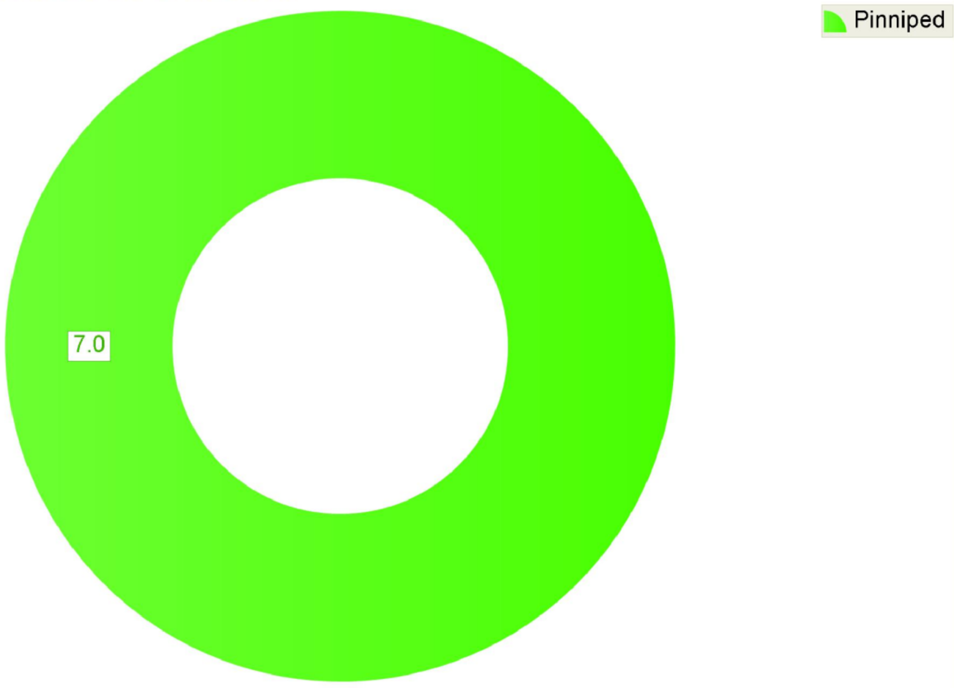
Week Starting 1 September 2013

PROJECT SIGHTINGS

SIGHTINGS BY CATEGORY

Category	Weekly	Project
Baleen Whale	0	3
Dolphin	0	3
Pinniped	7	26
Sperm Whale	0	1

WEEK SIGHTINGS BY CATEGORY



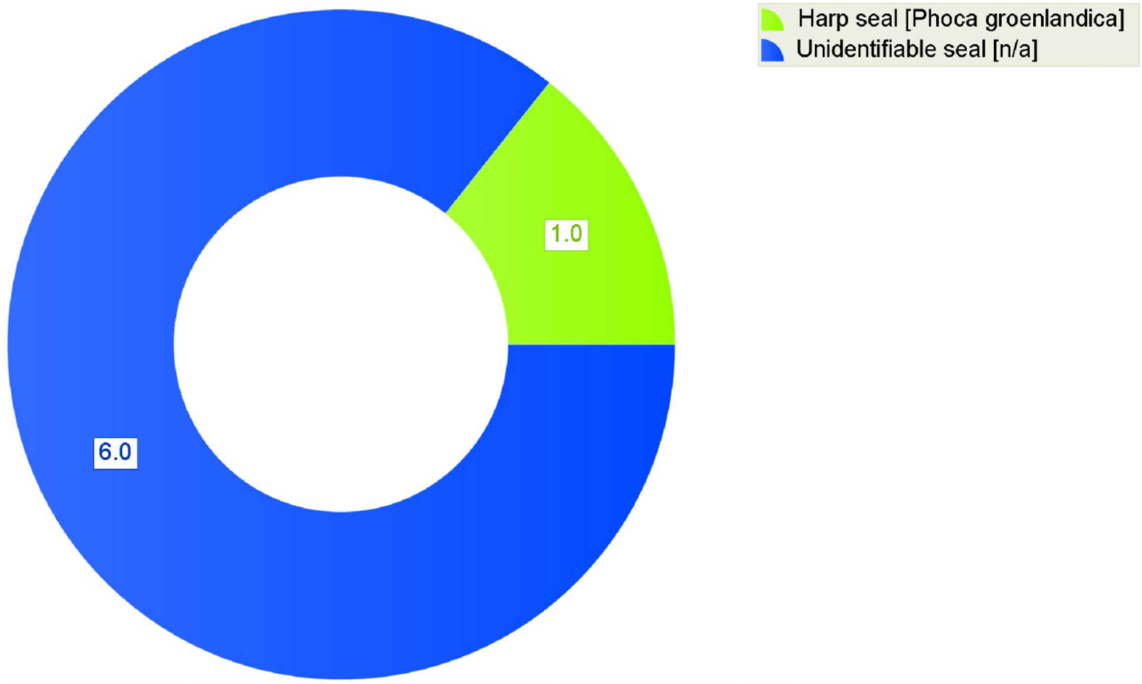
WEEKLY MMO REPORT

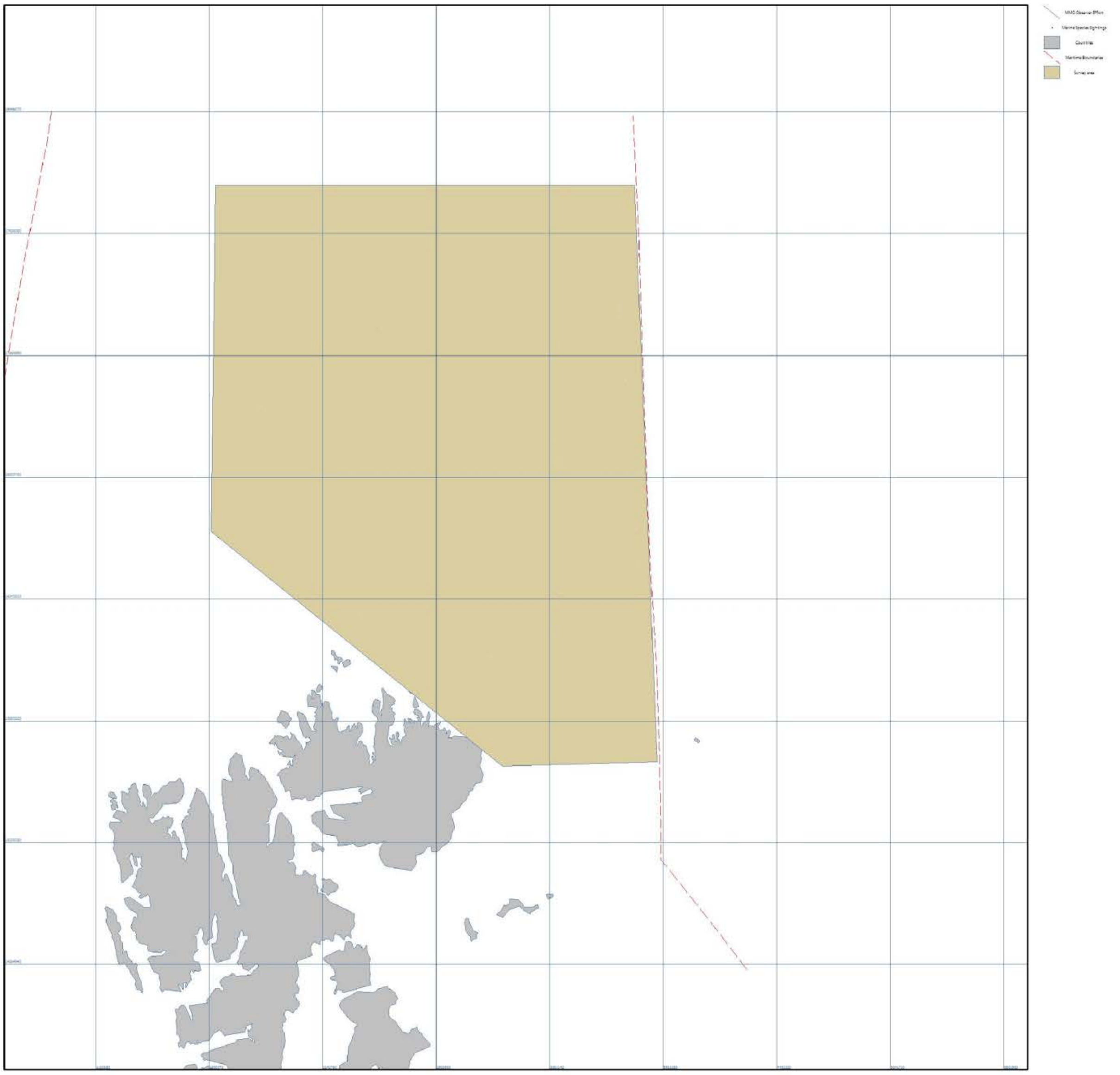
Week Starting 1 September 2013

SIGHTINGS BY SPECIES

Species	Weekly	Project
Fin whale [Balaenoptera physalus]	0	1
Unidentifiable baleen whale [n/a]	0	2
White-beaked dolphin [Lagenorhynchus albirostris]	0	2
Unidentifiable dolphin [n/a]	0	1
Walrus [Odobenus rosmarus]	0	1
Harp seal [Phoca groenlandica]	1	4
Ringed seal [Phoca hispida]	0	2
Unidentifiable seal [n/a]	6	19
Sperm whale [Physeter macrocephalus]	0	1

WEEK SIGHTINGS BY SPECIES




MMO Observer Effort
Marine Species Sightings
Countries
Maritime Boundaries
Survey area

A.9 List of figures

A.10 List of tables