ALKOR-Berichte

Student training cruises University Bremen

Cruise No. AL525/Leg 1+2+3

August 02 – August 16, 2019
Kiel (Germany) – Kiel (Germany)
SEEGEOPHYS. GÜ UNI BREMEN

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2022

Preface:

The student training cruise of the Faculty of Geosciences at the University of Bremen took place in 2019 during the Cruise AL 525. The cruise was dedicated to master and bachelor students. The master students took part in the frame of the course “Advanced marine geophysical survey project”, which is part of the module “Marine Field and Lab Practice” within the internationally oriented postgraduate study program Master of Science "Marine Geosciences". The module is mandatory for students in the first year of the curriculum. The data collected during the cruise are used for small scientific projects carried out by the students after the cruise. For the bachelor students, the cruise is the “Seegeophysikalische Geländeübung” as part of the module “Projektkurs”. This module is mandatory for students in their third academic year. The “Seegeophysikalische Geländeübung” is addressed to students which enrolled the core subject “angewandte Geophysik”. Within this core subject, the module “Marine Geophysik” is a major component of the second academic year of the students, and the content communicated in the module „Marine Geophysik“ should be applied during the cruise.

The cruise was split into three legs to exchange students. The first and third leg was assigned to the bachelor course, whereas the second leg was attributed to the master course. During the cruise seismo-acoustic data were collected using a multichannel seismic system, a multibeam system, and the hull mounted echosounders SES2000 and EK60. Additionally magnetic and CTD measurements were carried out.

As part of the assessment, the students have to write the cruise reports and submit them as a team by one document per leg. These documents are combined here. It should be noted, that the cruise reports are edited by the teachers but could contain still some errors. Due to limited number of students not all methods are described for all legs in detail.

ALKOR-Berichte

Seegeophysikalische GÜ

Cruise No. AL525/Leg 1

August 02 – August 06, 2019

Kiel (Germany) – Sassnitz (Germany)

SEEGEOPHYS. GÜ UNI BREMEN

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Table of Contents

1 Cruise Summary

1.1 Summary in English

The expedition took place from August 2nd till August 6th. The goal from the cruise AL525 Leg 1, is an instruction of Geosciences Bachelor students, from the University Bremen, how the operating geophysical Systems function in diverse fields (hydro-acoustic and magnetic): Seismic (Multi-channel seismic short MCS), sediment echosounder (SES 2000 medium), echosounder EK60, bathymetry (Reson Sea Bat 7125) and magnetic (SeaSPY2). And additionally, observing the stations all around the clock and the following evaluation from the measurements and geological interpretation of the profiles. Throughout the whole cruise the trainees were observed by PhD Dr. Tilmann Schwenk and other tutors.

In the following parts the itinerary of the cruise AL525, as well as the different geophysical measurement methods will be described more in detail.

1.2 Zusammenfassung

Die Expedition fand vom 2. bis 6. August statt. Das Ziel der Fahrt AL525 Leg 1, ist eine Unterweisung von Geowissenschafts-Bachelor-Studenten der Universität Bremen in die Funktionsweise der eingesetzten geophysikalischen Systeme in verschiedenen Bereichen (hydroakustisch und magnetisch): Seismik (Multikanal-Seismik kurz MCS), Sediment-Echolot (SES 2000 medium), Echolot EK60, Bathymetrie (Reson Sea Bat 7125) und Magnetik (SeaSPY2). Hinzu kam die Beobachtung der Stationen rund um die Uhr und die anschließende Auswertung der Messungen und geologische Interpretation der Profile. Während der gesamten Fahrt wurden die Praktikanten von Dr. Tilmann Schwenk und anderen Tutoren betreut.

In den folgenden Abschnitten werden der Ablauf der Fahrt AL525, sowie die verschiedenen geophysikalischen Messmethoden näher beschrieben.

2 Participants

2.1 Principal Investigators

Name	Institution
Schwenk, Tilmann, Dr.	Universität Bremen
Frederichs, Thomas, Dr.	Universität Bremen

2.2 Scientific Party

Name	Discipline	Institution
Schwenk, Tilmann, Dr.	Marine Geophysics / Chief Scientist	Uni Bremen
Frederichs, Thomas, Dr.	Marine Geophysics / Magnetics	Uni Bremen
Bergmann, Fenna, Dr.	Marine Geophysics / Seismic	Uni Bremen
Steinmann, Lena, Dr.	Marine Geophysics / Seismic	Uni Bremen
Brune, Rouven	Marine Geophysics / Hydroacoustic	Uni Bremen
Bach, Alissa	Student	Uni Bremen
Gottschalk, Arne	Student	Uni Bremen
Glatz, Kilian	Student	Uni Bremen
Porrmann, Simon	Student	Uni Bremen
Thoden, Rickmer	Student	Uni Bremen
Möller, Wilma	Student	Uni Bremen

2.3 Participating Institutions

Universität Bremen   Faculty of Geosciences

3 Research Program

3.1 Description of the Work Area

The cruise took place in the German part of the Baltic Sea. In particular, the cruise started in the Kiel Bay with focus on its part, followed by a survey in the Fehmarn Belt. Then the ship headed to Rügen across the Mecklenburg Bay to arrive in Sassnitz.

3.1.1 Quaternary Geology of the Working Area

The Quaternary sediments in the Baltic Sea Basement are dominated by processes influenced from the withdrawing ice sheet laying over Scandinavia (Andren et al., 2011). Using acoustic methods of Geophysics we can distinguish between 4 types of deposits which are linked to different stages in the development of the Baltic Sea (Toth et al., 2013). After the last glacial maximum which was around 21.000 years BP the Ice sheet started to shrink. The first Period called the Baltic Ice Lake (BIL) dominates the deposits from 16-11.7 ka (Andren et al., 2011). Glacial Deposits arose down in the southern Coastline while the melting created a glacial lake in Bornholm & Arkona basement. BIL deposits lying right above the glacial till and are made of varved clay.

With the beginning of the Holocene the period of the Yoldia Sea (11,7 – 10,7 ka) started (Andren et al., 2011). As consequents of a general warming the ice sheets melting was fastened. About almost the same time salt water found its way in the Yoldia Sea. Due to the isostatic adjustment that happened in the area of Sweden The Yoldia Sea was started to became isolated from the salt water in the same Period. By the end of Yoldia Sea the ice sheets most southern border was on the entrance to the Botnic gulf. Yoldia Sea deposits comprise homogeneous clay with some sulfuric parts in between.

The third Stage was the Ancylus Lake (10,7- 9,8 ka) that started during the final melting stage of the ice Sheet (Andren et al., 2011). The Huge amounts of melt water that entered made the Ancylus Lake low in nutrition and kept primary production small. The deposits from the Ancylus Lake period are made of homogenous clay.

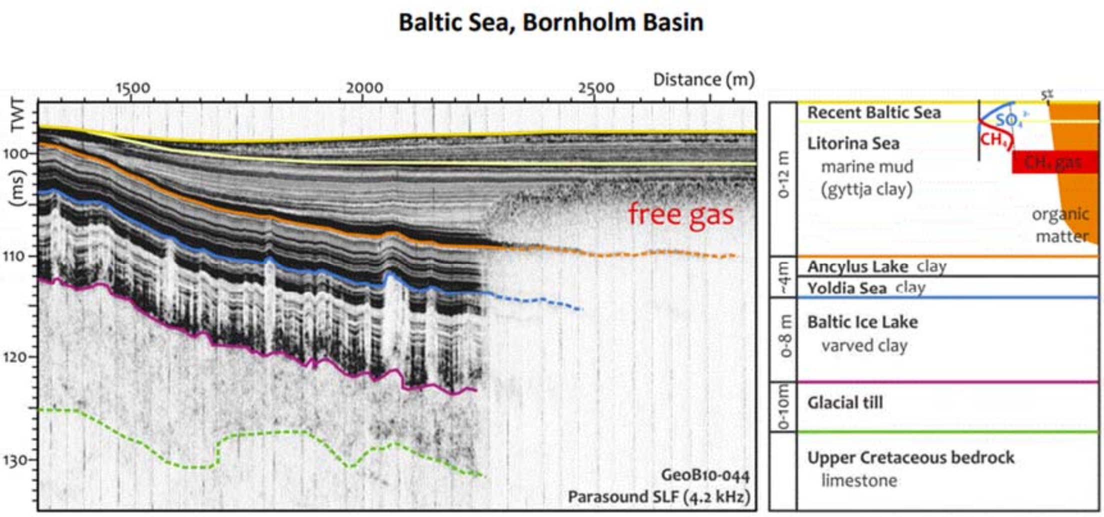

Fig. 3.1 Different stages of the Baltic Sea after the LGM as imaged in Parasound data (Toth et al., 2013)

The end of the Ancylus Lake period is marked by another saltwater intrusion that led to the Littorian Sea stage (9,8- 8 ka). The main melting event was over and there was saltwater entering the sea, this led to a raise in organic material which can be found in the marine mud deposits (Andren et al., 2011).

The development of the recent Baltic Sea (8 ka- present) is dominated by Sea Level Changes and changes in the shape of the channels connecting the Baltic Sea to the oceans (Andren et al., 2011). This was causing a certain alteration of the salinity in the Baltic Sea over the past 8 ka. recent sediments comprise marine mud with sulfuric clay.

3.2 Aims of the Cruise

The main aim of the cruise was to teach Bachelor students in their second year the acquisition of marine geophysical data including hydroacoustic, seismic and magnetic data. Scientifically, the focus lead in glacial and bottom current induced structures.

3.3 Agenda of the Cruise

After departure in Kiel at the 03.08.2019, all scientific equipment was started immediately, and measurements were conducted in the Kiel Bay by long east-west profiles. With all (working) systems running, the ship passed Fehmarn and crossed the Mecklenburg Bay. After some surveys north of Rügen, the ship arrived at the 06.08.2019 in Sassnitz.

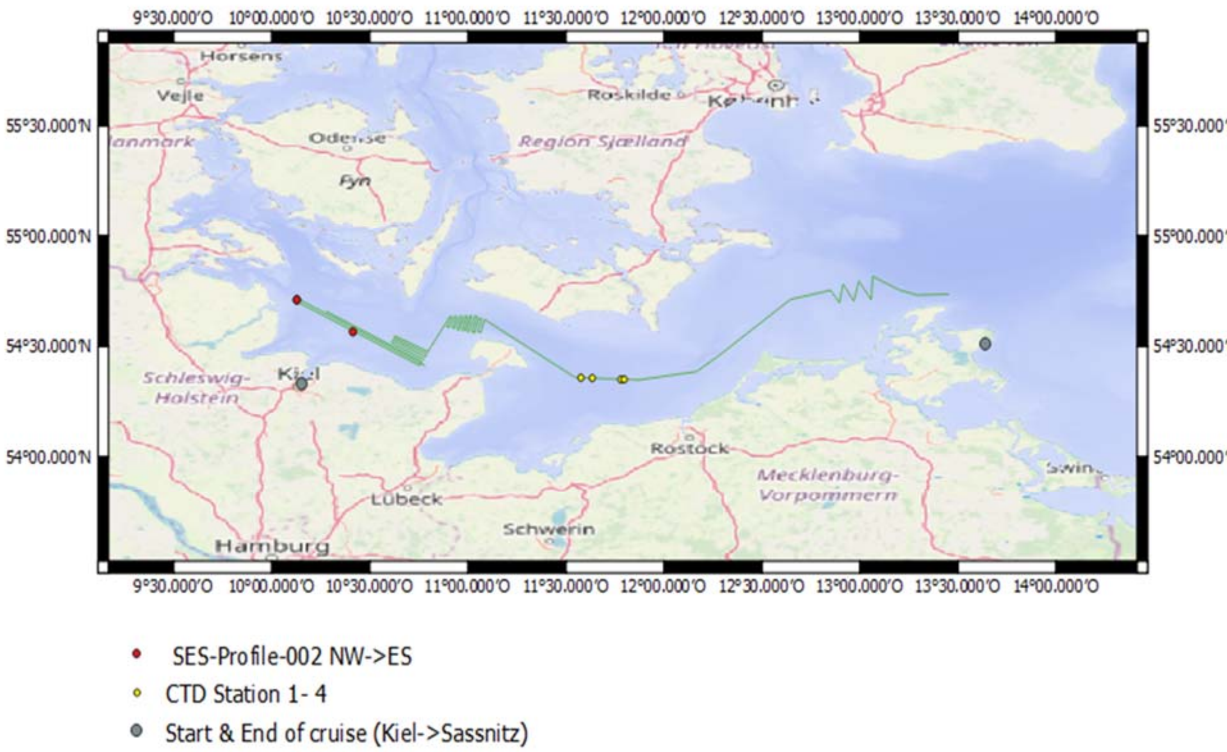

Fig. 3.2 Track chart of R/V ALKOR Cruise AL525/1.

4 Narrative of the Cruise

The entire time span on board AL525 Leg1 (2nd of August- 6th of August) the weather was very stable and the temperature during the day about 20°C with a slight breeze of wind. No further occurrences weather based.

The first day started with our arrival at the pier where the AL525 was docked, on the 2nd of August at 2:30pm. The equipment was prepared: the seismic station was getting connected with the streamer, as well as the compressor. The birds linked with the station and the Mini GI-Gun built together. Next to these preparations, the magnetometer (SeaSPY2) was built together and linked with the software and the Multi-beam was connected to the bathymetric station. The used geophysical observation terminals were installed in the dry laboratory.

The expedition started on the 3rd of August at 8:00am. The AL525 drove out, north-east, in the Kielerbucht. After lunch the streamer were let to water at 12:40am and while the work process the birds connected with the streamer. Shortly after the Mini GI-Gun was slowly let to water. Due to a varied shot rate within the first 3 s a problem was located (54° 39.09'N 10°17.17'E), a problem was suspected within the compressor, it did not deliver sufficient air to the GI-Gun, causing a pressure issue. The first seismic measurement had to be canceled and the GI-Gun had to be heaved back onboard.

The problem was solved, and the measurement proceeded. The first line, Geob19-216, started (54° 38.01'N 10° 19.45'E). Not to long after that, the whole seismic measurement operation had to be canceled completely (54° 35.69'N 10° 24.50'E). The compressor began to smoke. The electrician on board confirmed that there was no way on board to repair the compressor. The GI-Gun and the Streamer were retrieved (54° 32.00'N 10° 32.48'E). The other Systems: SES- Innomar, EK60, Multi beam and the Magnetometer were still functioning, and the measurements were successful. The following measurements within the Kielerbucht occurred with almost no incidents, at the location (54° 42.18'N 10° 09.27'E) on the 4th of August at 12:15pm, the magnetic data recording suddenly stopped. The Magnetometer had to heaved on deck. The issue was solved, and the recording could proceed.

A deviation off course had be maneuvered (54° 27.08'N 10° 44.68'E) due to avoid an object. Later on in the morning, an issue occurred within the dry laboratory, the “Werum- Display”, which gave us insight in the GPS-coordinates, heading and course. Not to long after that a solution was found.

The ship took course further north-east driving further out of the Kielerbucht, at the location 54°38.19'N 10°54.51'E. While continuing the geophysical measurements on board the ship maneuvered lines with a short period and rather narrow lines. The destined field of work was a glacial channel, first observations were partially filled sediments within the channel and deep depressions (15 m-26 m). In between a few incidents have occurred: ship was off track for a short period of time (54° 35.35'N 10° 59.53'E-54° 36.76'N 10° 59.89E) and the System of the SES-Innomar on board stopped recording shortly before midnight (54°36.07N 11°01.97'E-54°34.38'N 11°01.32'E), after a short period of time the issue could be solved.

On August 5th the AL525 took course east-south (54° 36.51N 11° 07.63E) through the Fehmarnbelt. While driving parallel to the coast of Fehmarn, the AL525 had to drive off track during the straight profile, due to explosives near the coast of Fehmarn and steadily driving past the Lübeckerbucht. Later that morning, four locations where determined for CTD- measurements (sampling: west to east), aiming a constructive insight of the layers within the water columns by comparing velocity, temperature and density of the inner water layers. In the mean while the magnetometer recovered and heaved on deck. These measurements were made between the location 54° 20.34'N 11° 51.91'E and 54°21.03'N 11°47.68'E. A while later, the magnetometer was let back to water (54°20.96'N 11°48.68'E) to proceed the magnetic data recording. The ship took course to the west coast in front of Rügen, to another glacial channel and with the same intention to observe. Between the locations 54° 23.71'N 12° 10.88’E and 54°42.64'N 13°03.25'E, the ship a row of narrow and short termed profile lines over the glacial channel.

In the early morning of August 6th the last geophysical measurements and observations were taken and the AL525 was taking course towards the port of Sassnitz, through the Mecklenburger Bucht. The ship docked at the port at 9:15am.

5 Preliminary Results

5.1 Multibeam

During FS Alkor Cruise AL525 two echo sounder systems, were used. For bathymetric mapping of the seafloor in shallow water the Reson Sea Bat 7125 was used. The recorded data will be used to get an overview of the seafloor in the Baltic Sea and will be used for the study group of the course applied geophysics as raw data. To get an insight of the sediment columns (about 70 m) under the sediment surface, the SES 2000 medium was used. Both systems were operated in a 24 hour watch mode by student groups of two. The raw data files were cut automatically, by Sea Bat, at a file size of around 250 MB.

The multibeam sonar was attached to a steel construction that was lowered down the moonpool and fixed at the keel. To get usable data a motion sensor was located next to the Reson system, which delivered its data directly to the multibeam sonar.

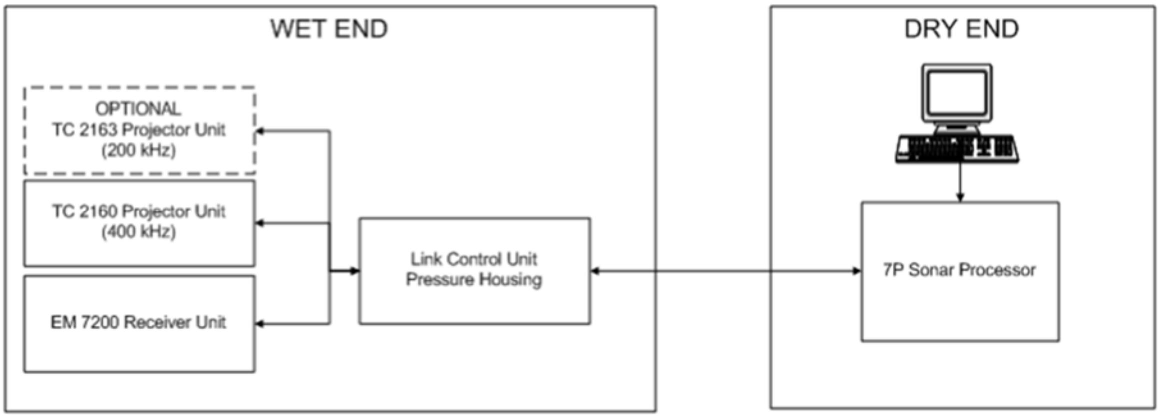

Fig. 5.1 Construction of Sea Bat 7125 from Sea Bat Operator Manual

The Sea Bat 7125 allows accurate bathymetric mapping in shallow water depths between 1-500 m. You can choose among the two-recording options baseline system and 200 kHz option. The baseline system, which was used at the cruise, is for measuring in water depths between 0 - 200 m. The sonar frequency is 400 kHz with an aperture angle of 128°. The reception is obtained from 256 beams, with a width of 1° across track. The Sea Bat allows a pulse width from 10 to 300 µs with a pingrate up to 48 p/s. The Sea Bat 7135 not only gives an overview over the sediment floor, but can also provide water column backscatter information. The multibeam sonar, which is divided into a projector (TC 2160) und receiver (EM 7200) unit, sends its data to the Link Control Unit (LCU). The LCU transmits the data then to the 7P Sonar Processor were to store the data by the computer in the ships control room. The Sonar Processor also provides beam forming and initial processing of the acoustical data.

The system worked reliable during the whole cruise, but due to problems with the GPS there are gaps in the recordings. The length of the gaps is about half a minute to a minute recording time. Because of the relatively slow speed of the vessel the used ping rate is max 4 p/s. The pulse width was 300 µs and the power was 220 dB with a gain of 83 dB. The Pulse Type CW was used, which means that the Sea Bat operated with a continuous wavelength during the measurements. The water depth varied between 5- 40 m throughout the route and the gates were changed manually due to the depth. Because the water column is very stratified and due to the relatively low water depths no water sound profile was determined. The assumed sound velocity of the water was 1480 m/s. EA was used as setting, which means that the angle between the beams are all equal. The absorption in the water column was 80 dB/km and the spreading 30 dB.

In Figure 5.2 a part of the bathymetric profile is shown. A depressional structure is clearly visible, possibly generated by strong bottom currents.

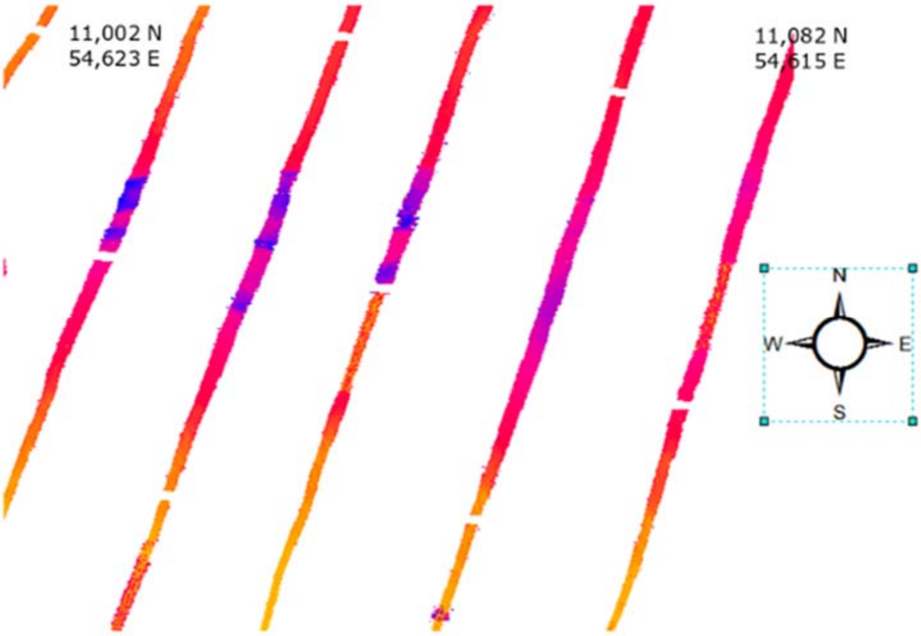

Fig. 5.2 Bathymetry data showing a depression north-west of Fehmarn

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5.2 Sub-bottom profiling

5.2.1 System overview and data handling

On FS Alkor, the SES 2000 medium is installed. For sub-bottom profiling sound pulses are transmitted to the seafloor. These pulses will be reflected at the seafloor or other objects like rocks and sediment layers. The reflected singles are used to calculate an echogram showing the sub-seafloor structure along the sailed track. Assuming a certain sound speed the travel time obtained can be converted into a distance, like water depth or layer thickness etc. The echo strength depends on the reflection coefficient, the attenuation of the signal and the roughness of the layer boundary. The resolution depends on the size of the footprint, the effective length of the transmitted sound pulls as well as the pulse repetition rate.

The SES 2000 has a range from 85 –115 kHz primary frequencies (PF). The secondary low frequency (SLF) is selectable with 4, 5, 6, 8, 10, 12 and 15 kHz. The transmit beam width (-3db) is approx. ± 1° Which allows a footprint of <3,5% of the water depth. Range/Layer resolution approx. 1 cm up to 5 cm. The sediment penetration goes up to 50m depending on the sediment type and noise. Water depth range has a range from 2-2000 m and the ping rate can be up to 40 pps. Pulse Typ is Ricker, CW, LFM Chirp and pulse width is selectable from 0.007 – 3.5 ms. During AL 525 the system was configured to achieve a SLF of 4 kHz, 8 kHz and 12 kHz.

The system was most of the times stable but during the cruise it stopped working several times. This led to to several data gaps of up to 1 hour.

Most of the time the pingrate was between 3.95 pps and 5.17 pps. The recording started at a depth of 10 m because of the depth of the seafloor.

The data was stored in raw and SES format. The raw data were routinely converted into sgy data with the custom-made software ps32sgy (Manufactured by H.Keil, University of Bremen) and loaded into the interpretation software „The Kingdom Software" (IHS).

5.2.2 Shipboard results

As visible in Fig. 5.3, which shows a NW to SE oriented SES profile from the Kieler Bucht with a water depth of about 16 m, this region is dominated by a channel with multiple parallel sediment layers. In the NW is a thick unit with vertical sediment layers, which get disturbed in the middle of the canyon. The layers are subparallel, continuous, high frequency and have a high amplitude. At the NW and the SE are reflector free parts which was guessed as gas deposits.

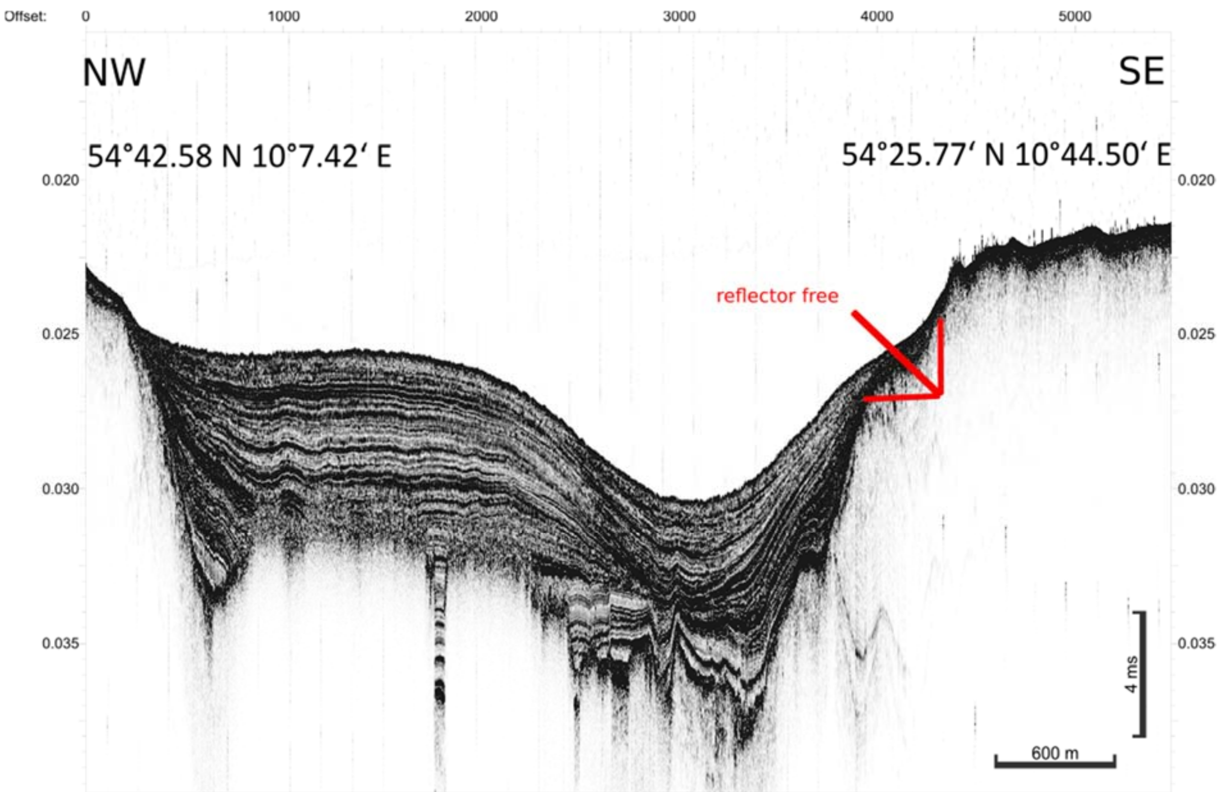

Fig. 5.3 SES profile crossing a channel in the Kiel Bay

5.3 EK60 and CTD measurements.

5.3.1 EK 60 sounder

The SIMRAD EK60 Echosounder, which is a fisch sounder, ran uninterruptedly for the entire length of the cruise. The echo sounder is permanently installed on board and is used by the ship's crew to determine water depths and possible obstacles on the seafloor. The frequencies used are 38 kHz, 70 kHz, 120kHz and 200 kHz with a ping rate of one ping per second.

A total of 38 EK60 profiles were recorded. The received data was stored in SEG-Y Format and interpreted in KingdomTM interpretation system. The signal penetration into the sediment of the EK60 does not exceed a depth of 5 m, which depends on the lithology, grain size and water saturation. The recorded profiles are therefore interesting for possible variations in seafloor topography and in the water column. Because of the variable density of water different water masses can be made visible, as well as particle flux, plankton or fishes, which cause a higher backscatter.

5.3.2 CTD measurements

The CTD system used is a CT_/070 type from Sea&Sun Technology Gmbh with a conductibility/area of 0.65 mS/cm. It is built into a rosette housing capable of holding 12 litre water sampler bottles, although no water samples were taken. The 4 CTD stations (Tab.5.1) have been chosen after recording EK60 Profile “AL525_023_Ek60”.

Station	ALKOR Station Nr.	Date	Time	Position Lat	Position Lon
CTD01	AL525_2-1	05.08.2019	11:34	54° 21’ 25.51’’N	11° 34’ 28.68’’E
CTD02	AL525_3-1	05.08.2019	12:06	54° 21’ 18.55’’N	11° 38’ 03.38’’E
CTD03	AL525_4-1	05.08.2019	12:39	54° 21’ 10.59’’N	11°41’ 40.51’’E
CTD04	AL525_5-1	05.08.2019	13:25	54° 20’ 58.78’’N	11° 47’ 42.37’’E

Table 5.1 CTD stations

With the CTD data the salinity, density, temperature and velocity of the water could be determined. Those parameters were plotted in a chart and put in correlation with the EK60 profile (Fig. 6.1). Density and salinity are not represented in figure 6.1 because of lower result significance.

The reflectors in the water column have a high amplitude from the sea surface to about 2 m water depth. Here they lower in amplitude with just a few sporadic reflectors. Those just above the seafloor could be caused by churned sediment and the high amplitude reflectors in the first few meters under the sea surface, are possibly caused by plankton or fishes. Correlating the CTD plots with the EK60 profile a clear discrepancy between CTD01 and CTD02, CTD03 and CTD04 can be seen. In CTD plot 01 the temperature and velocity increase the first 5 m until they reach a maximum at 4.9 m, whereas the temperature and velocity in the following CTD plots drop to a minimum at 5.2 (CTD02), 6.3 (CTD03) and 7.7 (CTD03) m. This is an indicator that the water mass in point CTD01 is different from the one in the following CTD plots.

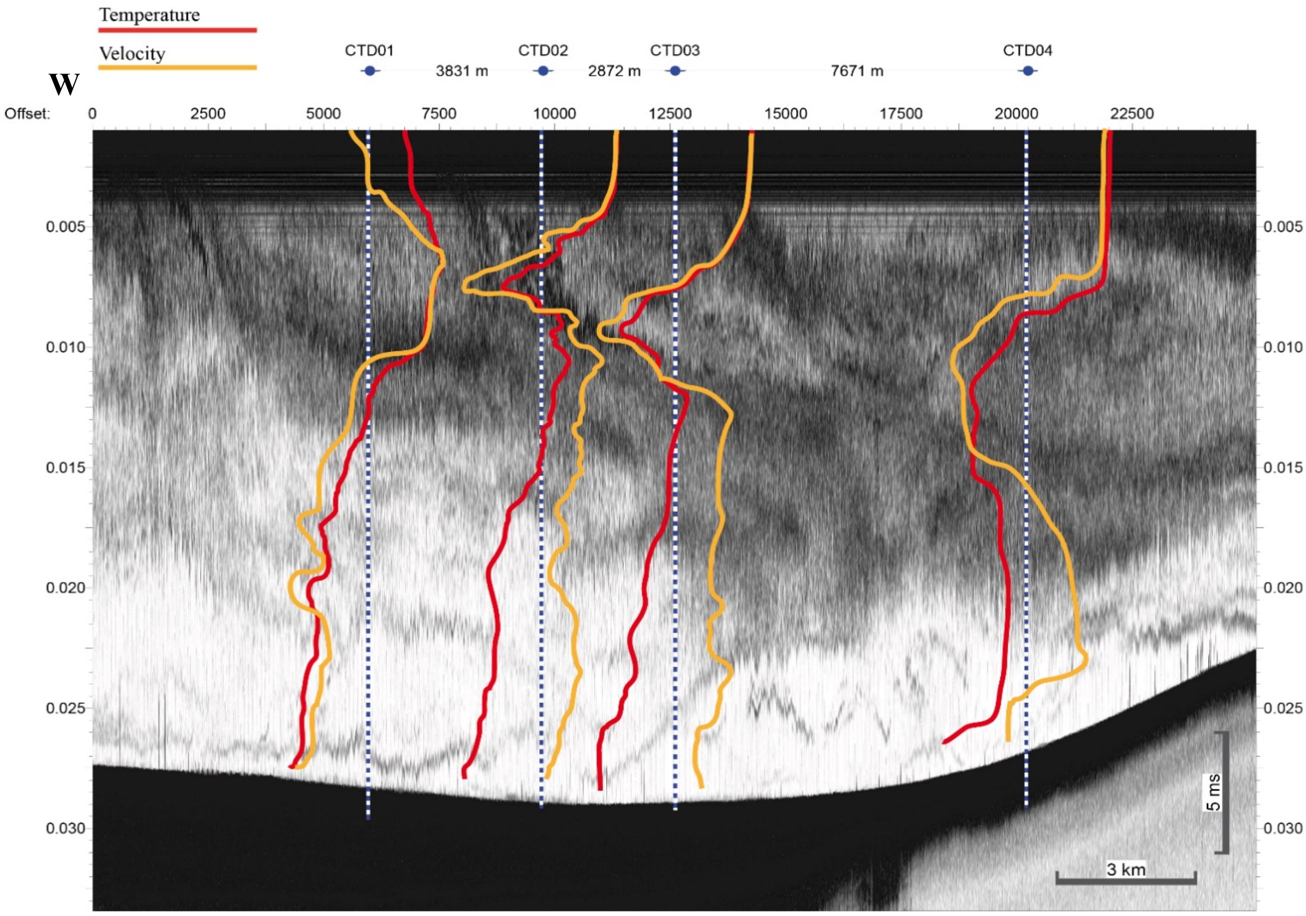

Fig. 5.4 CTD plots of temperature and velocity on the EK60 profile "AL525_023_Ek60"

5.4 Multichannel seismics

5.4.1 System overview

To collect data from older/deeper deposits we installed MCS system using a mini GI-Gun and a 250 m long streamer. We used the mini GI-gun with an additional filling part (so-called micro Gi-Gun) and ended up with a volume of 2×0.1 L. The gun shot every 4 s with a pressure around 120 Bar to reach a central frequency of 250 Hz. The streamer kept 96 hydrophones from which the first (nearest to the ship) third had a fixed spacing of 1 m the second third had 2 m spacing and the last third a spacing of 4 m. The streamer recorded for 2 s. We had 5 birds fixed on the streamer, these birds could be controlled from the Digi-Bird-controlling-unit in the lab. We used the birds to keep the streamer in a certain depth using their wings, which could be controlled from the lab. Main technical communication went through the trigger box which controlled information flux and digitized incoming signals from the streamers (A/D-converter) with a sampling rate from 125 microseconds. The digital data went straight into the Marine-Multi-Channel-system (MaMuCS) software which was used to digitize, visualize and save the data.

5.4.1 Shipboard results

Since the compressor was not able to generate enough pressure to supply the GI-Gun, we just have one profile from MCS data from Leg 1.

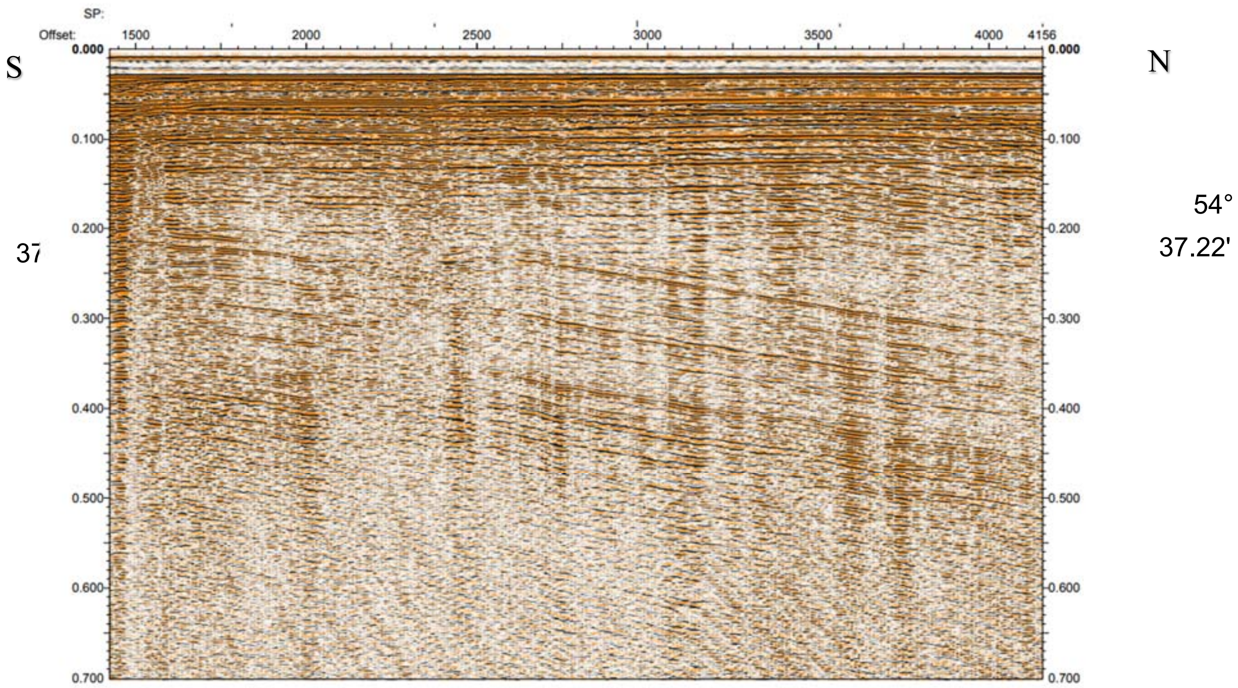

Fig. 5.5 Brutestack of multichannel seismic Profile GeoB19-216

The MCS was shot in front of the Kiel Bay on the 03.08.2019 from 13:50 to 14:22. The data goes down to ca. 400 m depth. In that preview (stack) to the processed data we already see two different layers from which the upper one is laying almost horizontal, while the deeper layer dipping with ca. 20° in direction NW. The first layer should represent all the Quaternary sediments, while the deposits from the dipping layer most likely represents the Cretaceous bedrock. The Quaternary sediment package shows strong and continuous reflectors, while the Cretaceous bedrock shows less and more discontinuous reflectors.

5.5 Magnetics

5.5.1 Magnetometer „SeaSPY2“

During the first leg of the cruise AL525 from Kiel to Sassnitz (02.08.-06.08.2019) the magnetometer SeaSPY2 by Marine Magnetics was used for magnetic measurements. It is designed to be towed behind a vessel and contains an Overhauser magnetometer. The SeaSPY2 system (Fig. 8.1) consists of a towfish, a marine tow cable, a deck leader cable, an isolation transceiver (powering and communication with the towfish), an RS232 interface cable, that conncets to a RS232 PC port, a universal input power supply (100 to 240 V AC) and the BOB software. The collected magnetic data can be displayed on a monitor in real time. The depth of the Overhauser Magnetometer is determined by a pressure sensor inside the towfish. An advantage of the SeaSPY2 is, that it can be operated by only one person.

The Overhauser total field sensor measures the magnetic flux density of the local magnetic field, which varies due to diurnal effects and para-/ or ferromagnetic objects. Since it is a scalar magnetometer it doesn’t measure the direction of the magnetic field. It operates on the proton spin resonance principle and uses the Overhauser effect, which allows the SeaSPY2 magnetometer to measure with one to two orders of magnitude more than a standard proton sensor (SeaSPY2 Manual, 2015). The proton spin resonance principle is based on the fact, that the protons in a hydrogen-rich fluid, when exposed to a magnetic field, align themselves to that magnetic field. When interrupting a current that causes a strong magnetic field, the protons will realign themselves according to the ambient magnetic field, this causes them to process, what can be measured as it produces a weak rotating magnetic field that is proportional to the ambient magnetic field.

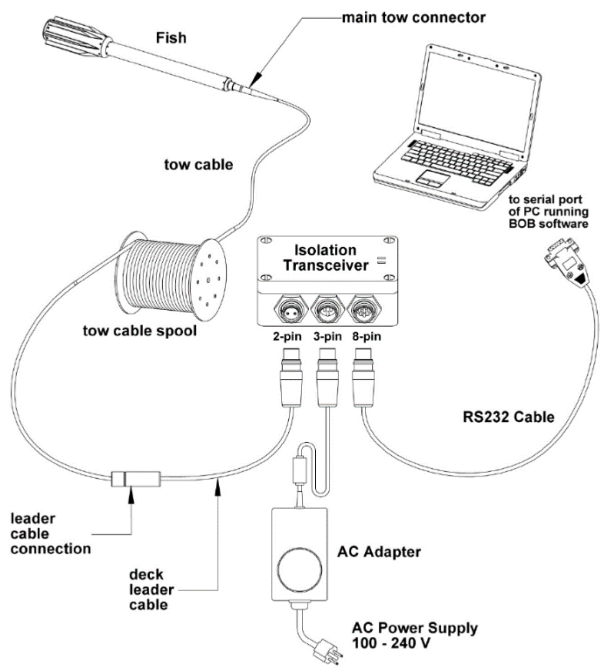

Fig. 5.6 Measuring configuration of the SeaSPY2 (SeaSPY2 Manual, 2015)

5.5.2 Measurements

Measurements were started on 03.08.2019 at 13:29. The first profile (GeoB19-216) was taken at 13:52. They are named according to the SES profiles since the compressor stopped working and there were no seismic profiles recorded after GeoB19-216 on the first leg. The sampling rate was set to 1 Hz. After testing the SeaSPY2 magnetometer on short tow cable lengths, the cable length was increased to 150 m. Depending on the water and magnetometer depth the tow cable length was increased up to 250 m. A long tow cable length results in higher data resolution, since the influence of the vessel on the magnetometer gets reduced. It was always required to check both depths, so the magnetometer does not get damaged. Whenever the cable length was changed or problems occurred (like failures of the ship intern GPS system) it was noted in the magnetic protocol.

All the magnetic profiles taken are shown in Fig. 5.7 and 5.8. There were no magnetic measurements while the CTD measurements were taken.

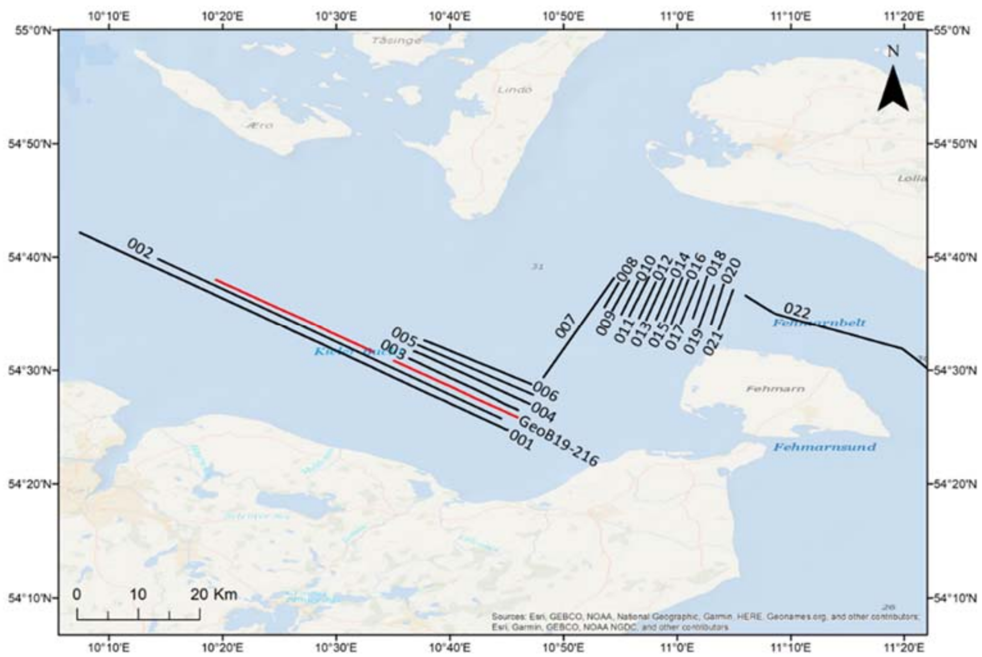

Fig. 5.7 Western part of the magnetic profiles. The red profile is the profile, where seismic measurements were done

Fig. 5.8 Eastern part of the magnetic profiles. Profile SES-Profile-025 is missing, because it is covered by profile 026

5.5.2 Shipboard results

Based on the magnetic data it can be distinguished between two types of magnetic anomalies. One anomaly is natural whereas the other is anthropogenic. The anthropogenic one can be identified in Fig. 5.9 at around 8:35, which was recorded on 04.08.2019.

The natural one has a much larger width and is hard to identify in the raw data, since the profiles are more or less in N-S-direction and so the influence of the latitude on the measured data is high. The anthropogenic anomaly was recorded in a time period under one minute. The larger width of the natural anomaly is caused by a large body with different magnetic properties than the surrounding seafloor sediments. In case of the AL525 the magnetic anomaly is caused by salt domes. The anthropogenic anomaly has a maximum peak of 50128 nT and a minimum of 50073 nT (Fig. 8.4). The small width and the high amplitude of the anthropogenic anomaly could be caused by a small, shallow and highly magnetized object, like a submarine cable.

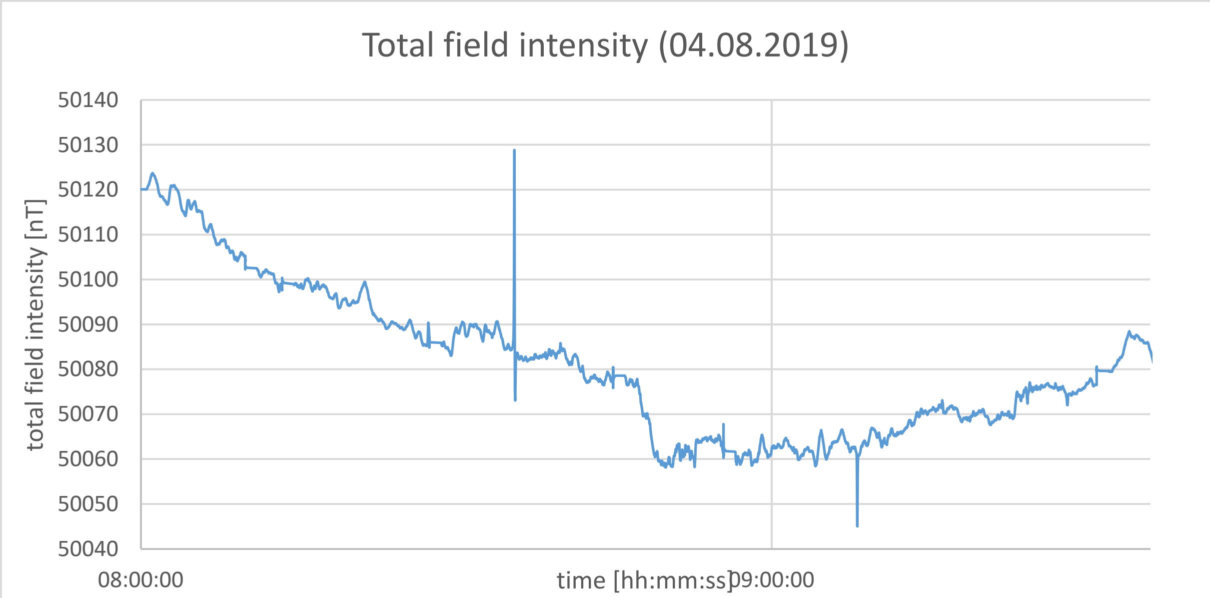

Fig. 5.9 Total field intensity measured at the 04.08.2019

For further interpretation the data has to be corrected by the diurnal variation (Figure 5.10). The diurnal variation for the 04.08.2019 was recorded by the Adolf Schmidt Observatory in Niemegk, near Potsdam. The diurnal variation is low (maximum 25 nT) compared to the variations of the recorded data on the cruise AL525. In addition to that, the exact position of the magnetometer has to be calculated with the distance between the GPS and the magnetometer and the heading of the vessel, therefore the data can be corrected with the International Geomagnetic Reference Field (IGRF).

For modelling the salt dome, a combination of magnetic and seismic data (not recorded on the first leg of AL525) could be used.

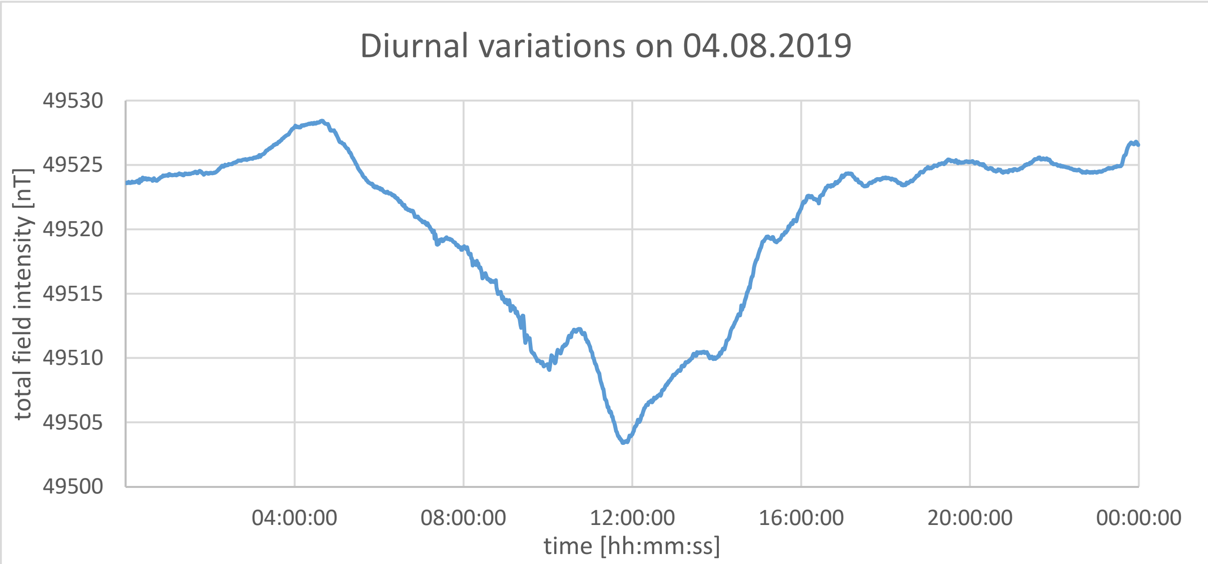

Fig. 5.10 Diurnal variations of the magnetic field at the 04.08.2019

6 Station List AL525/1

6.1 Profile Station List

Profile Name ALKOR [AL525_]	Profile Name Uni Bremen	Date start 2019	Time start	Latitude [°N]	Longitude [°E]	Date end 2019	Time end	Latitude [°N]	Longitude [°E]
1-1	GeoB19-216	03.08.	13:52	n.a.	10° 19,45'	03.08.	17:58	54° 25.83'	10° 46.02'
1-3	SES-Profile-001	03.08.	18:18	54° 24.76'	10° 44.94'	03.08.	23:56	54° 42.15'	10° 07.45
1-3	SES-Profile-002	04.08.	00:01	54° 42.58'	10° 07.42'	04.08.	05:26	54° 25.77'	10° 44,50'
1-3	SES-Profile-003	04.08.	05:38	54° 42.58'	10° 46.00'	04.08.	07:08	54° 31.12'	10° 36.27'
1-3	SES-Profile-004	04.08.	07:18	54° 31.61'	10° 37.96'	04.08.	08:54	54° 27.36'	10° 47.70'
1-3	SES-Profile-005	04.08.	09:02	54° 27.88'	10° 47.23'	04.08.	10:29	54° 32.24'	10° 37.18'
1-3	SES-Profile-006	04.08.	10:33	54° 32.53'	10° 37.19'	04.08.	12:00	54° 28.66'	10° 47.60'
1-3	SES-Profile-007	04.08.	12:06	54° 29.10'	10° 48.02'	04.08.	14:03	54°38.19'	10°54.51'
1-3	SES-Profile-008	04.08.	14:11	54° 37.89	10° 54.95'	04.08.	14:40	54° 35.32'	10° 53.44
1-3	SES-Profile-009	04.08.	14:51	54° 35.11'	10° 54.21'	04.08.	15:29	54° 38.23'	10° 55.93'
1-3	SES-Profile-010	04.08.	15:39	54° 37.87'	10° 56.54'	04.08.	16:18	54° 34.82'	10° 55.04'
1-3	SES-Profile-011	04.08.	16:22	54° 34.55'	10° 55,21	04.08.	17:12	54° 38.26'	10° 57.54'
1-3	SES-Profile-012	04.08.	17:18	54° 38.11'	10° 58.25	04.08.	18:05	54° 34.40'	10° 56.57'
1-3	SES-Profile-013	04.08.	18:08	54° 34.22'	10° 56,82'	04.08.	19:01	54° 38.37'	10° 59.10'
1-3	SES-Profile-014	04.08.	19:10	54° 38.07'	10° 59.70'	04.08.	19:58	54° 34.26'	10° 58.06'
1-3	SES-Profile-015	04.08.	20:06	54° 34.20'	10° 58.81'	04.08.	21:05	54° 38.41'	11° 00.55'
1-3	SES-Profile-016	04.08.	21:14	54° 38.15'	11° 01.03'	04.08.	22:05	54°34.07'	10°59.48'
1-3	SES-Profile-017	04.08.	22:14	54°33.96'	11°00.26'	04.08.	23:06	54°38.31	11°02.00'
1-3	SES-Profile-018	04.08.	23:11	54°38.35'	11° 02.59'	05.08.	00:10	54°33.72'	11°01.13'
1-3	SES-Profile-019	05.08.	00:15	54°33.61'	11°01.82'	05.08.	01:04	54°37.66'	11°03.31°
1-3	SES-Profile-020	05.08.	01:10	54°37.74'	11°03.91°	05.08.	01:59	54° 33.88'	11°02.92'
1-3	SES-Profile-021	05.08.	02:04	54° 33.60'	11°03.38'	05.08.	02:50	54° 37.21'	11° 04.97'
1-3	SES-Profile-022	05.08.	03:05	54° 36.41	11° 06.38'	05.08.	07:07	54° 21.57'	11° 32.72'
1-3	SES-Profile-023	05.08.	07:07	54° 21.57'	11° 32.72'	05.08.	09:25	54° 20.83'	11° 52.23'
1-3	SES-Profile-024	05.08.	09:33	54° 20.34'	11° 51.91'	05.08.	11:29	54°21.34'	11°34.51'
1-3	SES-Profile-CTD-Transect-001	05.08.	11:42	54°21.46'	11°34.53'	05.08.	13:35	54°21.03'	54°21.03'
6-1	SES-Profile-025	05.08.	13:44	54°20.96'	11°48.68'	05.08.	14:00	54°20.87	11°51.24
6-1	SES-Profile-026	05.08.	14:00	54°20.87	11°51.24	05.08.	16:00	54° 23.71'	12° 10.88
6-1	SES-Profile-027	05.08.	16:00	54° 23.71'	12° 10.88	05.08.	20:04	54° 42.65'	12° 38.55'
6-1	SES-Profile-028	05.08.	20:04	54° 42.65'	12° 38.55'	05.08.	21:18	54° 45.13'	12° 50.69'
6-1	SES-Profile-029	05.08.	21:20	54° 45.00'	12° 50.86'	05.08.	21:57	54°41.69'	12°53.58'
6-1	SES-Profile-030	05.08.	21:57	54°41.69'	12°53.58'	05.08.	22:49	54°46.71	12°54.66

6-1	SES-Profile-031	05.08.	22:53	54°46.74'	12°54.84'	05.08.	23:41	54°42.34'	12°57.90
6-1	SES-Profile-032	05.08.	23:43	54°42.22'	12°58.05'	06.08.	00:37	54°47.49'	12°59.34'
6-1	SES-Profile-033	06.08.	00:39	54°47.66'	12°59.45'	06.08.	01:35	54°42.64'	13°03.25'
6-1	SES-Profile-034	06.08.	01:37	54°42.57'	13°03.42'	06.08.	02:39	54°48.70'	13°03.72'
6-1	SES-Profile-035	06.08.	02:46	54° 48.83'	13°03.94'	06.08.	05:14	54°44.10'	13°27.40'

6.2 Sample Station List

Station	ALKOR Station Nr.	Date	Time	Position Lat	Position Lon
CTD01	AL525_2-1	05.08.2019	11:34	54° 21’ 25.51’’N	11° 34’ 28.68’’E
CTD02	AL525_3-1	05.08.2019	12:06	54° 21’ 18.55’’N	11° 38’ 03.38’’E
CTD03	AL525_4-1	05.08.2019	12:39	54° 21’ 10.59’’N	11°41’ 40.51’’E
CTD04	AL525_5-1	05.08.2019	13:25	54° 20’ 58.78’’N	11° 47’ 42.37’’E

7 Data and Sample Storage and Availability

Metadata and CSR were submitted to BSH/DOD after the cruise. Raw seismic and hydroacoustic data are stored in the data base of the Research Group "Marine Technology –Environmental Research" at Bremen University. Additionally, these data are stored in the central Green IT-Housing-Center of the University Bremen on servers belonging to the research group. All published data will be made freely available via PANGAEA immediately after publication. All data are made available on request after a moratorium of 3 years.

Table 7.1 Overview of data availability

Type	Database	Available	Free Access	Contact
Multichannel seismic and hydroacoustic data, CTD	Uni Bremen	20.08.2019	20.08.2022	Tilmann Schwenk FB5, Uni Bremen tschwenk@uni-bremen.del
Magnetics	Uni Bremen	20.08.2019	20.08.2022	Thomas Frederichs FB5, Uni Bremen frederichs@uni-bremen.de

8 Acknowledgements

We thank Captain Helge Volland and his crew for excellent support during the cruise.

9 References

Andren, T., Björck, S., Andrén, E., Conley, D., Zillén, L., Anjar. J., 2011. The Development of the Baltic Sea Basin During the Last 130 ka. In: J. Harff et al. (eds.), The Baltic Sea Basin, Central and Eastern European 75 Development Studies (CEEDES), DOI 10.1007/978-3-642-17220-5_4, Springer-Verlag Berlin Heidelberg 2011

Toth et al., 2014. Seismo-acoustic signatures of shallow free gas in the Bornholm Basin, Baltic Sea, Continental Shelf Research, V 88, pp. 228-239, https://doi.org/10.1016/j.csr.2014.08.007.

SeaBat 7125 Operator's Manual; 2006

SeaSPY2 Operation Manual Revision 6.2; 2015

SES-2000 Parametric Sub-bottom Profiler User’s Guide; 2009

Product Brochure GI-Gun MiniGI Gun

ALKOR-Berichte

Advanced marine geophysical survey project

Cruise No. AL525/Leg 2

06.08.2019 – 12.08.2019
Sassnitz (Germany) – Sassnitz (Germany)
SEEGEOPHYS. GÜ UNI BREMEN

Saheed Oladayo Abdulkarim, Sebastian Gfellner, Evelyn Oyikansola Ibolo, Konstantinos Kostopoulos, Shihan Li, Paola Natasha Morales Hernandez, David Tolulope Oludowole

Chief Scientist: Tilmann Schwenk
University of Bremen

2022

Table of Contents

1 Cruise Summary

1.1 Summary in English

Cruise AL525 Leg 2 of RV ALKOR took place from August 6th to August 12th 2019, departing from and returning to Sassnitz (Germany). This survey was planned in order to teach the main marine geophysical acquisition techniques to the students from the Marine Geosciences master program at Universität Bremen while covering data gaps in the Pomeranian Bay, Arkona Basin and Jasmund Bay areas, near the Rügen Island (NE Germany). An integrated dataset of approximately 1060.6 km of the SW Baltic Sea (between 54°05'29.5"- 55°00'30" N and 13°08'27.2"- 14°35'53" E) were measured and collected, including multichannel seismic data, hydroacoustic data utilizing a swathsounding systems as well as the (parametric) sediment echosounder SES2000 and the fishsounder EK60. Additionally, magnetic data were gathered along profiles, and CTD data were collected at eight stations in the northern part of the study area. The acquired data were roughly processed and interpreted by means of state-of-the art software. By that, regional and local geological (tectonic) subsurface features, as well as man-made structures like pipelines and cables, and oceanographic variations in the Arkona Basin and Jasmund Bay areas were studied and discussed.

1.2 Zusammenfassung

Die Fahrt AL525 (Leg 2) mit RV ALKOR fand vom 6. bis 12. August 2019 statt, Start- und Zielhafen war jeweils Sassnitz (Deutschland). Diese Fahrt wurde durchgeführt, um den Studierenden des Masterstudiengangs Marine Geowissenschaften an der Universität Bremen die wichtigsten meeresgeophysikalischen Messtechniken zu vermitteln und gleichzeitig Datenlücken in der Pommerschen Bucht, dem Arkonabecken und der Jasmunder Bucht in der Nähe der Insel Rügen (Nordostdeutschland) zu schließen. Ein integrierter Datensatz von ca. 1060,6 km der südwestlichen Ostsee (zwischen 54°05'29.5"- 55°00'30" N und 13°08'27.2"- 14°35'53" E) wurde vermessen und gesammelt, einschließlich seismischer Mehrkanaldaten, hydroakustischer Daten unter Verwendung eines Swathsounding-Systems sowie des (parametrischen) Sedimentecholots SES2000 und des Fischecholots EK60. Zusätzlich wurden magnetische Daten entlang von Profilen und CTD-Daten an acht Stationen im nördlichen Teil des Untersuchungsgebietes erhoben. Die gesammelten Daten wurden mit Hilfe von state-of-the-art software prozessiert und interpretiert. Somit konnten regionale und lokale geologische (tektonische) Untergrundstrukturen sowie anthropogene Strukturen wie Pipelines und Kabel, sowie ozeanografische Variationen im Arkona-Becken und in der Jasmunder Bucht studiert und diskutiert werden.

2 Participants

2.1 Principal Investigators

Name	Institution
Schwenk, Tilmann, Dr.	GEOB
Frederichs, Thomas, Dr.	GEOB

2.2 Scientific Party

Name	Discipline	Institution
Schwenk, Tilmann, Dr.	Marine Geophysics / Chief Scientist	GEOB
Frederichs, Thomas, Dr.	Marine Geophysics	GEOB
Bergmann, Fenna, Dr.	Marine Geophysics	GEOB
Brune, Rouven	Marine Geophysics	GEOB
Abdulkarim, Saheed Oladayo	M.Sc. Student	GEOB
Gfellner, Sebastian	M.Sc. Student	GEOB
Ibolo, Evelyn Oyinkansola	M.Sc. Student	GEOB
Kostopoulos, Konstantinos	M.Sc. Student	GEOB
Li, Shihan	M.Sc. Student	GEOB
Morales Hernandez, Paola Natasha	M.Sc. Student	GEOB
Oludowole, David Tolulope	M.Sc. Student	GEOB

2.3 Participating Institutions

GEOB Faculty of Geosciences University of Bremen

3 Research Program

(S. Li)

3.1 Description of the Work Area

The study area is located in the southwest Baltic Sea, including the North German Basin (NGB) and the transition zone to the Baltic Shield (Fig. 3.1). The NGB is one part of a larger basin structure—the Central European Basin.

The basin is filled with Palaeozoic, Mesozoic, and Cenozoic sediments and is eastwards bounded by the NW-SE striking Tornquist Zone, a normal fault zone (Mingram et al. 2005). This zone is divided into two segments, the Sorgenfrei-Tornquist Zone (STZ) and Teisseyre-Tornquist Zone (TTZ) (Maystrenko et al. 2008). The STZ is considered as being the southwestern border of the Precambrian Baltic Shield (Shomali et al., 2006). In this sector, the tectonic evolution of study area and main structures encountered during the cruise will be introduced briefly.

Pre-Quaternary Geology

The study area has been mainly influenced by several major tectonic events during pre- Quaternary times. These include: the Caledonian and Variscan Orogenies (Late Cambrian- Late Carboniferous), rifting phases (Early Permian), subsidence during much of the Mesozoic, Late

Cretaceous-Early Tertiary inversion and NW-SE extension since the Neogene. (Fig. 3.2; Al Hseinat and Hübscher 2017; Hübscher et al. 2010).

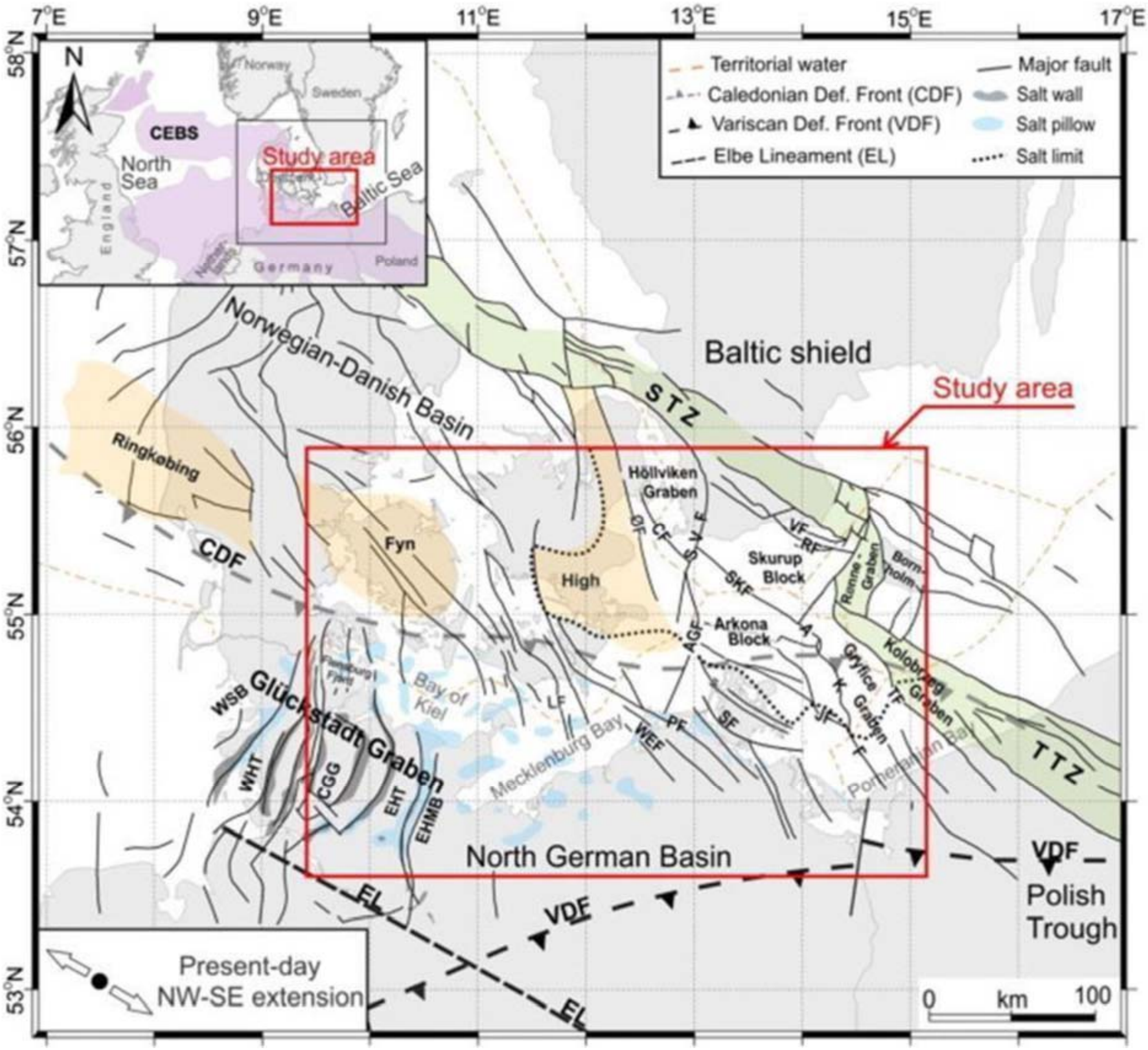

Fig. 3.1 Tectonic map and main structures within the study area (from Al Hseinat and Hübscher 2017). Important abbreviation meaning: CGG: Central Glückstadt Graben; EHMB: Eastholstein Mecklenburg Trough; JF: Jasmund Fault; LF: Langeland Fault; ØF: Øresund Fault; PF: Prerow Fault; RF: Romeleasen Fault; SF: Samtens Fault; SKF: Skurup Fault; STZ: Sorgenfrei-Tornquist Zone.

The STZ and TTZ are part of The Trans-European Suture Zone (TESZ), which separates the ancient crust of the Baltic Shield–East European Craton (EEC) from the younger crust of Western Europe (International Lithosphere Program. EUROPROBE Secretariat and Gee 1996). It formed during Ordovician–Silurian closure of the Thor Ocean–Tornquist Sea, when Baltica subducted southward under Avalonia (Smit et al. 2016). This boundary zone is currently in the covered by deep sedimentary basins of Permian to Cenozoic age, so there is limited direct observations and still controversies regarding of the exact collision zone and history (e.g., Smit et al. 2016; Pharaoh 1999).

The aggregated block then collided with the North American Craton at ca. 425 Ma (Soper and Woodcock 2003) to form Laurussia. Convergence between Gondwana and Laurussia with the closure of the Rheic Ocean occurred in the Late Paleozoic collisional tectonics of the Variscan orogeny the end of the Early Carboniferous. This orogeny caused an extensive phase in study area and controlled the formation of the Vomb Fault, Romeleasen Fault, Agricola-Svedala Fault System, North Rügen Fault, Rønne Graben and the southward half grabens, such as Gryfice Graben and Kolobrzeg Graben (Fig. 3.1; Al Hseinat and Hübscher 2017).

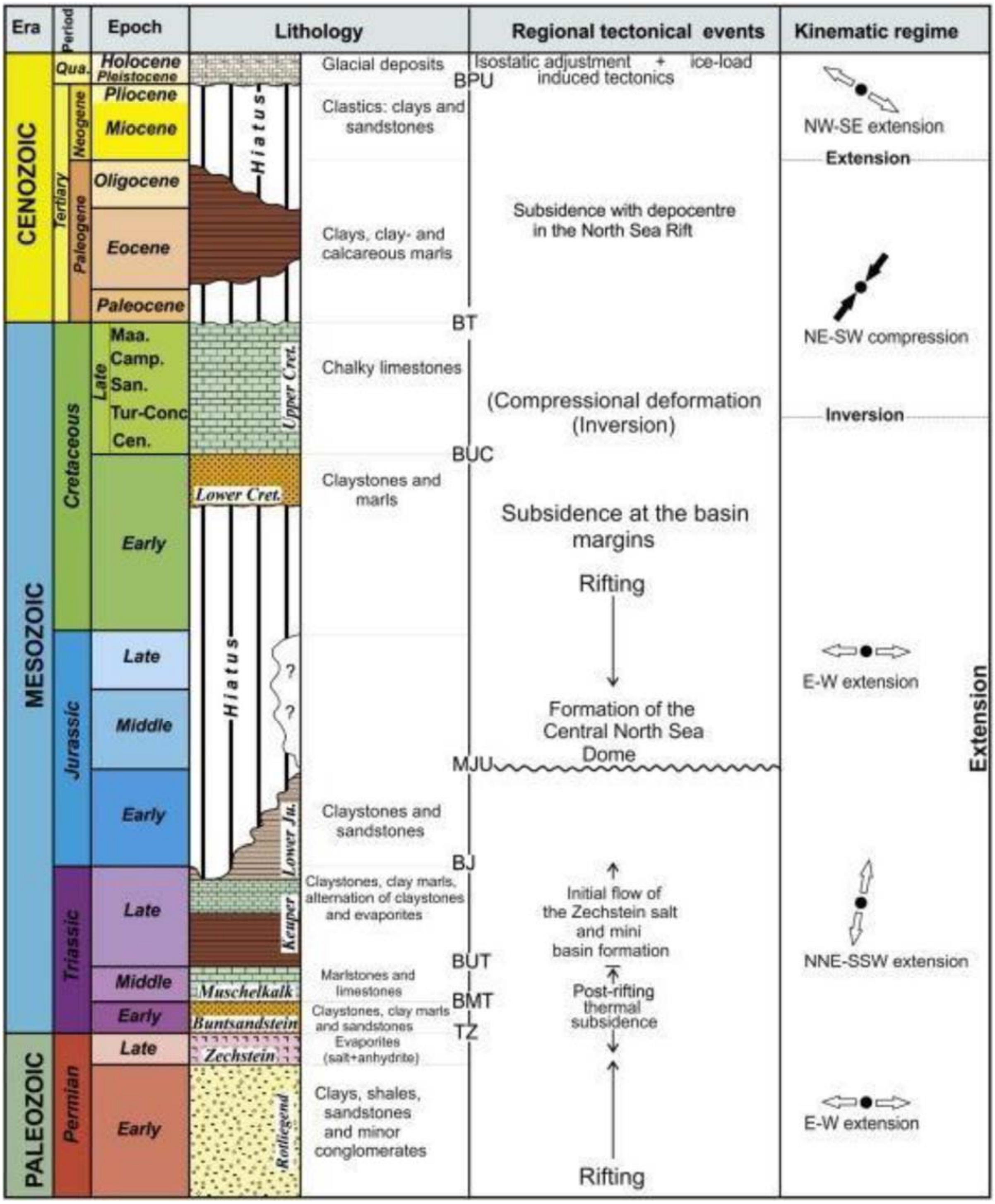

Fig. 3.2 Stratigraphic table showing the dominant tectonic evolution and consequential lithologies and sediment thicknesses of study area (from (Al Hseinat and Hübscher 2017).

The main phase of post-rifting subsidence of the Northeast German Basin first took place between Early Permian and Middle Triassic. At this time interval, the succession of Zechstein evaporites was deposited, probably as a result of several marine transgressions after a period of terrestrial conditions (Fig. 3.2; Kossow et al. 2000; Hübscher et al. 2010). From the Early Triassic period, several rifting phases affected much of northwest Europe, including the study area. Then, during the Middle Jurassic to Early Cretaceous, mantle plume activity caused the development of the central North Sea Dome, resulting a period of uplift and deposition hiatus (Fig. 3.2; Hübscher et al. 2010). Sediment deposition resumed at the end of the Early Cretaceous and continued without major tectonic activity until the Late Cretaceous.

In the latest Cretaceous Africa-Iberia-Europe collided, causing the formation of the Alpine Orogen (Ziegler 1990). The consequential compressional pressure caused the reactivation of the Tornquist Zone and salt inversion of adjoining faults. As for the Neogene, between the Late Eocene and Middle Miocene, the NGB experienced the change of principal stress orientation from a NE-SW to a NW-SE, the present-day orientation (Kley and Voigt 2008). These two events both leaded to the reactivation of previous faults and vertical salt movement (Al Hseinat and Hübscher 2017).

Quaternary Geology

The Baltic Sea is located in a high latitude area, therefore its development during Quaternary is very sensitive to recurring glaciation in the northern hemisphere. The study area and adjacent areas have experienced at least three extensive glaciations, including the Elsterian, Saalian and Weichselian ice sheets (Al Hseinat and Hübscher 2017). The buildup of ice sheet resulted in glacial and glaciofluvial erosion of the basin and its catchment and redistribution of unconsolidated sediments (Andrén et al. 2011b), while during phases of deglaciation, isostatic uplift rates in areas of different ice sheet thickness were different. The decay of the ice sheets is also likely to have changed the equilibrium situation in deep crust (Sirocko et al. 2008). Besides, since the Baltic Sea is at the rim of the northeastern Atlantic, its hydrological cycle is sensitive to changes in atmospheric and marine circulation patterns of the region. This connection is influenced by the combination of glacially forced global sea level changes and regional isostatic movements (Andrén et al. 2011b). Because the glacial erosion removed the previous sediments, little information can be got regarding of the conditions in pre last glacial cycle. So the evolution of the Baltic Sea since last interglacial will be introduced here.

Based on different researches, (Andrén et al. 2011b) summarized that the first Baltic glacial event took place during MIS 4 and the first advance into northern and southeastern Denmark at 65–60 ka BP and 55-55 ka BP, respectively. Then during MIS3, the SW Baltic may have experienced two major ice advances, at ca. 50 and 30 ka BP (Houmark-Nielsen 2007).

The decay course of European ice sheet since Last Glacial Maximum (LGM) is shown in Fig. 3.3, which is characterized by the irregular retreat, resulted from northern climatic oscillations during last deglaciation. The whole basin was glaciated during the LGM and the main phases after that are two lake stages (Baltic Ice Lake and Ancylus Lake) alternating with marine stages (Yoldia Sea and Littorina Sea) (Rosentau et al. 2017).

In study area, the ice sheet melted and the first embryo of the Baltic Ice Lake (16–11.7 ka BP) formed ca. 16 ka BP (Andrén et al. 2011a), whereas the deglaciation of the northern Baltic Sea took place much later (Fig. 3.3). The intensified isostatic uplift led to a difference in the sea level and ice lake level of around 10 m, as the eustatic sea level rise was much slower in comparison to the uplift (Andren et al., 2011). Therefore, the updamming of this large glacial lake started. When the ice in the area receded immediately north of Mt. Billingen, the first drainage of the Baltic Ice Lake took place at ca. 13 ka BP (Fig. 3.4). During younger Dryas cooling, the ice-sheet margin advanced and the area north of Mt. Billingen was blocked again, causing a second updamming period (Rosentau et al. 2017).

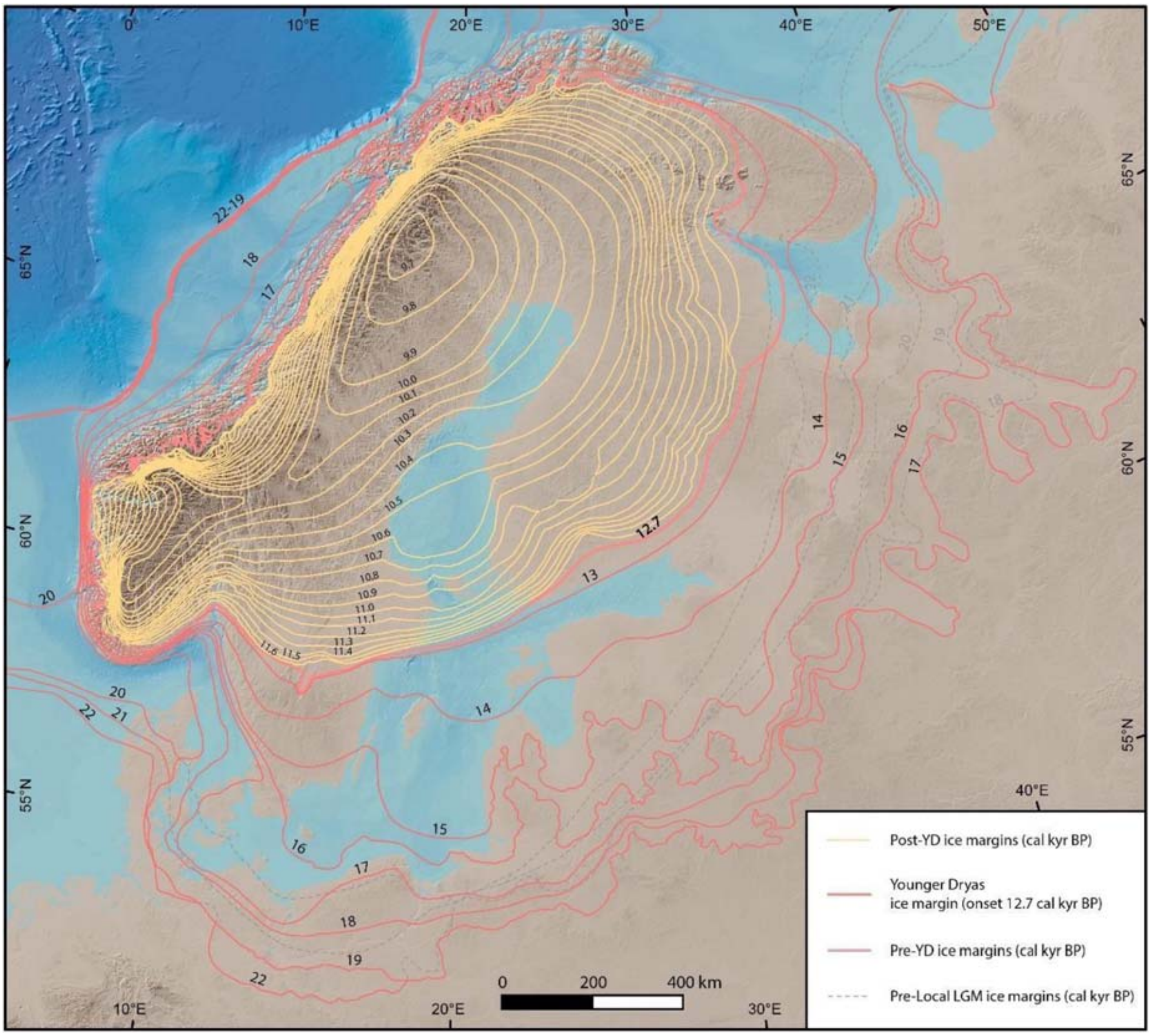

Fig. 3.3 Postglacial development of the Baltic Sea basin with alternating lake and marine stages, reproduced by Rosentau et al. (2017) from Andrén et al. 2011a.

The intrusion of salt water from the open ocean connection towards the Baltic Sea basin marked the next stage, the Yoldia Sea (Fig. 3.4; 11.7–10.7 ka BP). However, south-central Sweden uplifted rapidly, so the strait area became shallower, which together with the large outflow of fresh water prevented saline water input. As a result, the Yoldia Sea was transformed into a huge freshwater lake (Rosentau et al. 2017). The Ancylus Lake stage (10.7– 9.8 ka BP) started when the straits in the south-central Swedish lowland were closed. In this stage, the southern part of the Baltic experienced transgression, whereas areas to the north experienced a continued regression (Rosentau et al. 2017).

Since 9.8 ka BP, the freshwater Ancylus Lake was transformed first to a brackish-water stage and later to a marine stage, which resulted from the opening of Danish Strait and thereby repeated salt water inflow (Fig. 3.3). It was also accompanied by remarkable changes in the Baltic Sea and its ecosystem, which shaped the present Baltic conditions.

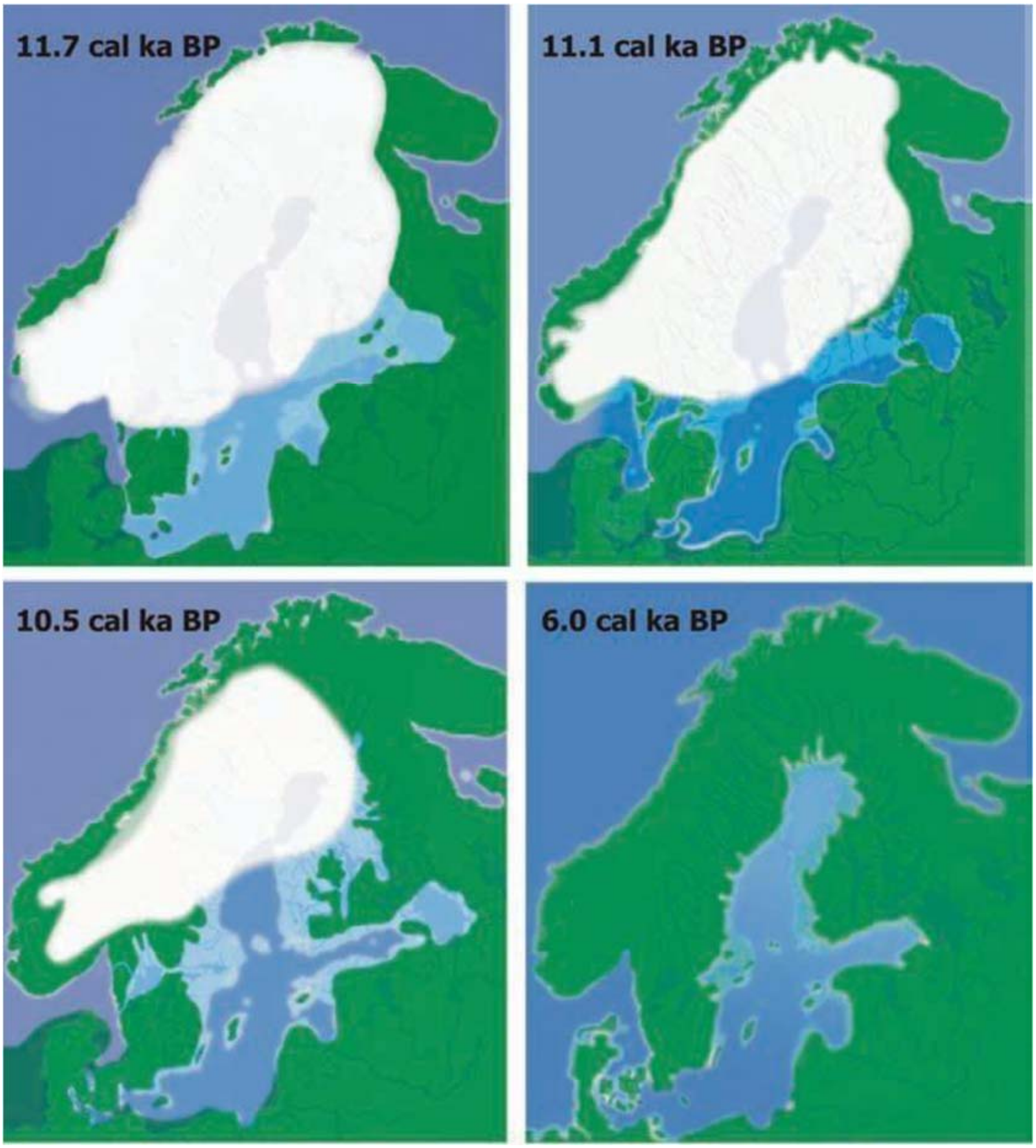

Fig. 3.4 Postglacial development of the Baltic Sea basin with alternating lake and marine stages, reproduced by Rosentau et al. (2017) from Andrén et al. 2011a.

3.2 Aims of the Cruise

The main aim of the cruise was teaching the master students in first year the acquisition, pre-processing and (joined) interpretation of marine geophysical data sets including hydroacoustic, seismic and magnetic data. Also survey and station planning was part of the activities on bord. Scientifically, the focus was the imaging of human-made structures, tectonic structures and marine sedimentation processes in the Holocene.

3.3 Agenda of the Cruise

After departure in Sassnitz at the 07.08.2019, scientific equipment was started immediately, and measurements focused in the area east of Rügen to study both, the Northstream pipeline and the tectonic structures in this area. Afterwards the RV ALKOR headed to the North to image sedimentary structures and tectonic structures in the Arkona Basin in areas that will be blocken in near future by offshore windfarms. The last days were used to map the Tromper Wiek and cretaceous surface and subsurface structures east of Jasmund, before the ship was steaming back to Sassnitz.

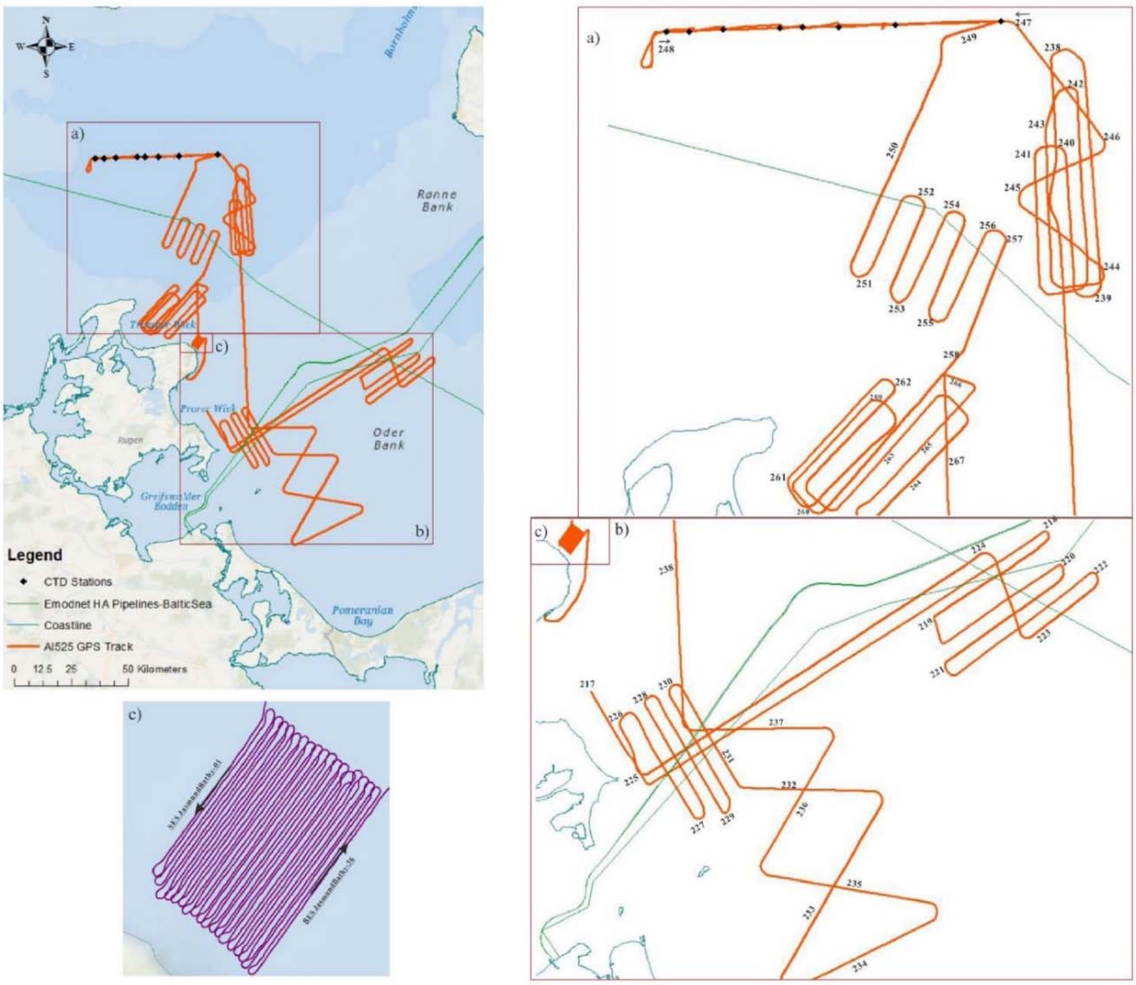

Fig. 3.5 Track chart of the cruise AL525/2. The map shows the location of the acquired profiles including MBES, SES,MCS,EK60 and magnetics data, as well as the CTD stations from the northern part of the Arkona Basin.

4 Narrative of the Cruise

(D.T. Oludowole)

The scientific expedition crew arrived onboard the R/V ALKOR in Sassnitz, Germany on Tuesday, 6th of August, 2019 at 13:20 to participate in the Cruise AL525 Leg 2. The crew comprised of MSc. Students from the University of Bremen.

After boarding, safety protocols and instructions were explained to the crew by the Ship's First Officer. Later in the evening geology (Quaternary and Pre-quaternary) of the area of interest was presented to the scientific party. The area of interest was the SouthWest Baltic Sea between latitude 54 14.00'N and 55 58.90'N and longitude 13 16.37'E and 14 42.00'E. This study area is the Arkona Basin. Multi-beam sonar system SeaBat 7125, sediment echo-sounder SES2000medium and EK-60 systems were already installed when the scientific crew arrived on-board.

7th of August, 2019

The crew departed the port of Sassnitz at 07:00 and headed towards the study area, during transit more presentations on the different equipments to be used on the expedition and oceanography were presented. Geophysical profiling which included parametric echo-sounding (SES2000), EK-60 and multi-beam (SeaBat 7125) started.

At 08:48 the streamers, birds and Mini-Gi gun were deployed to start the seismic acquisition. Data acquisition for the multi-channel seismic started shortly after deployment with Profiles Line GeoB19-216 acquired. The magnetometer was deployed at 09.30 and data acquisition started immediately after deployment. During data acquisition the operating software for the multi-channel seismic MaMUCS (Marine multi-channel seismics) crashed during profile GeoB19-218 and had to be restarted. Profiling continued and more lines were acquired.

8th of August, 2019

Geophysical profiling continued and 14 more seismic and SES profiles were acquired during the course of the day. At 06:45 the depth of the birds were changed from 1m to 3m due to the presence of a sailing boat nearby, after the boat passed the birds depth was restored back to 1m. MaMUCS crashed 3 times during data acquisition and had to be restarted.

9th of August, 2019

Data acquisition continued on all the equipment as the ship headed towards the Arkona basin. At 09:33 the ship arrived at the Arkona basin and GeoB19-238 was shot across the basin. However, due to presence of buoys the ship had to deviate off course a bit to avoid hitting them. At 10:00 the birds guiding the streamers were lowered to 3m due to the presence of another sailing boat crossing over the streamers.

MaMUCS crashed at 10:55 when profile GeoB19-238 was shot within the basin. Multi-beam also stopped during the course of profile GeoB19-238 acquisition and had to be restarted. Within the basin, the length of the magnetometer cable was increased from 100m to 150m due to increase of sea floor depth. After checking the weather forecast for the region, the crew decided to take CTD readings the next day due to favorable weather conditions.

At 19:15 the Mini GI-gun stopped working and had to be retrieved and repaired, during the course of repairs bathymetry readings was halted but magnetics and SES acquisition continued.

The repaired Mini GI-gun was deployed back into the water at 20:43 and seismic and bathymetry profiling resumed shortly after. A total of 11 seismic profiles were gathered during the day.

10th of August, 2019

Data acquisition for all equipment on board the ship apart from the EK-60 was stopped at 06:25 to prepare for the CTD data acquisition. Magnetometer, Mini GI-gun and streamers were received and preparations for CTD readings started. The CTD points were determined by the crew members using the SES-ALK 525 GeoB19- 249 profile. 8 stations were selected to be tested. After the points selection, SES2000medium and bathymetry were turned back while the R/V ALKOR proceeded to the test area. CTD readings started at 09:29 and finished at 16:00. After the completion of the CTD survey, the magnetometer and multi-channel seismic equipment were deployed back into the water to continue data acquisition at 16:15. Readings continued with profile GeoB19-250pre and 9 points were gathered in total.

11th of August, 2019

Geophysical survey continued with all the equipments recording and gathering data, 13 profiles were acquired on the multi channel seismic and SES. Final seismic acquisition came to an end at16:36 with profile GeoB19-268 ending the multi channel seismic survey. At 16:48 after the end of the survey, magnetometer SEASpy and multi channel seismic equipment which included the Mini GI-gun, birds and streamers were retrieved and stored. SES and bathymetry readings were also terminated leaving just the EK-60 running. The R/V ALKOR set course towards the Jasmund bathymetry survey area at 17:00, this area was close to the island of Rügen. Bathymetry and SESmedium-2000 was turned on and the JasmundBathy survey began at 18:15.

12th of August, 2019

Jasmund bathymetry survey continued from the previous day and ended at 05:43 and a total of 36 profiles were gathered from the SES and bathymetry. After the Jasmund bathymetry survey,SES2000medium was terminated, bathymetry was also terminated and the multi beam sonar was pulled up in the moon-pool, this brought an end of the geo-scientific expedition. The R/V ALKOR ship headed back to the port of Sassnitz at 07:00. After retrieval of the multi beam sonar, on-board processing continued and data gathered from the cruise was backed up and uploaded into the drives.

5 Preliminary Results

5.1 Underway Hydroacoustics

(P.N. Morales Hernandez, S. Gfellner, S.O. Abdulkarim)

5.1.1 Multibeam Echo Sounder (MBES) Measurements

During cruise AL525 Leg 2, a MBES dataset of approximately 1060.6 km of the SW Baltic Sea (between 54°05'29.5"- 55°00'30" N and 13°08'27.2"- 14°35'53" E) was measured and collected using the SeaBat 7125, which includes bathymetry, acoustic backscatter, and water column data. This survey was planned in order to cover data gaps in the Pomeranian bay, Arkona Basin and Jasmund bay areas, near the Rügen island (NE Germany) to integrate it with other hydroacoustic (SES, MCS and EK60) and magnetic information.

The data acquisition was continuous and started from August 07th, 2019 at 07:15 until August 12th, 2019 at 05:54 (UTC) near Sassnitz port. The dataset was divided in two surveys: The GeoB survey was measured during the first five days on the Pomeranian bay and Arkona basin (lines GeoB19-217-pre to 268) whereas the JasmundBathy survey was measured during the last day on the Jasmund bay area, NE Rügen. The cruise track was planned to go as near as possible to the coastline (until approx. 14 m water depth) and closely spaced laterally every 50 m and resulting in a a 1.83 x 2.75 km very high-resolution survey 'grid' (lines AL525-SES-JasmundBathy-01 to 36).

Method (Working principle)

Multibeam bathymetric echo sounders are a type of underwater acoustic sonars used to measurewide water bodies rapidly and accurately to map high resolution data, being a valuable tool for marine sciences by helping to determine the water depth, which is relevant for water column, seafloor and subseafloor research. It records not only bathymetry but also the acoustic backscatter, and water column data.

This hydrographic device, as any other sonar, is based on acoustic principles. Here, a sound wave or pulse is emitted in a fan shape from the transmitter and recorded after its reflection when it finds an interphase by the receiver (Fig. 5.1). The transmitting and receiving arrays, which consist of equally spaced sensors, are arranged in a T-like configuration (Fig. 5.1). This complex arrangement of transducer chains results in a swath that is narrow along-track (transmitting the acoustic pulse) and wide across-track (receiving the echo), which constitutes the main difference with single beam echosounders (SBES), where one transmitter and one receiver generate one depth measurement vertically beneath the vessel. The swath is produced by two processes: The beam forming creates a narrow swath (using the principles of constructive and destructive interferences) perpendicular to the ship during transmission, whereas the beam steering creates electronically multiple beams during reception.

Transmitting the signal with multiple transducers leads to interference within the water column and therefore it is important to consider the beam angle and the ray bending as well due to possible refraction within the water column. If the velocity is known, the depth and position of the reflector (in this case the seafloor) is calculated for each pulse using the time that the signal travels from the source and back to the receiver (note that this is two-way travel time: TWT). Therefore, the water column velocity needs to be known in order to calculate the water depth. Theoretically, in marine environments the sound velocity of seawater is approximately 1500 m/s. Nevertheless, this value varies according to different variables such as pressure, salinity and temperature, which has the strongest influence in open oceans. To obtain more accurate velocity values of each working area, different measurements such as CTD (Conductivity Temperature Depth) or SVP (Sound Velocity Profiles) must be taken to calibrate the acquired dataset.

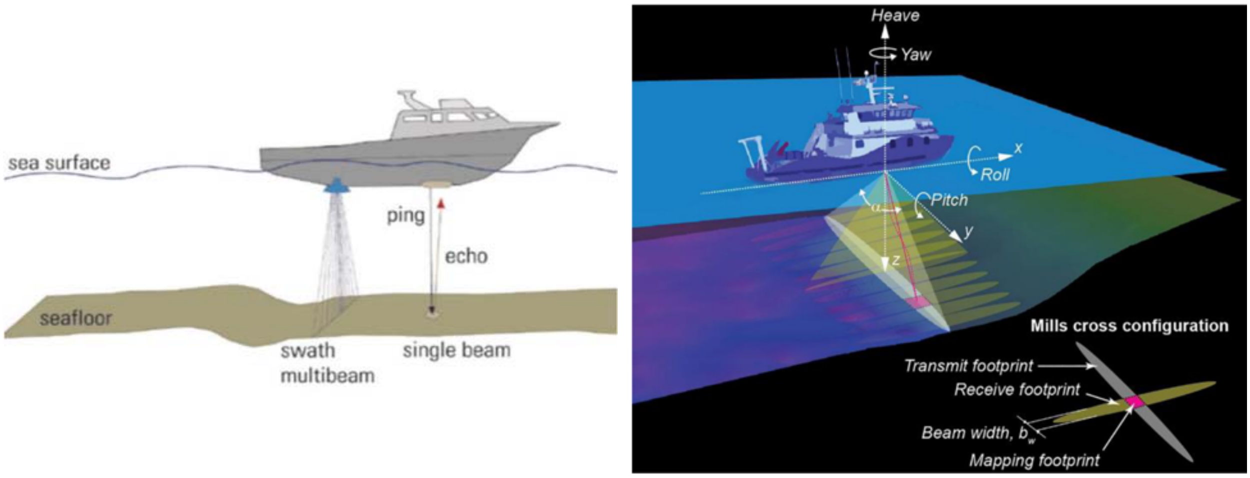

Fig. 5.1 a) Multi Beam Echo Sounder Principle (U.S. Geological Survey Department of the Interior/USGS, https://coastal.er.usgs.gov/capabilities/shipboard/sonar/bathysonar.html 2016) b) footprint resulting from a T-like transducer configuration (Jakobsson et al., 2016, https://mem.lyellcollection.org/content/46/1/17/tab-figures-data)

System overview

Multibeam data on board the RV ALKOR were acquired continuously during cruise AL525 using the hull-mounted SeaBat 7125, which collects bathymetric, corrected backscatter and water column imaging (WCI) deep water data. This type of high-resolution multibeam sonar system has two operating modes, the baseline system and the 200kHz mode (Table 5.1), which are selected depending on the measuring sector. During this leg, the sonar was operated using the baseline system throughout the entire cruise, which uses an operating frequency of 400 kHz, with 256 beams across track that are spaced 0.4688° apart and a ping rate up to 48 pings per second, resulting in a depth resolution of 5 mm.

PARAMETERS	BASELINE SYSTEM	200 kHz
Sonar Operating Frequency	400 kHz	200 kHz
Depth	1 – 200 m	1 – 500 m
Swath Coverage	128°	128°
Across-Track Beam width	Transmit: >128° Receive: 0.5° (center)	Transmit: >128° Receive: 1° (center)
Along-Track Beam Width	Transmit: 1° Receive: 27°	Transmit: 2° Receive: 27°
Number of Across-Track Beams	256 beams, spaced 0.4688° apart	128 beams, spaced 0.4688° apart
Pulse Length	10 to 300 µsec	10 to 300 µsec
Ping rate	Up to 48 pings per second	Up to 48 pings per Second
Depth Resolution	5 mm	5 mm

Table 5.1 SeaBat7125 Acquisition parameters. (SeaBat7125 operator's manual, RESON, v.3, 2006).

With this configuration it is possible to map down to 200m water depth, which is in accordance with the shallow depth of the SW Baltic sea. The transducers are, as mentioned above, aligned perpendicular to each other (mills cross in Fig. 5.1). The beam geometry is 1° along track and 0.5° across-track which results in a swath coverage of 128°.As seen before, the used device comprises a transducer and separated units that transmit and receive the acoustic pulses. Then, the receiving unit digitizes the signal and sends it to the Link Control Unit (LCU) which provides the connection between the Projector/Receiving units in the wet end or moonpool (Fig. 5.2) and the processing unit which manages the data flow and enables to view and process the raw data, which was operated in the dry end with the software SeaBat (Fig. 5.3).

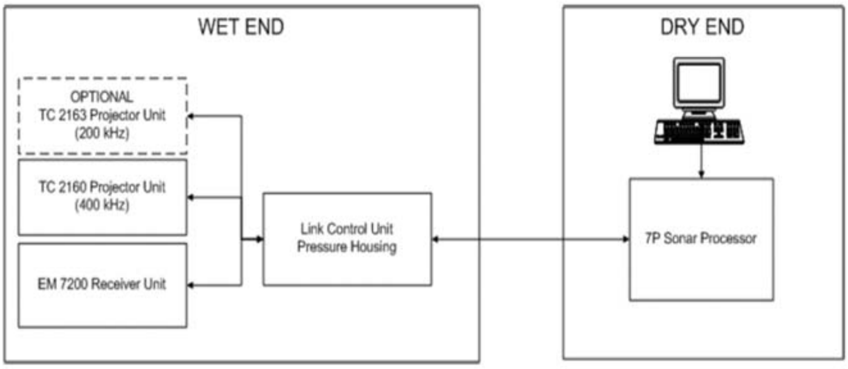

Fig. 5.2 Theoretical equipment assembly showing its wet and dry ends (SeaBat7125 operator's manual, RESON, v.3, 2006).

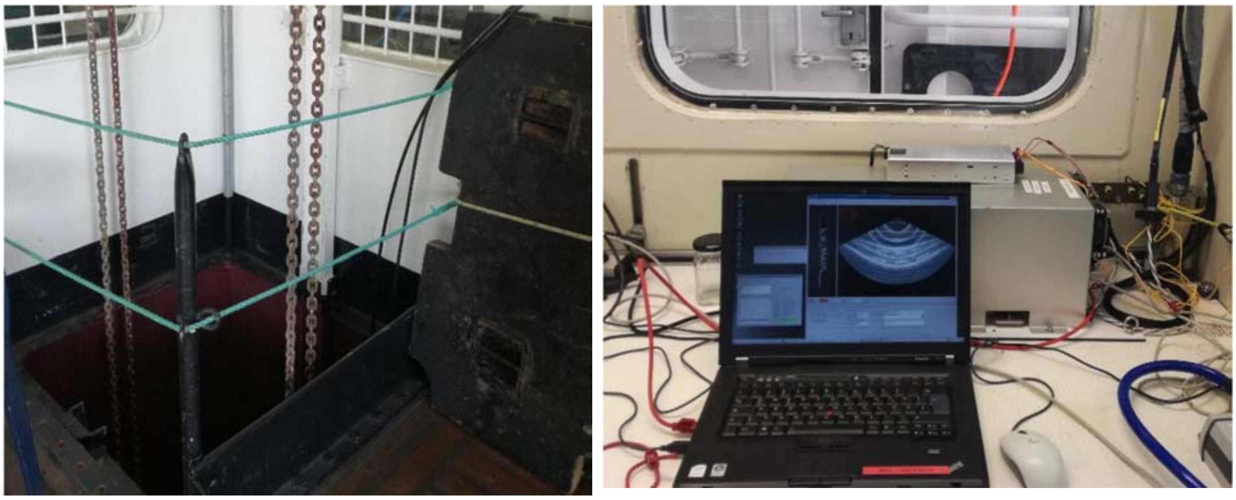

Fig. 5.3 AL525 MBES equipment assembly. Left image shows the moonpool or wet end at the center of the ship (See Deck Plan) and the right image shows the working station or dry end with the processing unit (software SeaBat.) and motion sensor.

Data management and pre-processing

The MBES acquisition was continuous and started from August 07th, 2019 at 07:15 until August 12th, 2019 at 05:54 (UTC). The data was collected at a ship speed rate of approximately 4- 5 kn during the multichannel seismic surveying (GeoB survey) in the area of the Pomeranian bay and the Arkona basin (greater water depths). During the CTD measurements MBES data were continuously recorded. The ship speed decreased to 2-3 kn during transit near the selected areas and down to 0.5-1 kn during the rosette deployment. The survey speed near the shallower Jasmund Bay (JasmundBathy survey) during the mapping operations was set to 4-5 kn and down to 2 kn during turns. Transit data were also collected at approximately 5 kn. Further cleaning and filtering from the recorded data will be done during the pre- processing stage.

During the MBES data acquisition, the depth range was adjusted continuously according to the depth changes in the measured sector. A constant offset of +/- 5 to 10 m from the measured depth was given to maintain the depth window. The maximum power was set to 20dB and the pulse length to 300ms. The water velocity data was set the first day to an initial value of 1480 m/s, from the CTD data measured on the previous Leg 1. On August 10th, 2019 the sound velocity was adjusted to 1491 m/s, after the CTD measurements carried out on the Arkona Basin (Fig. 5.4).

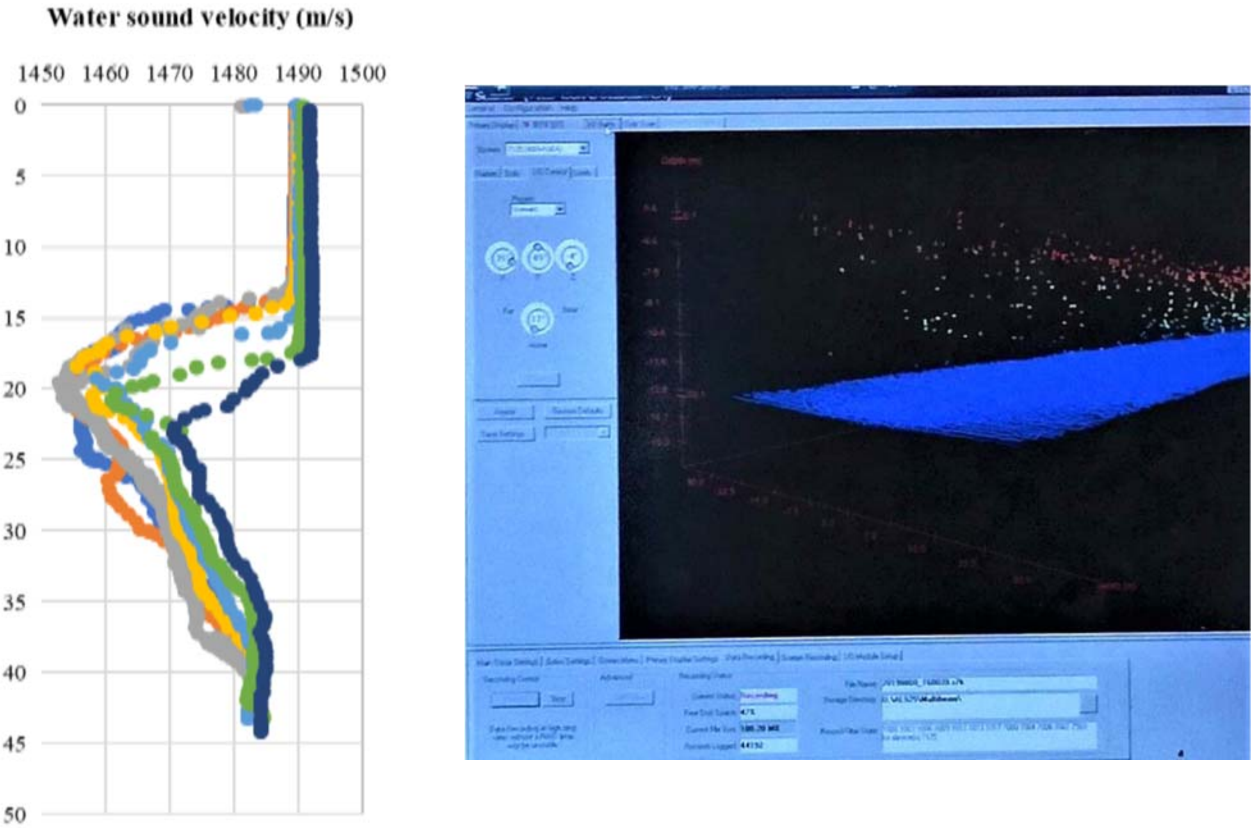

Fig. 5.4 Left: Water sound velocity data from CTD measurements on AL252 Leg 2. Right: Surveyed MBES visualized from SeaBat software showing outlier data cloud.

The data storage procedure was set to stop and start recording data every 30 min resulting in 150- 250MB files, which are more manageable in terms of storage capacity and further processing and gridding. The multibeam echosounder was not adapted to water depth during a short period of time on August 11th 2019, and therefore the beginning of the JasmundBathy survey data might be noisy, with some information lost. Additionally, there was a time difference on the GPS data, resulting on a wrong time stamp of the data and therefore the navigation is shifted by 34 seconds or 90 m at 5 kn (see Fig. 5.7)

In order to correctly process the multibeam data, two aspects must be considered: the sonar location and the ship's movement. For the first case, the precise location of the SeaBat on board the RV Alkor needs to be known using the Deck plan (Fig. XX) which shows where the moonpool is found (Fig. 5.3). On the other hand, the required ship's movement is given by the motion sensor of the ship (Fig. 5.3) and is used to calibrate and correct the heave, pitch, roll and yaw movements from the cruise, which generate outlier data, as seen in the point cloud on Fig. 5.4.

The multibeam data was pre-processed onboard using the open source software MB-System™. After gridding and exporting the data, the processed grids were imported to QGIS and some preliminary maps were produced for group discussions and further profile planning.

Data examples

During cruise AL525 Leg 2, approximately 1060.6 km of seafloor were mapped along the ship track around the north and northeast coast of the island of Rügen (NE Germany) using the hull-mounted SeaBat 7125. An overview of the cruise track with the regional (GEBCO) and the adquired bathymetric data of the working area is given on Fig. 5.5 with both, the GeoB and JasmundBathy survey data examples highlighted.

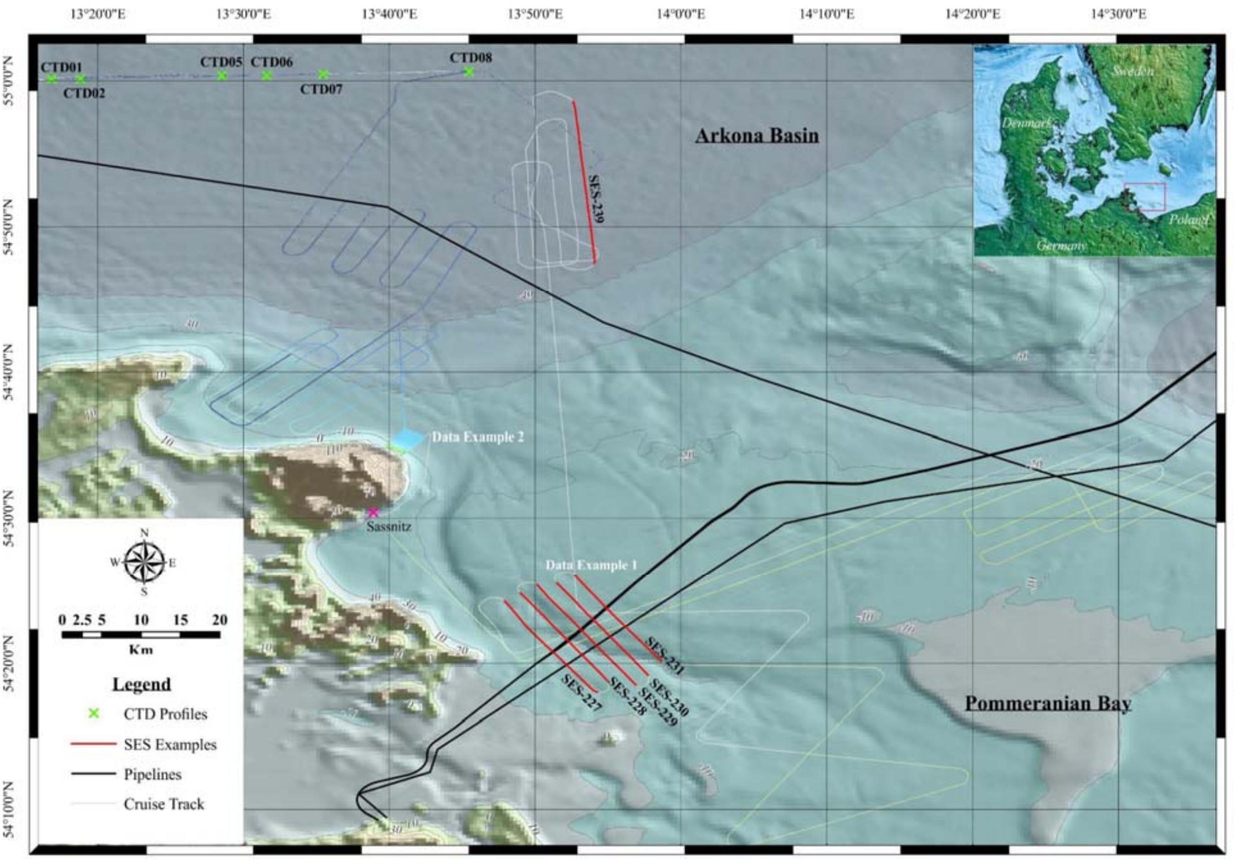

Fig. 5.5 Overview of the adquied MBES data and CTD profiles in the Arkona Basin, Pommeranian and Jasmund Bay (regional GEBCO bathymetry as background: Contours every 10m)

Example 1: GeoB survey

The MBES data shows in general shallow water depths typical for the Baltic Sea, ranging from 0 m near the coastline to over 40 m in the Arkona basin which is expressed as a regional deepening trend towards north with local shallow zones at the SE and SW related to sand banks (GEBCO background bathymetry in Fig. 5.5).

Nevertheless, the acquired high resolution bathymetry allowed a more detailed overview of local depth variations and lineaments related to submarine infrastructure in the study area. Fig. 5.6

shows a close up image from SES lines 227 to 230 highlighted on Fig. 12 (Data Example 1 label), which are part of the GeoB Survey dataset gathered on August 7th 2019 . The area is located approximately 20 km southeast of Sassnitz, between 54°20´00´´N/ 13°50´00´´E and 54°25´00´´N/ 13°55´00´´E.

Fig. 5.6 shows a relatively continuous and shallow morphology with local water depths ranging from 11-13 m as well as two disctintive lineaments trending NE-SE, which are less than 10 m wide and are approximately 60 m separated from each other. These lineaments are parallel to each other and perpendicular to lines SES-227, 228 and 229 (see Fig. 5.10). Their morphology varies along its trend, having sharper edges towards the SW (SES-227 and 228) than to the NE (SES-229) where the edges are smoother. Their sharp-edged and elongated geometry changing the local water depth, as well as the signal anomalies seen by SES data (Fig. 5.10) and the location of the Nordstream pipeline (black line on Figs. 5.5/5.6) suggest the presence of this type of submarine infrastructure in the study area. Additionally, the lineament geometry gives information about the changes in the relative position of the pipelines with respect to the seafloor, from being on top of the seabed to the NW, to being buried towards the NE (sharp vs. smooth edges).

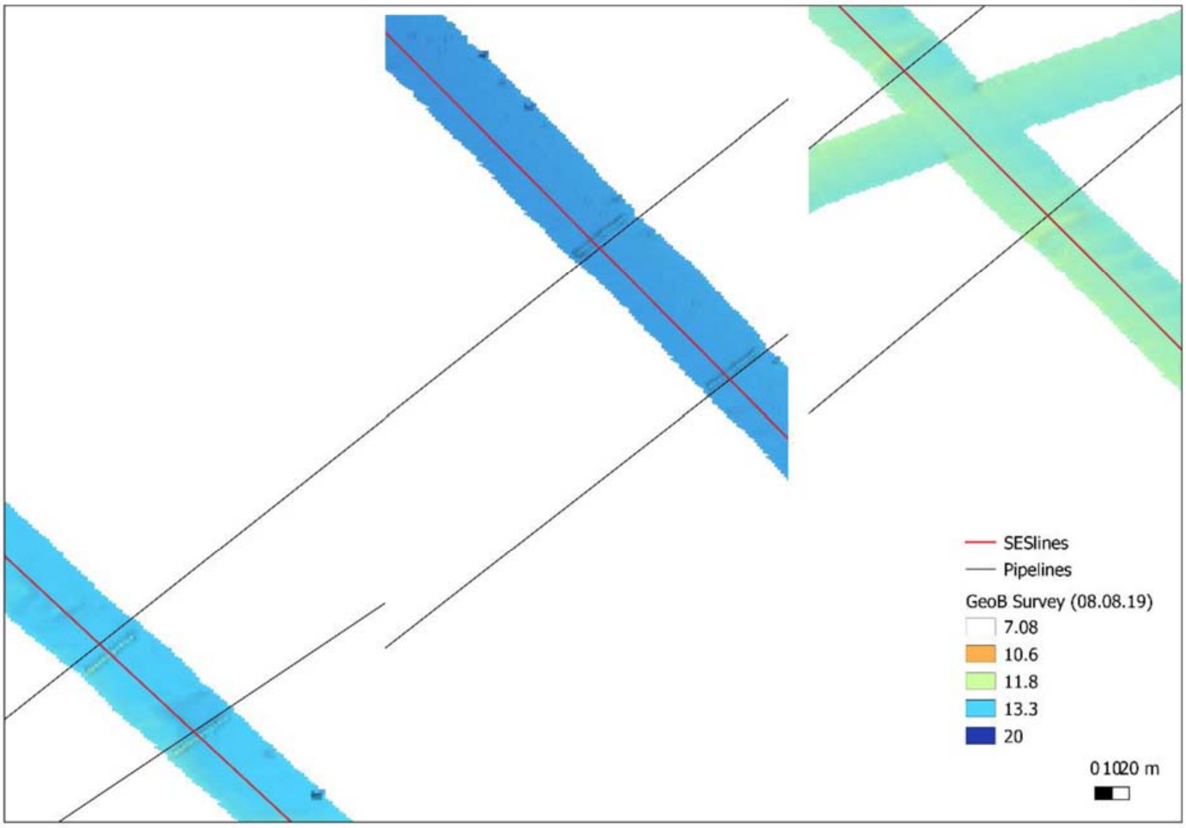

Fig. 5.6 Data example from GeoB survey evidencing a relation between bathymetric lineaments and pipelines location (black lines) and its variations from SW to NE (SES-227 to SES-229). For location refer to Fig. 5.5. SES profiles (red lines) are displayed in Fig. 5.10.

<u>Example 2: Jasmund Bay survey</u>

Fig. 5.7 shows the complete JasmundBathy survey that is highlighted on Fig. 5.5 (Data Example 2 label), gathered on August 11-12th 2019 . The area is located approximately 5 km northeast of Sassnitz (54°35´00´´N/ 13°42´00´´E).

The bathymetric data shows a shallowing trend towards the SW, where the coastline is located, perpendicular to the ship and survey track. The water depth in this area is varying rapidly from 13-14 m to 20 m, due to the outcropping of the cretaceous chalk cliffs onland (see Fig. A.1 in Appendices).

Although the seafloor morphology is relatively continuous, Fig. 5.7 evidences as well some artifacts product of noise due to the lack of proper adjustment of the water depth window at the beginning of the acquisition (lines to the NW). Moreover, there was a time difference on the GPS data, resulting on a wrong time stamp of the data and therefore the navigation is shifted by 34 seconds or 90 m at 5 kn, which will be corrected during the data processing stage (shifted colors between survey lines).

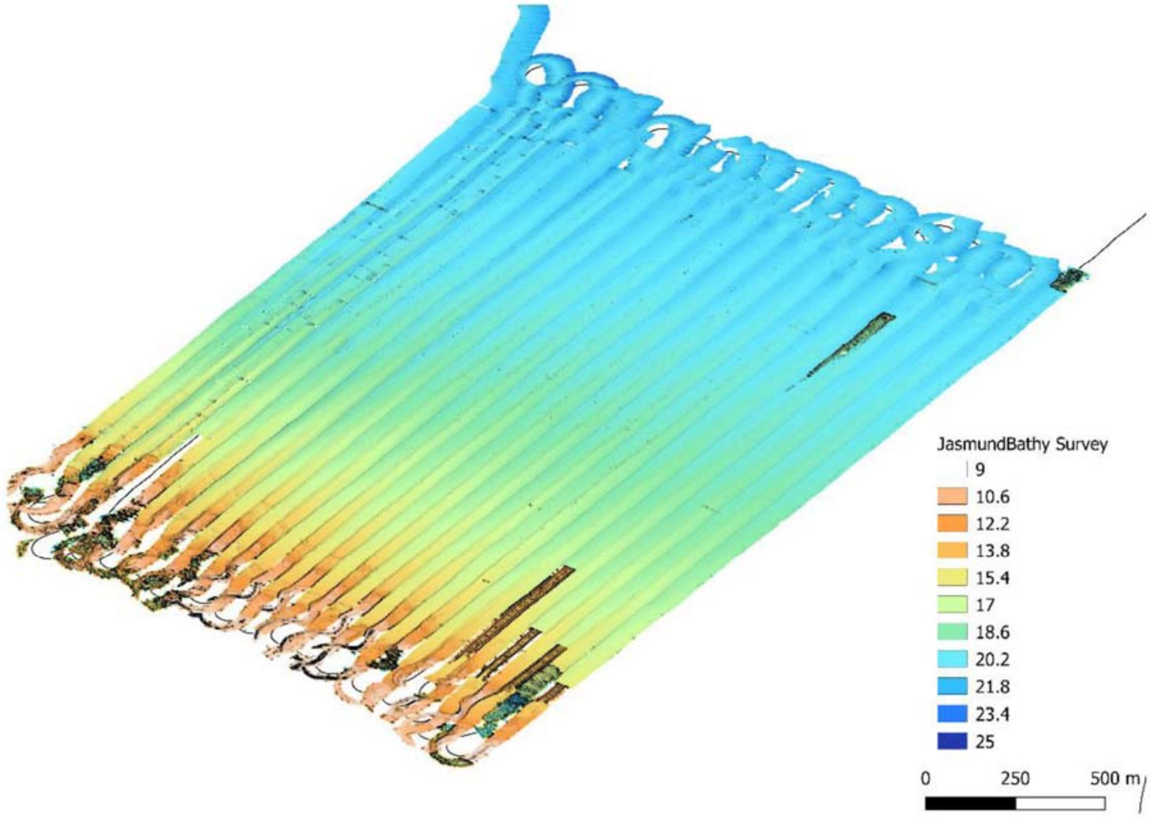

Fig. 5.7 Data example from the JasmundBathy survey evidencing a shallowing trend towards the SW and the shifted navigation due to a time stamp error in the GPS.

5.1.2 Sediment Echo Sounder (SES) Measurements

Equipment description

On the cruise AL525 Leg 2, a ship mounted sediment echosounder (SES) by Innomar Technologie GmbH (SES-2000 medium), consisting of a main unit (transmitter, amplifier and receiver), an extension unit for deeper terrain and a transducer, all connected to a PC onboard (see Fig. 5.8 for a schematic overview). Started at the departure of the ship, it was operated continuously throughout the whole cruise and shut down at the arrival back in the port. The location of the SES can be found in the deck plan (see A.1 in Appendix). Since it is a hull-mounted device, the motion correction was applied following the ship motion sensor. Therefore, small variations due to the different locations than the user can occur.

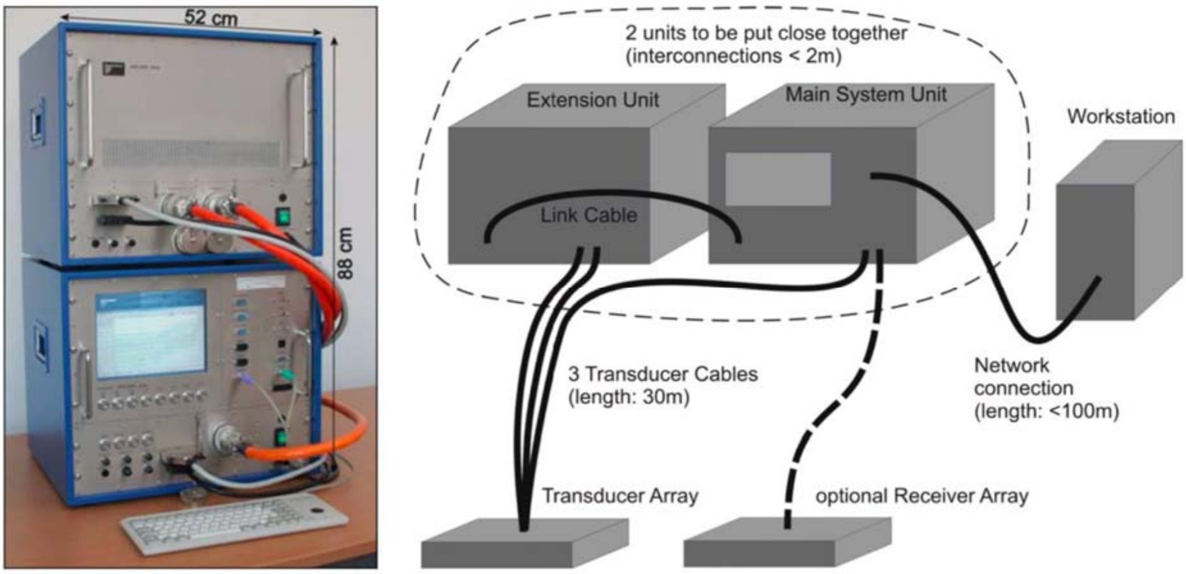

Fig. 5.8 Schematic overview of the SES-2000 medium, consisting of a main unit (transmitter, amplifier and receiver), an extension unit for deeper terrain and a transducer (SES2000 User's Guide by Innomar Technologie GmbH, V 2.8 June 2009)

Working principles

Sub-bottom profiling

While sound pulses are transmitted to the seafloor, they get reflected from the seafloor, the underlaying sediments and embedded objects (e.g. boulders). Subsequently, an echoprint can be calculated out of the reflected signals showing the sub-seafloor structures. When assuming a certain sound speed (e.g. 1480 m/s for saltwater), the observed travel time can be further converted into a distance, varying with the material specific reflection coefficients and the roughness of the layer boundaries. The footprint is the size of the sounded area by the sound source and is proportional to the aperture angle of the transducer (e.g. for SES-2000 medium: $\Theta \sim 1°$) and the water depth. Generally, it can be said, "the narrower the sound beams the smaller the footprint". See Fig. 5.9 for a graphical overview of the basic working principles.

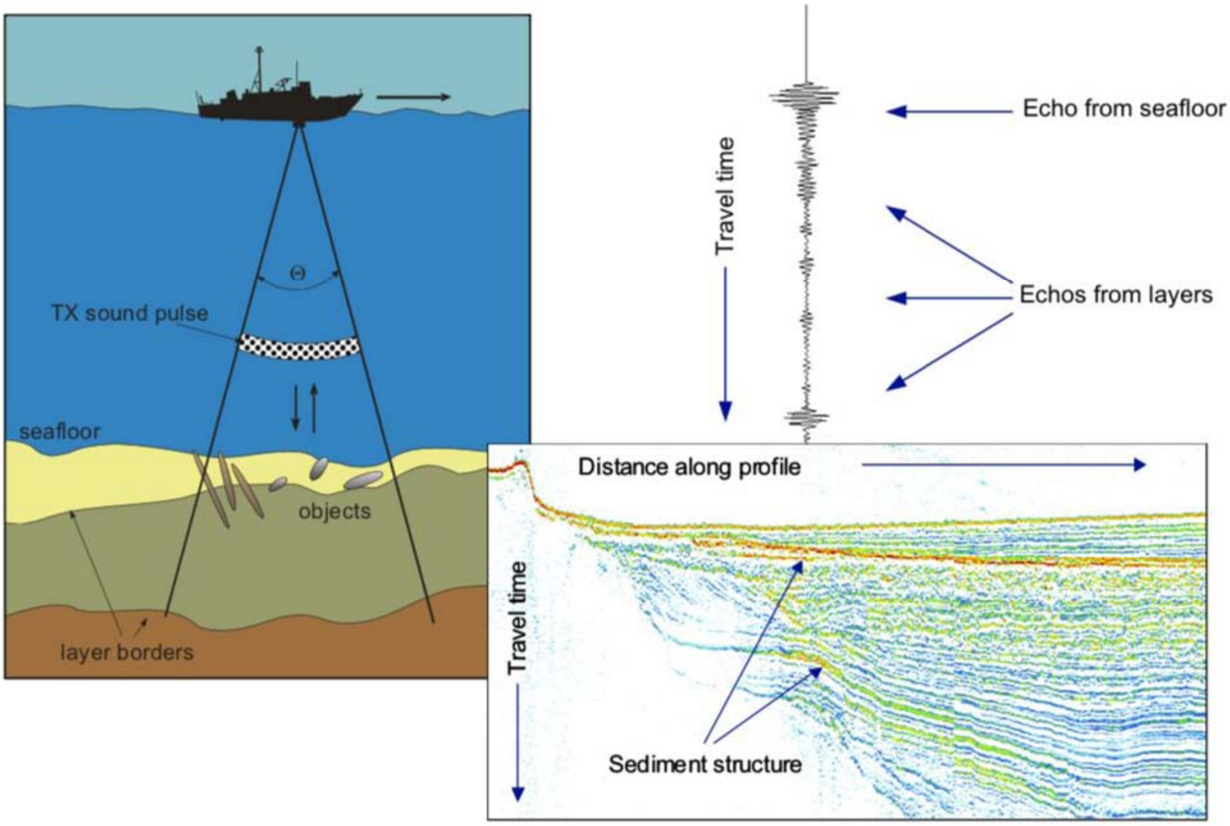

Fig. 5.9 Schematic overview of the SES-2000 medium, consisting of a main unit (transmitter, amplifier and receiver), an extension unit for deeper terrain and a transducer (SES2000 User's Guide by Innomar Technologie GmbH, V 2.8 June 2009)

Nonlinear (parametric) sub-bottom profilers

A nonlinear sound generation uses the parametric acoustical effect. This results in nonlinearities in sound propagations due to the high sound pressure of the transmitted sound waves. When transmitted simultaneously, the two different frequencies f1 and f2 (primary frequencies) interact in the water, generating new frequencies (secondary frequencies). Because the difference of the frequencies F = |f2-f1| (4-15 kHz for SES-2000 medium) is low enough to penetrate the seafloor, the reflected primary frequencies can be used to mirror the exact water depths. This fact gives the nonlinear sub-bottom profiling advantages over the conventional sub-bottom profiling (e.g. narrow sound beams at low frequencies with small portable transducers and no side lobes of the directivity of the frequencies).

Technical specifications

Table 5.2 shows the different parameters regarding the technical specifications of the nonlinear sub-bottom profiler SES-2000 medium taken form the SES2000 User's Guide by Innomar Technologie GmbH.

PARAMETER	DESCRIPTION
Transducer	non-linear transmitter, linear receiver dimensions of active area: about 0.45m x 0.40m half-power beam width for transmission: ±1.0°
Transmitter	• primary frequency: about 100kHz • secondary frequency: 3.5, 5, 6, 8, 10, 12, 15kHz (user adjustable) • pulse width: 66 – 800µs (user adjustable) • transmission pulses: CW, Ricker, Chirp • Multi-frequency Signals • Option: Chirp Signal (LFM 4–15kHz / 1.2ms) • Transmitting channels: 48
Electrical Pulse Power	> 50 kW
Transmitting Sensitivity	> 246 dB/µPa re 1m
Heave Compensation	yes, depending on valid motion sensor data
Roll / Pitch Compensation and Beam Steering	Roll compensation by electronic beam steering in a range of 32 deg. depending on valid motion sensor data
Pulse Repetition Rate	up to 30/s; Deep Sea Pulse Mode / Deep Sea Burst Mode
Depth Range	5 – 2,000m
Penetration	up to 70m; depends on sediment, frequency, noise level
Multiple Target Resolution	> 5 cm; depends on frequency and pulse length
Accuracy	100 kHz : 0.02 m + 0.02 % of water depth 10 kHz : 0.04 m + 0.02 % of water depth (at pulse length 0.1ms)
Trigger Output	TTL (SES-2000 as master)
Trigger Input	TTL (max. ±12V), low active (SES-2000 as slave)
Analog Output	band limited LF-signal, ±10V
Analog Input	Option: Input range: ±5V, 2 ... 22 kHz
Data Record	2 channels (primary frequency HF and secondary frequency LF); both channels envelope and full waveform for the selected range
Amplifier	0 - 90dB in 1dB steps manually or AGC; TVG
Digitization	16 bit / 96kHz for full waveform data (for envelope data sample rate depending on selected range)
Signal Processing	• bandpass filters adjusted automatically according to transmission pulse characteristics • noise reduction: different filters and stacking/smoothing • DSP for improved resolution and penetration into sediment (e.g., matched filtering and spike removal) • heave compensation and swell filter • adjustable TVG • on-line view of processed echo-prints • replay of previously recorded files
Data Output	• on-line recording of envelope and full waveform data for the selected range of both receiver channels, system parameters and navigation data on hard disk • backup: USB hard disk, network (LAN) • echogram on-line B/W or color print • integrated TFT-Display, external monitor • Serial output (RS232) for depth values with navigation data (adjustable ASCII format) • network (LAN) output of echo-print data and auxiliary data for HYPACK integration or additional monitoring
Data Input	• Serial (RS232) or network input for navigation data (NMEA compatible or adjustable ASCII format) • Serial (RS232) input for motion sensor data used for heave and roll/pitch compensation • Multi-purpose Input (RS232 serial input)
Control Unit	state of the art integrated PC (MS WINDOWS XP professional operating system)
Power Supply Requirements	• 115-230 V AC +5%/-10%, 50-60 Hz, • power consumption: < 900 W • power-on current / surge duration: < 25A / <0.1sec • power line fused ≥ 16A slow
Environmental Conditions	• storage: -10–60 °C / <90% non-condensing rel. humidity (in transport boxes) • operation: 0–35 °C / <70% non-condensing rel. humidity
EMC	The SES-2000 *medium* system complies with IEC 1000-4 (resistance against electrical interference) EN 55011 (emission) standards.

Table 5.2 Technical specifications of the nonlinear sub-bottom profiler SES-2000 medium (SES2000 User's Guide by Innomar Technologie GmbH, V 2.8 June 2009).

Modus operandi

At the start of the recording, the penetration depth (around 80m) was adapted to the corresponding water depth. The SES-2000 medium was operated with a ping rate of 4 pps in a multifrequency mode (5, 10 & 15 kHz). In accordance with the frequencies, the following vertical resolutions can be calculated following Eq. 1, as seen in Table 5.3. The accuracy of the vertical resolution decreases in the with depth. For further corrections, the average velocity of the ship was 5 knots.

$\lambda = v \,/\, 2 \times f$ (Eq. 1) (λ = wavelength, v = velocity, f = frequency)

Multifrequency mode	Following Eq. 1	Vertical resolution
5 kHz	1480 [m/s]/(2 x 5000 [Hz])	0.148 m
10 kHz	1480 [m/s]/(2 x 10.000 [Hz])	0.074 m
15 kHz	1480 [m/s]/(2 x 15.000 [Hz])	0.049 m

Table 5.3 Vertical resolutions of the mode of operation during AL525 Leg 2.

Data processing

The raw data (*.raw) was converted with a self-programmed converter into a *.sgy-file and afterwards visualized and processed with the software Kingdom. In addition to the normal plots the files were plotted as envelopes.

Data examples

Below in Fig. 5.10 data examples are shown regarding presumably pipelines visible in the SES data Lines AL525-SES-GeoB19-227 to 231 (5 kHz). Remarkable is that in a) and b) the pipelines are elevated while in c), d) and e) the pipelines are buried underground.

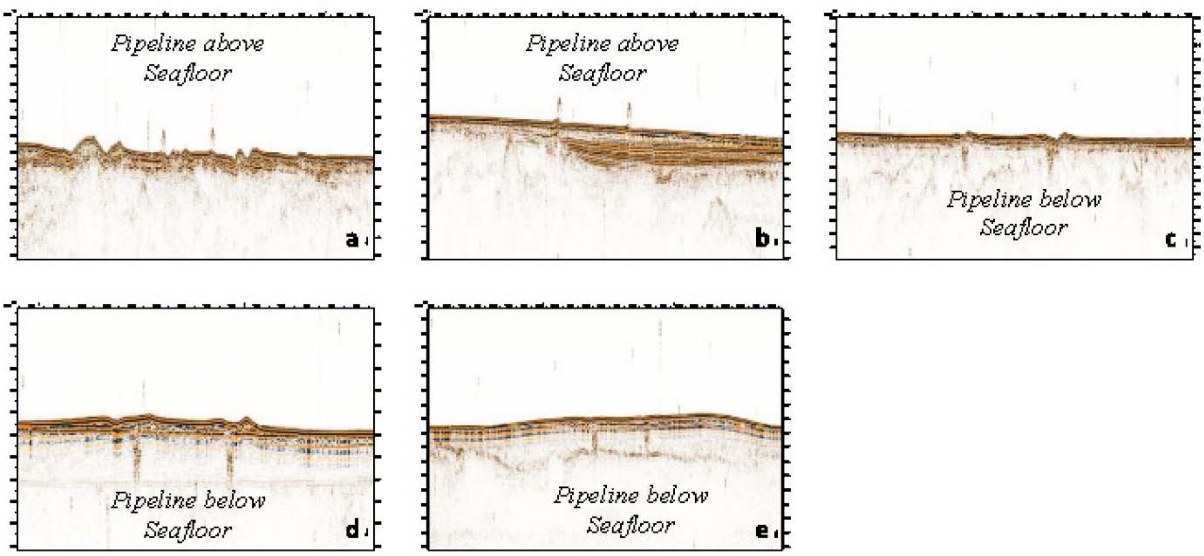

Fig. 5.10 Data examples of SES-2000 medium showing assumable pipelines. In a and b the pipelines are elevated above the seafloor while in c, d and e, they are buried underground.

Further, Fig. 5.11 is an example of the differences in resolution following the different frequencies. Picture a is representing 5 kHz, b 10 kHz and c 15 kHz. Typical features are distinguishable as the seafloor, sediment layers below and distinct lithologies underneath. The repetition of some lines at the bottom of the pictures are no actual features but so-called multiples, which are a result of the interference of the various echosounds.

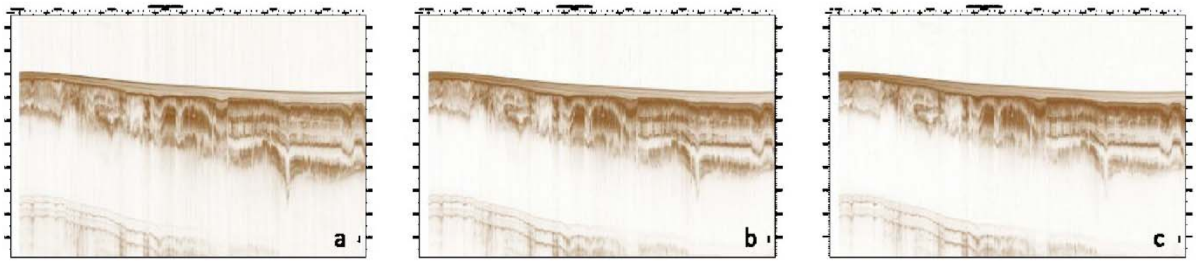

Fig. 5.11 Different frequencies resulting in different resolutions of sub-seafloor features. Picture a is representative for 5 kHz, b 10 kHz and c 15 kHz.

5.1.3 Fishing Echo Sounder (EK 60) and CTD Measurements

EK60 Measurements

The Simrad EK60 was one of the devices employed in data collection for the cruise AL525 Leg 2. It is a special type of echosounder that was permanently mounted on the hull of the ship. It is a split-beam echo sounder that operates on Windows (TM) and has a built-in calibration, consisting of one transducer, one transceiver unit and one processor unit (computer) as illustrated in the schematic diagram (Fig. 5.12) below (Kongsberg Maritime AS, 2012). However, any combination of transducer and transceiver can be achieved to fit any research purpose. The EK60 data for this research was sampled at frequencies of 38 kHz, 70 kHz and 120 kHz. Sampling at 200 kHz could not be achieved due to technical issues.

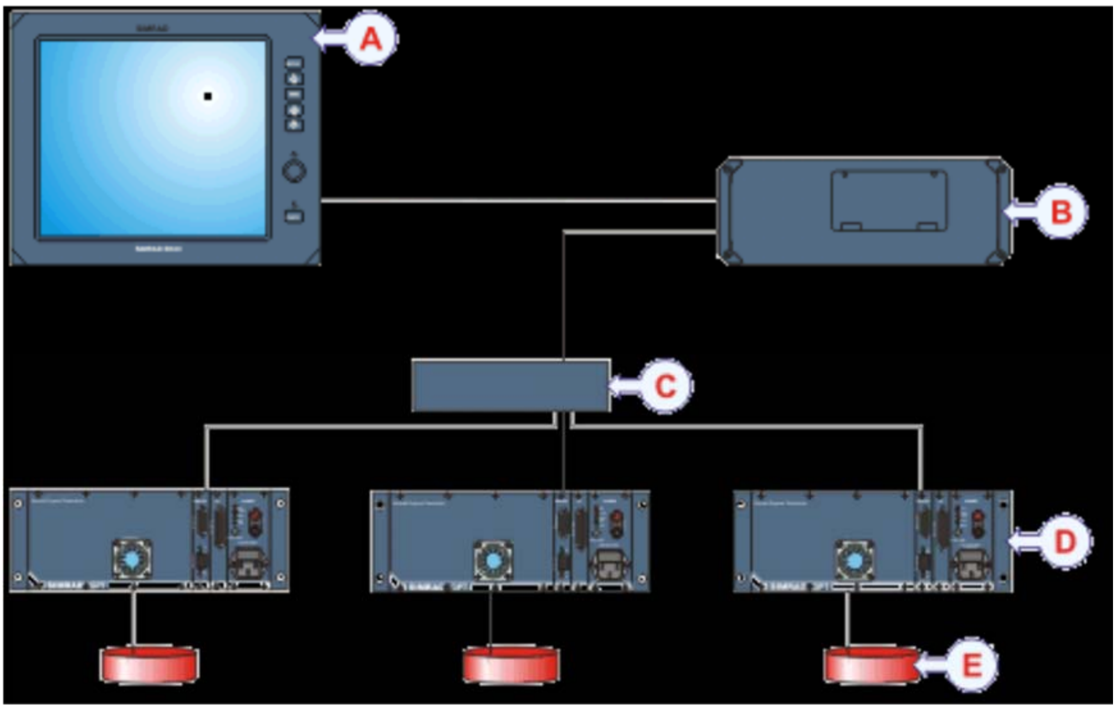

Fig. 5.12 Schematic representation of an EK60 configuration with with labels representing: (A) Display unit (B) Processor Unit (personal computer) (C) Ethernet Switch (D) Transciever Unit and (D) Transducers.

CTD Measurements

Equipment Description

A rosette CTD device produced by HYDRO-BIOS Apparatebau GmbH was used for the measurements. The device is made up of a cylindrical metal frame, consisting of 24 water bottles for water sampling called OceanLab 3 and a CT-SET FOR MULTI WATER SAMPLER MWS which consist of one conductivity sensor, one temperature sensor and an additional electronics board which are integrated into the motor unit. The measuring data of the CT-Set are completely integrated into the data acquisition software OceanLab and from this configuration (Fig. 5.13), the different physical properties of the ocean which include conductivity, temperature, salinity, sound velocity, density as well as dissolved oxygen and nitrate concentration can be measured.

But for the purpose of the cruise AL525 Leg 2, majorly conductivity, temperature, salinity and some other data are put into consideration. The water bottles were left open so no water samples were collected.

Fig. 5.13 Image of the Rosette with CTD device.

Method of Operation

The device was placed on the open side of the deck on the starboard side of the R/V ALKOR. At each of the sampling stations, the ship was positioned with the bow in the windward direction, and the method of ctd measurement involved lowering the equipment into the ocean with the help of a wench. Attempt was made to maintain a lowering rate of 0.1 m/s speed for station one, and this was increased to 0.3 m/s for all other stations as presented in Station List (7.2).

The increment in the wench lowering speed was as a result of the weather. At first it was relatively calm with low waves, but then we experienced higher waves intermittently. The CTD units gather data using electronic sensors and this data is displayed on a computer monitor on the ship (Fig. 5.14). The sampling rate of the device was 0.1 seconds.

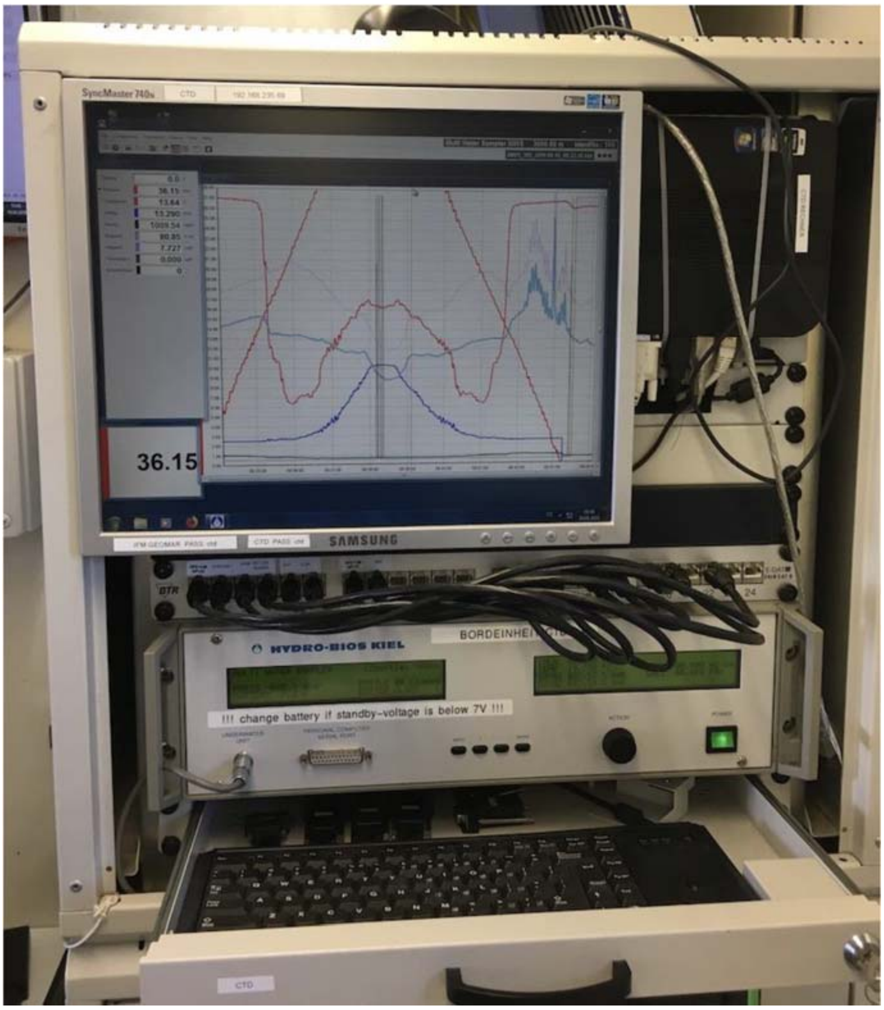

Fig. 5.14 Recorded CTD data displayed on a computer monitor in the lab.

The progressive descent of the device and data collected by the device was monitored on a computer on deck. Each time the device was deployed and whenever a maximum cable length close to the seabed was reached, an alarm would be displayed on the computer screen and then the equipment would be pulled back on deck. The data measured during the deployment and decent of the device into the sea is known as downcast, while the data recorded during ascent of the device is known as the upcast.

The CTD data were collected and analyzed in order to understand the composition of the Baltic sea and how it has changed over time. Certain precautions were observed during data collection, example of which are: A total of eight CTD sampling stations were selected from EK60 profile AL525-EK60-GeoB19-249 (Fig. 5.15). The selections were point of interest and were chosen based on the acoustic impedance contrast as observed within the water column in profile AL525-

EK60-GeoB19-249. The GPS coordinates for each of the CTD stations is as presented in the Station List (Chapter 7.2).

Data example

The EK60 data were properly backed-up on an external drive, then converted into a .sgy format (SEG-Y) by the use of a software called PS32SGY and loaded onto kingdom. Example of the resulting data is line AL525-EK60-GeoB19-249 (Fig. 5.15). From the profile, some form of non-continuous layering due to difference in acoustic impedence can be observed within the water column.

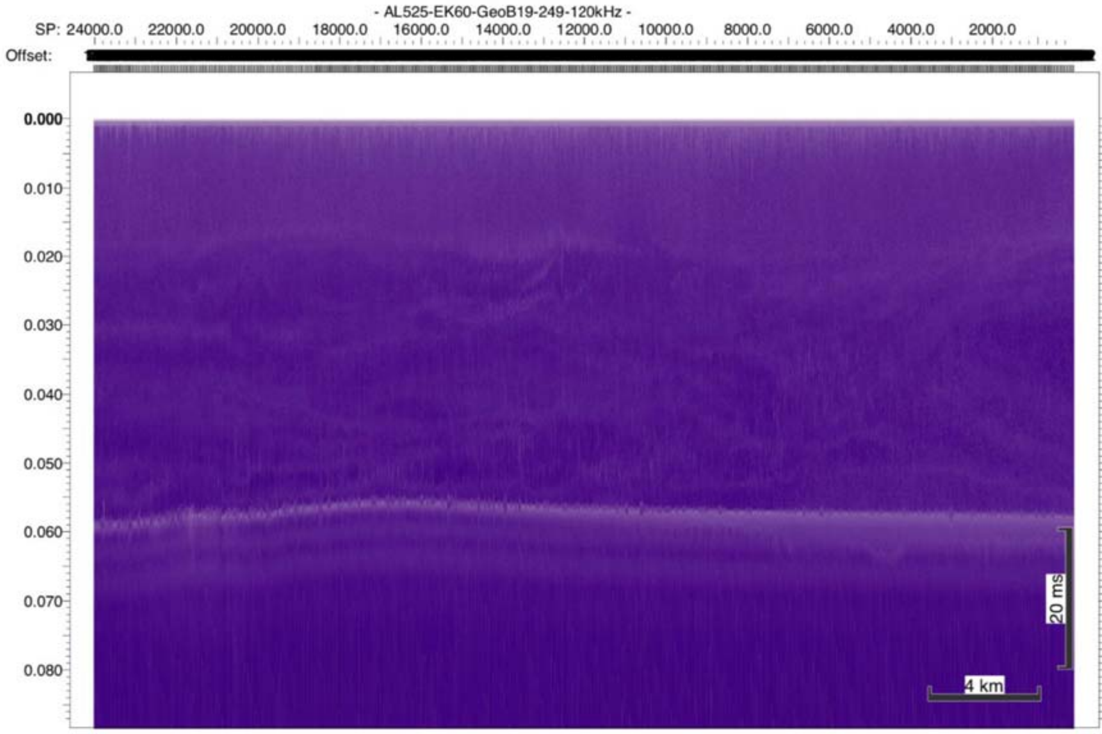

Fig. 5.15 EK60 data showing density contrast in water column on profile GeoB19-249.

Attempt was also made to compare the CTD result with the acoustic survey signature of the EK60 and hence a plot was made of the CTD data measured for each station CTD-1 to CTD-8 on the EK60 profile AL525-EK60-GeoB19-249 as presented in Fig. 5.16.

From the plot, it can be observed that the curve of temperature and sound velocity recorded from the CTD data follows the same trend. They maintained a progressive decreasing value from a depth of 0.015m (0.02ms) up to depth of 0.023m (0.03ms), followed by a rapid increase in value. This data also correlates with the contrast in acoustic impedance on AL525-EK60-GeoB19-249 (Fig. 5.15).

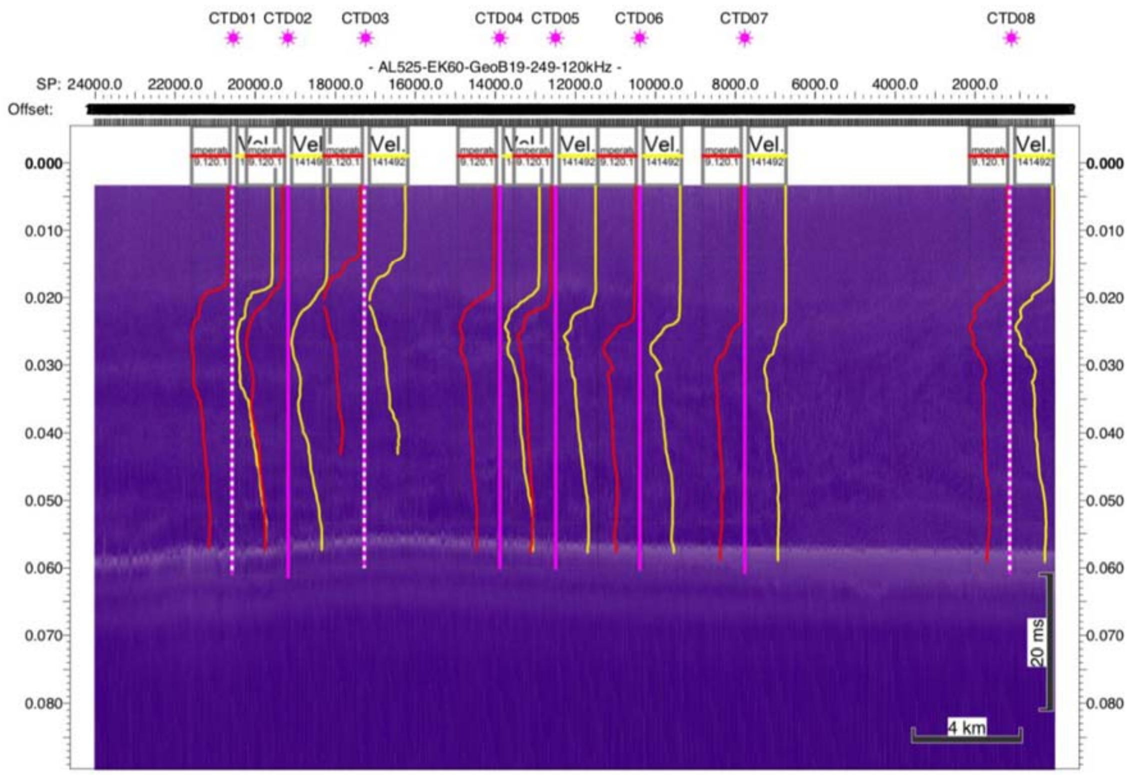

Fig. 5.16 Plot of velocity and temperature data on profile AL525-EK60-GeoB19-249.

5.2 Multichannel seismics

(E.O. Ibolo)

The Bremen multichannel seismic system is well suitable for high-resolution imaging of the subsurface from shallow waters of few meters to deep sediments ranging from few hundred meters to over 1.5 km. High resolution seismic was done in the AL 525 project to delineate the pre-cambrian basement, cretaceous sediments (limestones), tectonic structures and recent sediments of the of the working area (Baltic Sea) although the latter was better surveyed using sediment echosounder EK 60.

The seismic survey was done using the SERCEL Mini Generator-Injector Gun as source which was stabilized by a buoy and the pressure was supplied and monitored with the EEL Airbridge Compressor, custom made GeoB multichannel streamer and data was recorded using the custom-programmed MaMuCs software Version. The seismic survey system is shown in the Fig. 5.17 and the components are described in the following. Positions of seismic source and streamer with respect to GPS antenna are shown in the Appendix (Fig. A.1).

Mini GI Air Gun

The SERCEL Mini Generator-Injector Gun was used throughout for the seismic survey and was set up to the “harmonic mode of operation”, this being a configuration where the Generator and the Injector have the same volume (0.1L), and the firing of the injector has been delayed from the firing of the Generator by approximately half the time of the generator fired alone. The two chambers were set up to contain 0.1L each using plastic volume reducers. It was towed at approximately 1m depth under a stabilizing buoy approx. 20m behind the ship on the starboard side. This configuration leads to a seismic signal with a main frequency of ~ 250 Hz which allows for high vertical resolution of the acquired seismic data. The gun was connected to the air buffer bottle (Fig. 5.18) and shot at intervals of 6 to 7 seconds.

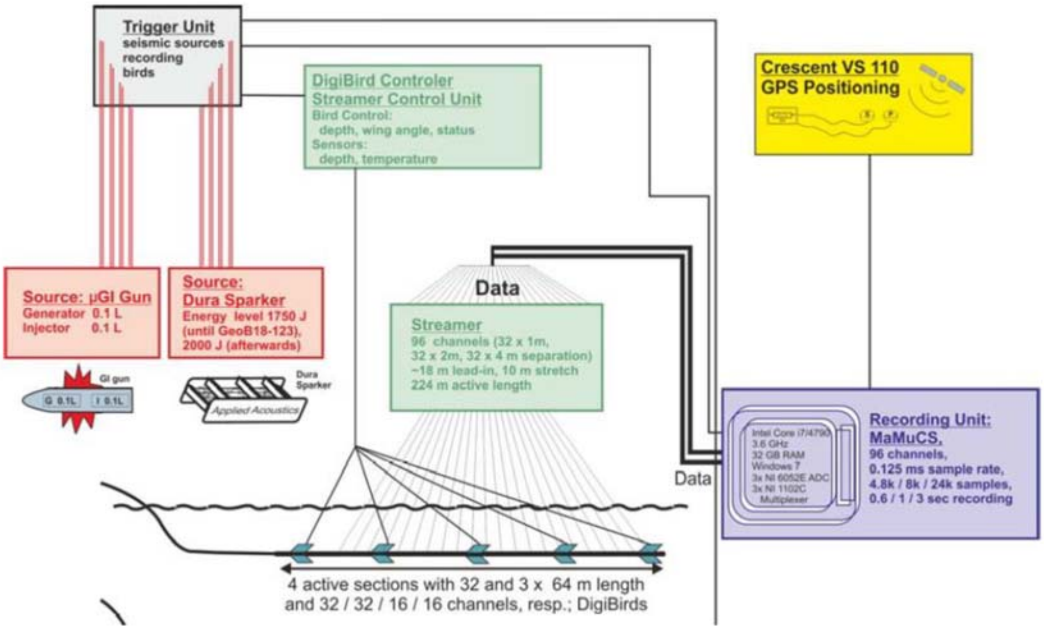

Fig. 5.17 Plot of velocity and temperature data on profile AL525-EK60-GeoB19-249.

Fig. 5.18 Plot of velocity and temperature data on profile AL525-EK60-GeoB19-249.

The shot interval was not constant for all profiles as upon deployment of the streamer and Mini GI Gun, the shot interval was set at 5 seconds for profiles GeoB19-216-pre and the start of GeoB19-217, as the compressor (Fig. 5.19) could not keep up with the shooting interval, the shot rate was changed to 6 seconds for the continuation of GeoB19- 217 at which the pressured air was provided at 100 bar by the EEL Airbridge Compressor ABC 898. The shot rate of 6 s was maintained for GeoB-19-218 through GeoB-19- 221. On profile change to GeoB-19-222 the shot rate was changed to 6.5 s and Pressure increased to 105 bars, the shot rate was maintained through to GeoB19-241 where the rate changed to 7 s.

The pressured air supplied by the compressor was monitored and the watch keep team was entrusted to notify the chief scientist for pressure drops below 100 bars and this happened during the profile GeoB19-243 were pressure dropped from 120 bars to 90 bars. The profile line was ended and MiniGI Gun was disabled and retried from the sea. The O-rings were discovered to have been worn out hence, the air within the chambers collapsed. The shot rate at the time was zero and the compressor also was shut off. The air gun was fixed and redeployed for survey at which the pressure was restored to 130 bars, shot rate was changed to 6.5 s and 7s thereafter reduced to 120 bars.

Fig. 5.19 The AirBridge Compressor and gauges used for pressured air for the air gun

Multi channel Streamer and data recording

The multi-channel seismic data was recorded using the custom-made GeoB multi-channel gel-filled streamer designed by Teledyne; the streamer was deployed at the center behind the ship's stern. The streamer consists of 96 single hydrophone channels with different channel spacing: Channels 1 to 32 have hydrophone spacing of 1m, channels 33 to 64 have a spacing of 2m, channels 65 to 96 have spacing of 4m.

The streamer is deployed into the sea by unwinding from the whinch and is supported by a buoy at the end (5.20). Streamer depth was controlled with "Birds" (Fig. 5.21) which were attached at the different channels. The active part of the streamer has a total length of 224 m, a 25m stretch is deployed after the active length to keep the streamer distant from the ship (to avoid artefact readings from the ship metallic body). The stretch is connected via the lead-in (which is 20.58m from the ship) and deck cable to the seismic recording units in the working lab.

Multichannel data were recorded in the working room using the GeoB custom built MaMuCS-Sytem (Marine Multi Channel Seismic Acquisition System, software Version 1.8.4), which wasdeveloped by Dr. Hanno Keil (University of Bremen). The hardware consists of an Intel i7 based PC (32GB RAM, Windows 7) with three NI6052E 16bit AD-converters. Each ADC is connected to a 32 channel multiplexer (NI-SCXI1102-C) with onboard preamplification and anti-alias filter. The system therefore provides a maximum of 96 channels at maximum sampling rate of 10 kHz per channel. The acquisition software provides nearly continuous recording of the 96 channels with data storage in demultiplexed SEG-Y format (floating-point IEEE) to hard disk. The software allows online quality control by displaying shot gathers and an online profile plot using brute stacks of user-selected channels. The online profile can additionally be printed immediately to an attached windows printer and/or stored in SEG-Y format (Fig. 5.20).

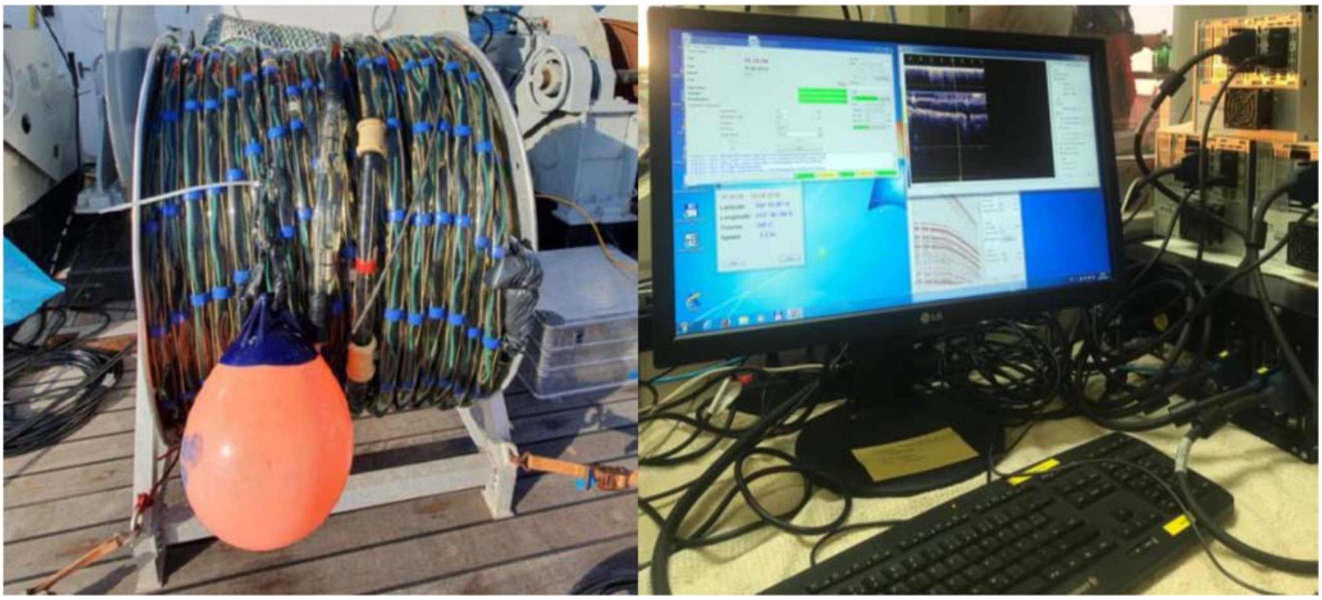

Fig. 5.20 Left: Streamer on winch before deployment. Right: Control interface of MaMuCs system

The MaMuCS PC was also used for logging the external GPS data which were further distributed using Franson GPS Gate over the network to other systems (sediment echosounder, navigation GIS, magnetic and EK60).

Depth Control of the multichannel streamer (Bird control)

For depth control, up to five cable levelers called birds were deployed with the streamer for communication with the hydrophones and also for real time monitoring and depth positioning of the streamer in the water column. Bird position were as follows: Two birds attached in the first section (Channels 1-32)- bird space left empty- One bird attached in the second section (Channels 33-64) – bird space empty – two birds attached in between the third section (Channels 65-96) and at the end of the streamer. Upon deployment of streamer bird depth were set to 1 m as seismic data acquisition started at water depth of 16.33 m and ship speed of 3.1 kN. Birds' depth was lowered to 3m during profile GeoB19-225c as a boat sailed across the survey area; the birds' depth was changed back to 1 m when the boat sailed away. This process was repeated during GeoB19-238. Communication with birds was lost at intervals during survey but this was rectified each time.

Fig. 5.21 The five "birds" for depth controlling of the streamer..

Trigger

The custom trigger unit used during AL525 controlled seismic sources and bird controller. The trigger box 'Schwarzbox' was programmed via a graphical user interface on a laptop. Trigger signals were also used to synchronize recording of the data with the generation of the seismic signals, the multichannel MaMuCs PC were connected to the trigger box.

Onboard data Processing

During the cruise, backup copies of all data was created using the Total Commander program and raw seismic data acquired were converted from .raw to .segy format using the PS32SGY (version 164), the .segy format was then imported into the Kingdom software using the "Multiple 2D SEG Y files with Coordinates" option, the coordinate scale factor was changed from 1 to 0.01 and Imported Trace window set to start frorm 0 to +0.1 s of the end time of the imported trace and then output data format set to 32-Bit. The output from the Kingdom software was further processed using the VISTA for windows by Schlumberger, Onboard brute stacks were created, the four channels closest to the ship was selected, Field Record number (FFN), coordinates, trace headers and the .segy files was imported to Vista. Bulk shifting, Ormsby filtering were applied to the data for gun delay and Spherical divergence to correct for attenuating amplitudes. The output processed brute stacks brute stacks were then uploaded to the Kingdom project.

Data quality and statistics

A total of 52 profiles 2D seismic data were acquired during AL525 Leg 2 and range from AL525-GeoB19- 217 to AL525- GeoB19- 268. All of which were processed and included in the Kingdom project with the exception of profiles AL525-GeoB-19- 250 where the MaMuCs program crashed and AL525-GeoB-19- 258 that had been skipped mistakenly in the profile naming and therefore has no data.

The seismic data was acquired with relatively low frequency and this resulted in high resolution data with allows deep geological and structures to be delineated. Few examples of the data acquired are shown below.

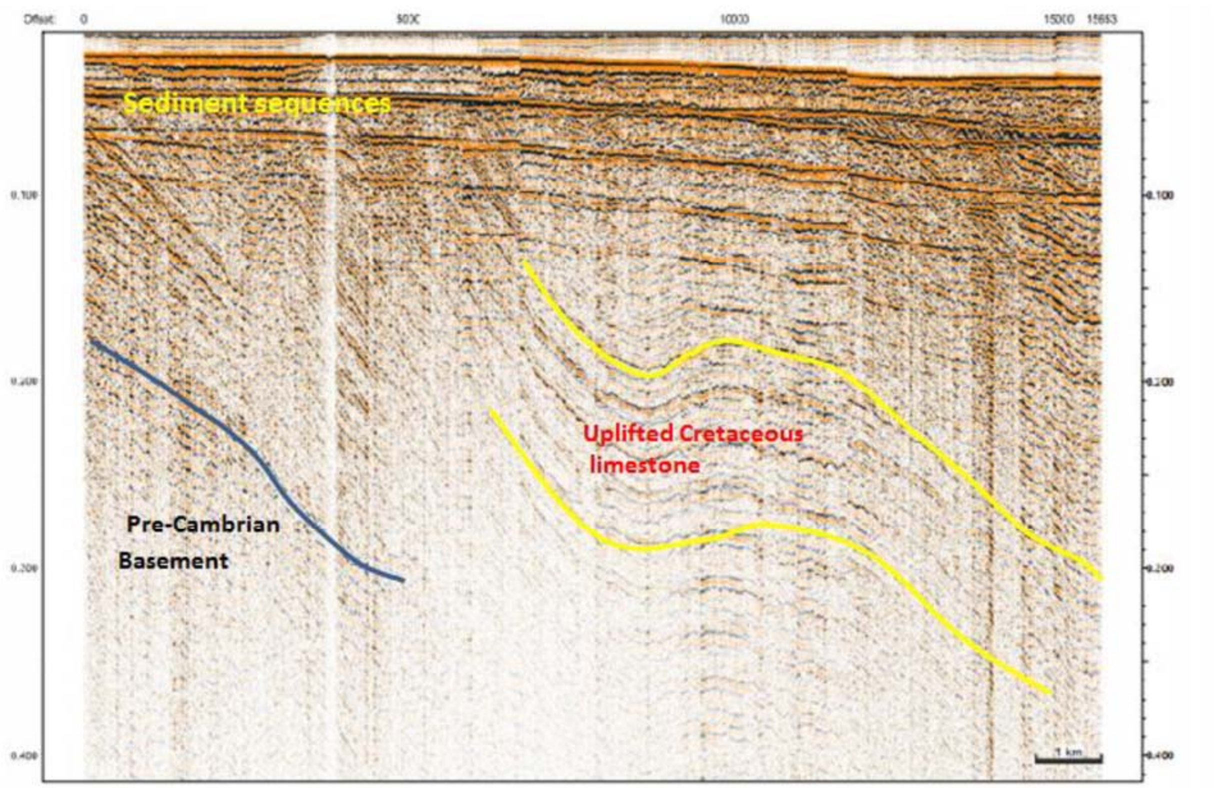

Fig. 5.22 Seismic image of AL525-GeoB19-218 showing the basement, limestones and the quaternary sediments.

GeoB19-218 (Fig. 5.22) cuts across the Skurup Fault (SKF) and a graben. The seismic profile shows sequence of uplifted cretaceous limestones commonly called 'Chalk' and dips upwards, there seem to be an unconformity as the recent sediments are deposited on the uplifted limestones. The seismic profile shows significant blanking and is evident for gas.

GeoB19-225 (Fig. 5.23) cuts across the North Stream pipe line and this is evident as some upwelling or noise is seen on the profile. The AL525-GeoB19-225 cuts across the Jasmund fault and this is seen as discontinuous horizons and upthrust regions are seen on the profile. The seafloor topography is generally smooth and hummocky structure is observed for the sedimentary sequence which typifies that the sediments is soft, recently deposited and from geology perhaps, mud.

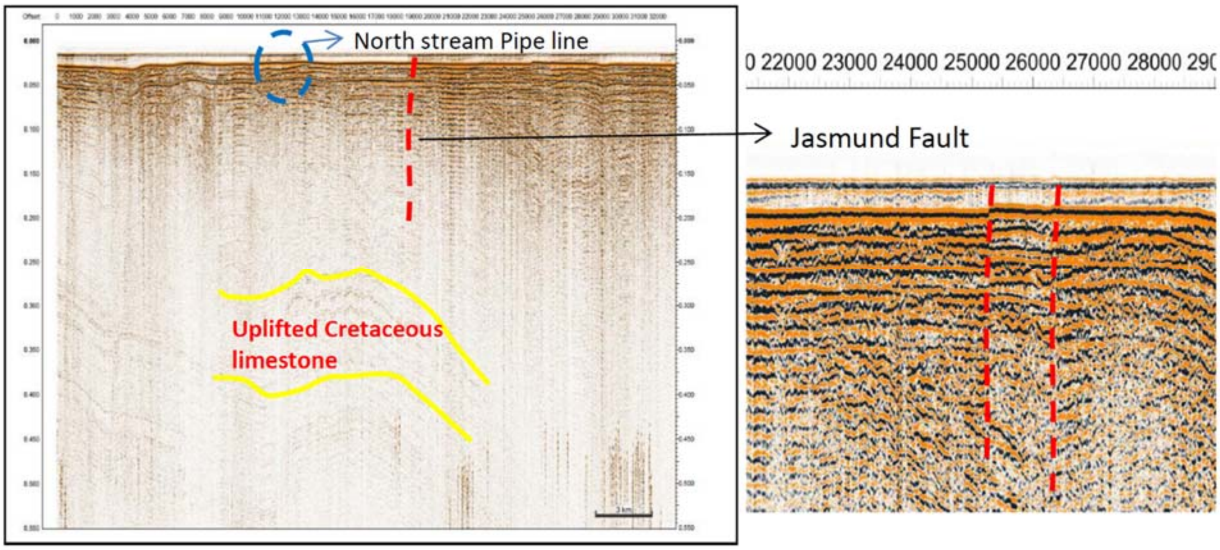

Fig. 5.23 Seismic image of AL525-GeoB19-225 showing Faults and the North stream pipe line signature.

5.3 Magnetic measurements

(K. Kostopolous)

Introduction

A magnetometer is a device that measures magnetism — the direction, strength, or relative change of a magnetic field at a particular location. For this cruise, the magnetometer was used mainly to measure the magnetic field of the sub-bottom geological features for the cause of interpretation and secondarily for the observation and pinpointing of man-made objects such as the offshore natural gas pipe line (Nord Stream). A field may be defined as some function of a vector within a region of space, so that a vector quantity is defined at every point in the region.

Brief overview of the concept behind measuring magnetic fields

A magnetic field's intensity is measured in Amperes per meter (A/m). To visualize it, we use the concept of magnetic flux density, which is represented by the concentration of contour lines around an object exerting a magnetic field in a magnetic contour map.

Magnetic flux density in measured in Tesla (T). In free space, a magnetic field produces magnetic flux that is described by the equation $B=\mu 0 *H$, where B accounts for magnetic flux density, μ0 accounts for the permeability of free space (4π * 10-7 H/m) and H accounts for the magnetic fields intensity. As the world is not a free space, the different materials it contains influence the distribution of magnetic flux transforming the equation to $B= \mu 0*\mu r*H$, where mr is the relative magnetic permeability of the material. A material for which this parameter is less than one is called diamagnetic, and tends to "oppose" the applied magnetic field whilst for the opposite the material is called paramagnetic and tends to "amplify" the applied field. Materials with very high permeability are categorized as magnetic and are called ferromagnetic. When a large magnetic field is applied to a ferromagnetic material and then removed, the material will retain the magnetization that was induced by the high field. This magnetization is known as a permanent dipole (according to Gauss's law, a magnetic field must exist in the form of a dipole. This means that every source of magnetic field has a positive (north) and negative (south) pole which control the flow of the magnetic flux creating a closed loop).

Furthermore, the magnetic behavior of a material can also be categorized through its magnetic susceptibility. It is defined byIH, where I is the induced magnetization of the material, namely the magnetic field created by the interaction of the material with an applied field. Diamagnetic materials have a negative susceptibility while paramagnetic and ferromagnetic materials have a positive susceptibility.

Although the two aforementioned concepts are indeed helpful, they can't model an object's total magnetic influence without the use of a third concept, called the Magnetic Moment, which represents the total strength of a dipole. It is the integral of the object's magnetization over its volume: $M=Bi*V\mu0$, where Bi is the material's internal flux density and V is the material's volume. The units that characterize the Magnetic Moment are A*m2. Once an object's magnetic moment is known, it is possible to calculate its magnetic influence at varying distances.

Accounting for the Earth's Magnetic Field

As a member of the solar system, the Earth, and more specifically its magnetic field is within the influence of the Sun's magnetic field and by a constant stream of free ions and electrons that flow from the Sun, called the solar wind. Therefore, changes in the Sun's magnetic properties affect the Earth's field – different levels of solar activity can result in changes of several hundred nT in the course of a few hours.

In order to account for these changes, special kinds of magnetometers called base station magnetometers are used to measure diurnal variations, for subsequent correction of mobile survey data. Alternatively, worldwide magnetic observatory data can be used for the same purpose. As the SeaSPY used, is a total field magnetometer (therefore measures only the magnitude of the magnetic field vector) it is necessary to apply the diurnal correction to end up with the true deviation of the magnetic field.

Equipment

In the course of the geophysical survey AL525 the magnetometer used was the SeaSPY2, manufactured by the company Marine Magnetics. SeaSPY2 is a high – sensitive total field magnetometer packaged in a rugged marine housing that is designed to be towed behind a marine vessel. The towing must be at a sufficient distance (about two ship lengths) away from the ship so as to not pollute the collected data with the ship's magnetic properties. The SeaSPY2 employs Overhauser sensors which collect accurate data omnidirectionally and are not affected by header error. The SeaSPY2 used in AL525 had the specifications as shown in Table 5.4.

Deployment, acquisition and on – board processing

The deployment of the magnetometer happened shortly before the vessel got in position for the first geophysical survey. The magnetometer was lowered in the sea on the starboard of the ship supported by a crane (Fig. 5.24). As the vessel's length is approximately 50m the length of the cable should always be at least 100m long unless the water is not deep enough to allow it. As a result the tow cable was always between 100m and 250m depending on the depth.

Performance			
Operating Zones		NO RESTRICTIONS	
Absolute Accuracy		0.1 nT	
Sensor Sensitivity		0.01 nT	
Counter Sensitivity		0.001 nT	
Resolution		0.001 nT	
Dead Zone		NONE	
Heading Error		NONE	
Temperature Drift		NONE	
Power Consumption		1 W standby, 3 W maximum	
Range		18.000 nT to 120.000 nT	
Gradient Tolerance		Over 10.000 nT/m	
Sampling Range		4 Hz – 0.1 Hz	
Communications		RS-232, 9600 bps	
Power Supply		9-30 VDC or 100-240 VAC	
Tow Cable			
Conductors	Twisted pair	Color	Yellow
Breaking Strength	2.500 kg (5.500 lbs)	Strength Member	Vectran
Outer Diameter	1 cm (0.4 in)	Jacket Material	Polyurethane
Weight in Air	125 g/m (8.4 lb/100 ft)	Waterproof	YES
Weight in Water	44 g/m (3 lb./100 ft)	Resistance to damage	Loads up to 1000 lbs
Cable Termination	Field Replaceable	Resistance to breakage	Loads up to 6000 lbs

Table 5.4 Specification of Magnetometer SeaSPY

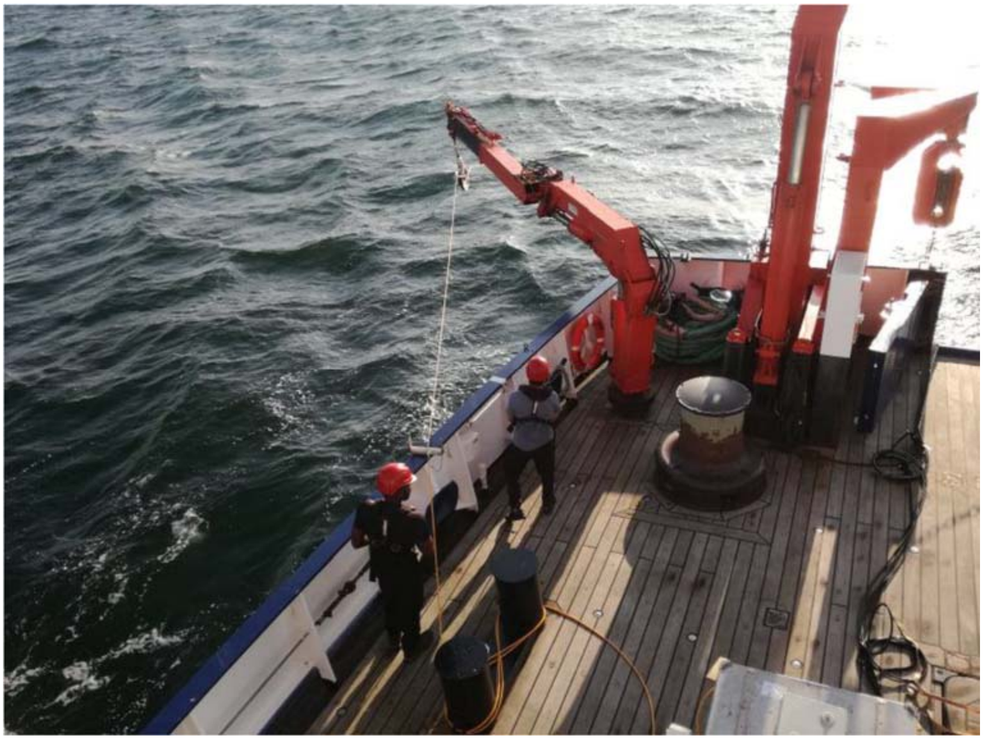

Fig. 5.24 Deployment of the SeaSPY2 magnetometer.

Data was acquired on a PC using a special SeaSPY2 Underwater Magnetometer Data Acquisition & Control Software (Fig. 5.25), which provided a real time data plot interface, displaying the magnetic field (yellow) and the current towfish depth (blue). The software also provided live GPS data including coordinates, time (UTC) as well as the course (deg) and speed (kn) of the ship, used to fill out the protocol form for the cruise report. The protocol was to be filled out every 15 minutes or whenever something worthy of mentioning occurred such as changes of the towing cable. The protocol included all the GPS data aforementioned along with the depth of the towfish, the length of the cable and special remarks. Sampling rate was constant at 1 Hz.

Fig. 5.25 SeaSPY2 Underwater Magnetometer Data Acquisition & Control Software.

On board data processing was done using the software Oasis in which the data acquired was imported and subsequently subjected to diurnal variation and IGRF (International Geomagnetic Reference Field) correction. Diurnal variation correction was done using data acquired by the Niemegk (NGK) observatory (Fig. 5.26). This way, it was possible to end up with the true deviation (anomaly) of our data to the magnetic field that is not caused by diurnal variation. In the end, we produced a map displaying the magnetic anomaly data as a grid on the vessel's surveys.

Fig. 5.26 Difference between the Graphs of the Total Field before (red) and after (gray) diurnal variation.

Magnetic Data Examples

During the cruise the magnetometer was active for the whole duration with the exception of only the Jasmund profiles where only bathymetry was active. Therefore the map with the Ship's GPS track during the cruise depicts the areas where magnetics were active.

As mentioned before, the data acquired using the magnetometer not only include the total field of the geological surface and subsurface but also manmade objects such as pipelines. Therefore during interpretation attention should be given to the signal anomalies in order to distinguish between geological structures and artificial features. The anomaly is relatively simple to find since the magnetometer measures a more or less constant magnetic flux density due to the Earth's magnetic field (Fig. 5.26)

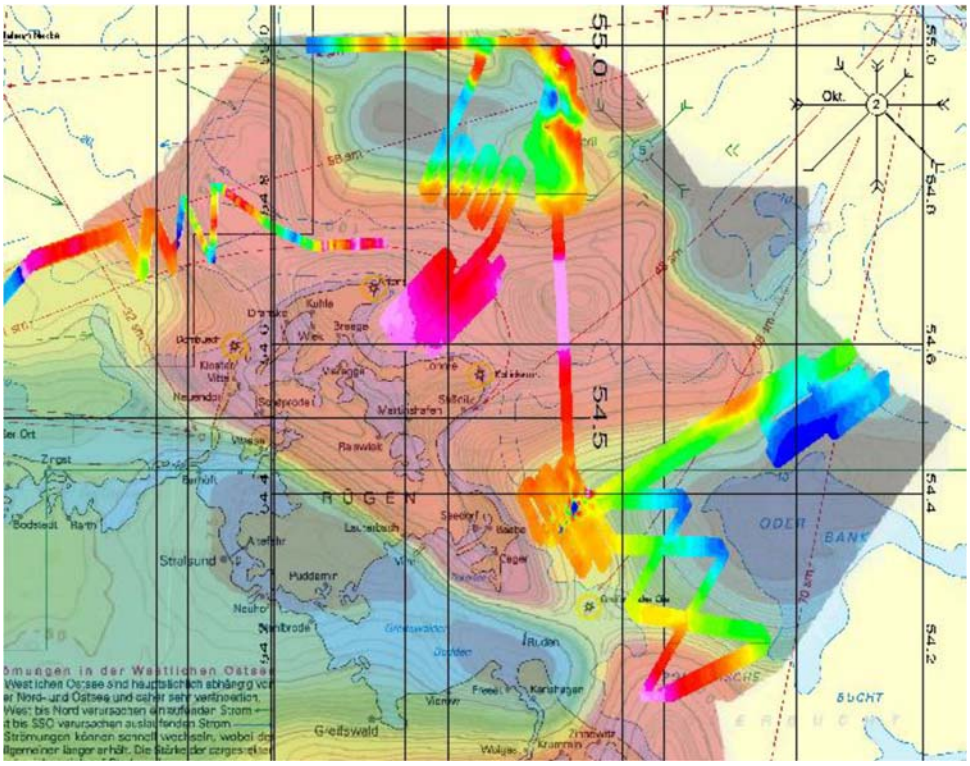

Fig. 5.26 Map of magnetic intensity on top of structural geology map (Al-Hseinat et al., 2017).

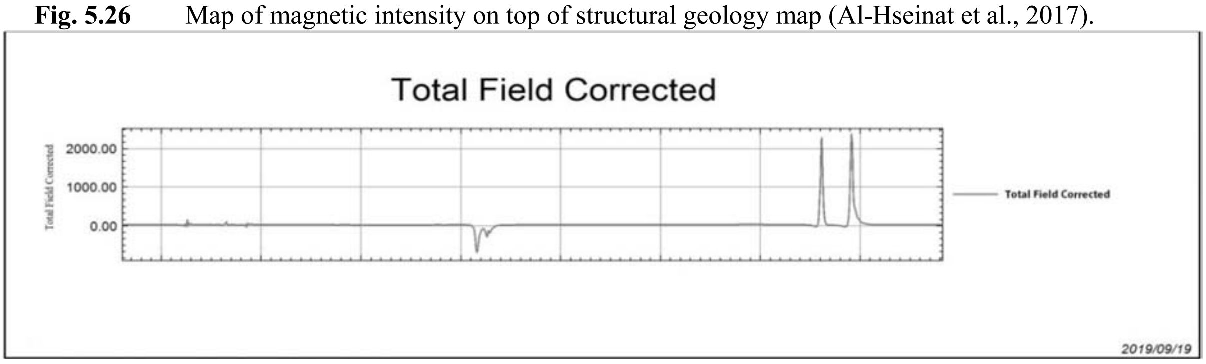

Fig. 5.27 Map of magnetic intensity on top of structural geology map (Al-Hseinat et al., 2017).

Fig. 5.27 shows the corrected total field after passing over a power cable during the cruise. The anomalies on the right side have a positive peak and are more or less symmetrical meaning that the direction of the power cable was perpendicular to that of the vessel at the time.

6 Station List AL525/Leg2

6.1 Profile Station List

6.1.1 Seismic and Magnetic Profiles

Station No.	Profile Station No.	Date start	Time start	Latitude start	Longitude start	Time end	Latitude end	Longitude end
ALKOR AL525_	GeoB-19	2019	UTC	[°N]	[°E]	UTC	[°N]	[°E]
7-1	217	7.8.	9:42	54°20.405	13°50.037	15:17	54°26.6961	14°34.2849
7-1	218	7.8.	15:29	54°34.96	14°31.07	17:06	54°30.52	14°19.56
7-1	219	7.8.	17:13	54°30.14	14°19.5	17:29	54°28.82	14°20.28
7-1	220	7.8.	17:33	54°28.900	14°20.721	19:10	54° 33. 565	14° 32 461
7-1	221	7.8.	19:27	54 32.54	14.32.392	21:08	54° 27.692	14° 20.734
7-1	222	7.8.	21:23	54°26.979	14°22.000	23.21	54°33.037	14°35.697
7-1	223	7.8.	8:38	54°32.449	14°36.620	0:41	54°29.180	14°29.530
7-1	224	8.8	0:41	54°29.343	14°28.603	01:47	54°34.005	14°25.799
7-1	225	8.8	2:02	54°34.177	14°24.023	6:50	54° 20. 769	13° 49. 040
7-1	226	8.8	7:25	54° 23.141	13° 46.662	07:36	54° 23.698	13° 46. 169
7-1	227	8.8	7:53	54° 24 286	13° 47.902	9:19	54° 18.029	13° 54 262
7-1	228	8.8	9:32	54° 18 797	13° 54.947	10.55	54°24.840	13°48.975
7-1	229	8.8	11:11	54°25.411	13°50.132	12:45	54°18.513	13°56.908
7-1	230	8.8	13:01	54°19.186	13°57.750	14:28	54°25.54	13°51.48
7-1	231	8.8	14:44	54°26.05	13°52.74	16:05	54°20.10	13°56.73
7-1	232	8.8	16:15	54°19.91	14°00.14	17:43	54°17.716	14°12.986
7-1	233	8.8	17:57	54°18.86	14°13.806	20:20	54° 6.405	14° 3.371
7-1	234	8.8	20:36	54° 7.383	14° 4.008	22:32	54°11.788	14°19.437
7-1	235	8.8	22:47	54°12.877	14°19.071	0:50	54°14.519	14°1.921
7-1	236	9.8.	1:01	54°15.254	14°1.0978	2:42	54°22.55	14°08.36
7-1	237	9.8.	3:00	54°26.62	14°07.70	4:34	54°23.47	13°53.85
7-1	238	9.8.	4:46	54°24.10	13°52.82	11:36	54°58.786	13°4986
7-1	239	9.8.	12:00	54°58.581	13°52.596	14:09	54°47.49	13°54.04
7-1	240	9.8.	14:33	54°47.64	13°51.76	15:47	54°54.02	13°51.09
7-1	241	9.8.	16:13	54°53.88	13°48.42	17:27	54°47.74	13°51.09
7-1	242	9.8.	17:42	54°47.25	13°50.63	17:49	54°47.38	13°51.76
7-1	243	9.8.	18:05	54°48.26	13°52.93	19:15	54° 54.212	13° 52.300
7-1	244	9.8.	21:22	54° 54.842	13° 49.368	22:49	54°47.963	13°49.865
7-1	245	9.8.	22:58	54°47.533	13°51.109	23:17	54°47.714	13°53.813
7-1	246	9.8.	23:34	54°48.868	13°53.422	0:27	54°51.500	13°47.318
7-1	247	10.08.	0:39	54°52.432	13°47.580	1:26	54°54.133	13°53.934
7-1	248	10.08	1:36	54°54.866	13°54.262	2:58	54°00.46	13°46.80
7-1	249	10.08	3:06	55°00.63	13°45.81	6:25	55° 0.108	13° 16.480
16-1	250	10.08	17:01	55°00.06	13°41.78	17:41	54°57.57	13°39.602
16-1	251	10.08	17:42	54°57.45	13°39.508	19:34	54° 48.703	13°38.684
16-1	252	10.08	19:52	54° 48.302	13° 34.288	20:35	54° 51.011	13° 38.684
16-1	253	10.08	20:55	54° 51.359	13° 38.904	21:44	54° 47.589	13° 36.157
16-1	254	10.08	22:00	54° 47.179	13° 37.653	22:53	54°51.067	13°40.834
16-1	255	11.8.	23:10	54°50.659	13°42.354	0:03	54°46.443	13°39.363
16-1	256	11.8.	0:19	54°46.112	13°40.932	1:11	54°50.151	13°44.208
16-1	257	11.8.	1:29	54°49.735	13°45.922	2:31	54°44.89	13°42.64
16-1	258	11.8.	2:41	54°44.20	13°41.29	4:40	54°36.43	13°30.34
16-1	259	11.8.	4:50	54°36.55	13°29.08	5:02	54°37.37	13°27.89
16-1	260	11.8.	5:31	54°39.27	13°30.08	6:13	54° 41.819	13° 34.227
16-1	261	11.8.	6:39	54° 40.715	13° 36.406	7:44	54° 36.831	13° 29.626

16-1	262	11.8.	8:13	54° 38.187	13° 27.498	9:30	54° 42.868	13° 35.125
16-1	263	11.8.	9:46	54° 42.248	13° 36.200	10:56	54°37.953	13°29.011
16-1	264	11.8.	11:04	54°37.315	13°29.030	11:18	54°36.570	13°30.566
16-1	265	11.8.	11:26	54°36.603	13°31.613	12:53	54°42.042	13°40.020
16-1	266	11.8.	13:00	54°42.003	13°41.194	13:14	54°41.294	13°42.462
16-1	267	11.8.	13:22	54°40.633	13°42.375	14:42	54°35.85	13°34.42
16-1	268	11.8.	15:00	54°36.68	13°33.58	16:36	54°58.786	13.43.21

6.1.2 Multibeam and SES Survey "Jasmund"

Station No.	Profile Station No.	Date start	Time start	Latitude start	Longitude start	Time end	Latitude end	Longitude end
ALKOR AL525_	Jasmun Bathy--	2019	UTC	[°N]	[°E]	UTC	[°N]	[°E]
17-1	1	11.8.	16:36	54°42.43	13°43.21	18:15	54° 35.75	13° 40.64
17-1	2	11.8.	18:15	54° 35.75	13° 40.64	18:30	54° 34.99	13° 39.76
17-1	3	11.8.	18:32	54° 34.99	13° 39.82	18:46	54° 35.99	13° 41.00
17-1	4	11.8.	18:47	54° 36.09	13° 41.04	19:06	54° 34.98	13° 39.75
17-1	5	11.8.	19:08	54° 34.95	13° 39.77	19:24	54° 36.06	13° 41.15
17-1	6	11.8.	19:25	54° 34.84	13° 41.23	19:43	54° 34.91	13° 39.81
17-1	7	11.8.	19:44	54° 34.84	13° 39.78	20:02	54° 35.96	13° 41.17
17-1	8	11.8.	20:03	54° 36.03	13° 41.25	20:22	54° 34.83	13° 39.89
17-1	9	11.8.	20:23	54° 35.99	13° 39.96	20:39	54° 35.91	13° 41.25
17-1	10	11.8.	20:40	54° 35.99	13° 41.28	20:59	54° 34.84	13° 39.33
17-1	11	11.8.	21:01	54° 34.85	13° 40.07	21:17	54° 35.90	13° 41.33
17-1	12	11.8.	21:19	54° 35.94	13° 41.44	21:36	54° 34.84	13° 40.04
17-1	13	11.8.	21:38	54° 34.79	13° 40.05	21:55	54° 35.83	13° 41.38
17-1	14	11.8.	21:56	54°35.93	13° 41.47	22:14	54°34.74	13°40.13
17-1	15	11.8.	22:17	54°34.81	13°40.24	22:32	54°35.83	13°41.48
17-1	16	11.8.	22:36	54°35.77	13°41.47	22:51	54°34.78	13°40.20
17-1	17	11.8.	22:53	54°34.72	13°40.20	23:08	54°35.77	13°41.54
17-1	18	11.8.	23:11	54°35.86	13°41.68	23:28	54°34.74	13°40.28
17-1	19	11.8.	23:30	54°34.68	13°40.25	23:47	54°35.76	13°41.63
17-1	20	12.8.	23:49	54°35.84	13°41.76	0:05	54°34.71	13°40.31
17-1	21	12.8.	0:07	54°34.66	13°40.29	0:24	54°35.77	13°41.73
17-1	22	12.8.	0:26	54°35.81	13°41.83	0:43	54°34.69	13°40.46
17-1	23	12.8.	0:45	54°34.62	13°40.44	1:01	54°35.68	13°41.77
17-1	24	12.8.	1:03	54°35.77	13°41.90	1:20	54°34.66	13°40.54
17-1	25	12.8.	1:22	54°34.56	13°40.48	1:40	54°35.68	13°41.87
17-1	26	12.8.	1:42	54°35.74	13°41.96	2:00	54°34.62	13°40.60
17-1	27	12.8.	2:02	54°34.54	13°40.51	2:19	54°35.63	13°41.90
17-1	28	12.8.	2:21	54°35.69	13°42.05	2:39	54°34.56	13°40.63
17-1	29	12.8.	2:42	54°34.94	13°40.64	2:59	54°35.58	13°41.98
17-1	30	12.8.	3:01	54°35.70	13°42.13	3:21	54°34.53	13°40.73
17-1	31	12.8.	3:23	54°34.46	13°40.69	3:40	54°35.55	13°42.07
17-1	32	12.8.	3:42	54°35.66	13°42.20	4:01	54°34.47	13°40.74
17-1	33	12.8.	4:03	54°34.41	13°40.77	4:20	54°35.52	13°42.15
17-1	34	12.8.	4:22	54°35.59	13°42.29	4:42	54°34.42	13°40.80
17-1	35	12.8.	4:44	54°34.37	13°40.79	5:01	54°35.50	13°42.24
17-1	36	12.8.	5:03	54°35.59	13°42.34	5:22	54°34.38	13°40.88

6.3 CTD Station List

Station No.	Sample Station No.	Date	Time start	Latitude	Longitude	Water Depth	Time bottom	Time end
ALKOR		2019	H [UTC]	[°N]	[°W]	[m]	H [UTC]	H [UTC]
AL525_8-1	1	10.08.	09:29	55°00.11	13°16.83	45.76	09:38	09:43
AL525_9-1	2	10.08	10:23	55°00.11	13°18.81	45.92	10:25	10:17
AL525_10-1	3	10.08	11:13	55°00.24	13°21.67	44.67	11:15	11:17
AL525_11-1	4	10.08	12:13	55°00.32	13°26.54	44.68	12:15	12:18
AL525_12-1	5	10.08	12:46	55°00.34	13°28.51	44.69	12:48	12:50
AL525_13-1	6	10.08	13:41	55°00.34	13°31.58	45.10	13:43	13:46
AL525_14-1	7	10.08	14:33	55°00.44	13°35.46	45.52	14:36	14:38
AL525_15-1	8	10.08	15:56	55°00.44	13°45.46	45.70	15:58	16:00

7 Data and Sample Storage and Availability

Metadata and CSR were submitted to BSH/DOD after the cruise. Raw seismic and hydroacoustic data are stored in the data base of the Research Group "Marine Technology –Environmental Research" at Bremen University. Additionally, these data are stored in the central Green IT-Housing-Center of the University Bremen on servers belonging to the research group. All published data will be made freely available via PANGAEA immediately after publication. All data are made available on request after a moratorium of 3 years.

Table 8.1 Overview of data availability

Type	Database	Available	Free Access	Contact
Multichannel seismic and hydroacoustic data, CTD	Uni Bremen	20.08.2019	20.08.2022	Tilmann Schwenk FB5, Uni Bremen tschwenk@uni-bremen.del
Magnetics	Uni Bremen	20.08.2019	20.08.2022	Thomas Frederichs FB5, Uni Bremen frederichs@uni-bremen.de

8 Acknowledgements

We would like to thank the Captain and the entire crew from the cruise AL525 Leg 2 for all the support and accompaniment given during the Expedition. We would also like to specially acknowledge the University of Bremen for granting this space for educational purposes onboard.

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10 Abbreviations

CTD	Conductivity, Temperature, Depth
GEOB	Institute of Geosciences / University of Bremen
MBES	Multi-Beam Echo Sounder
MCS	Multi-Channel Seismics
SES	Sediment Echo Sounder

11 Appendices

11.1 Decksplan

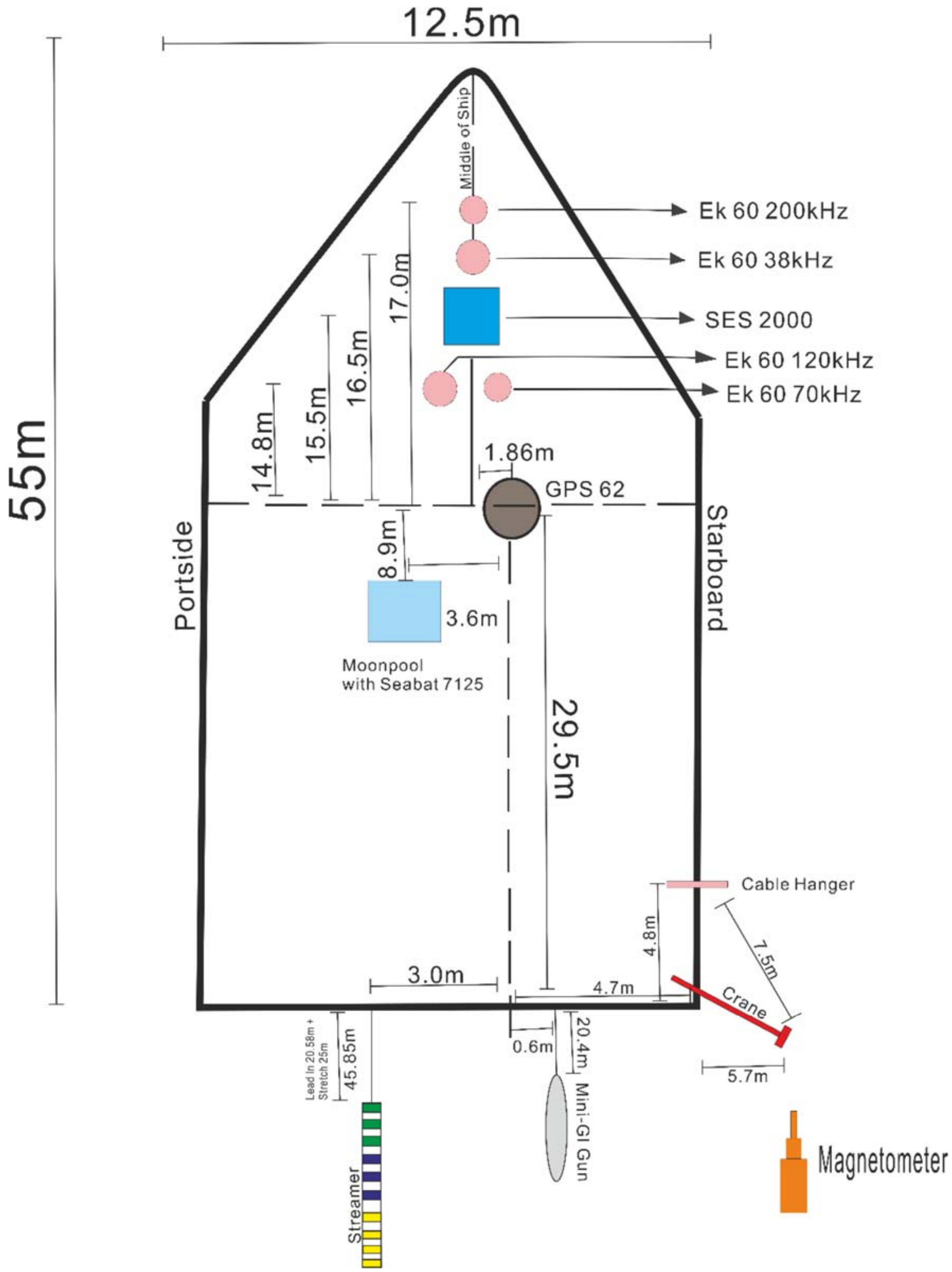

Fig. A.1 Schematic decksplan showing the positions of all devices with respect to the GPS antenna.

ALKOR-Berichte

Geology of Jasmund

Cruise No. AL525/Leg 3

12.08.2019 – 16.08.2019
Sassnitz (Germany) – Kiel (Germany)
SEEGEOPHYS. GÜ UNI BREMEN

P. Albrecht, A. Bugenings, M. Lampe, J. Schraad, J. Seeliger, N. Warnken

Chief Scientist: Dr. Tilmann Schwenk
Institution: University Bremen

2022

Table of Contents

1 Cruise Summary

1.1 Summary in English

The cruise with the R.V. ALKOR (Research Vessel) from Sassnitz to Kiel took place from August 12 – August 16, 2019. The main objective of the cruise was to investigate the surrounding of the peninsula Jasmund using several instruments and techniques. For the investigation following survey instruments were used: the sediment echosounder"SES2000", the fish-sounder "EK60", a "Magnetometer", a "Multibeam Echo Sounder" and a "Mini GI-Gun with streamer" for seismic measurements. All these instruments have been used at the same time, so they delivered important information for instance about the sub-bottom, the sediment formation of the seafloor and the magnetic anomalies. The measurements were evaluated on board with several computers. Another essential aspect of this cruise -in particular for the students -was, to get an insight into the common procedure on a cruise like this. The six students were divided into three groups of two students. There were six shifts a day with four hours per shift and two daily shifts per group of two. An example for such a shift system like that would be a shift from 8 am to 12 am and 8 pm to 12 pm. Throughout these shifts all measurements were documented in a protocol every 15 minutes. The pressure of the Mini Gi-Gun was also controlled every 15 minutes. Besides the shifts, the students were supposed to process the data of the measurements. Furthermore the students had to create a deck plan noting the positions of each respective device used on board. The data will be used for a processing class within the WiSe 2019/20. The one important thing was to gather information about the geology of Jasmund by using this data, but also to use it for the teaching.

1.2 Zusammenfassung

Die Ausfahrt mit der F.S. ALKOR von Sassnitz nach Kiel, fand zwischen dem 12.08 und 16.08.2019 statt. Das Hauptziel dieser Reise war es, die marine Umgebung der Halbinsel Jasmund mit verschiedensten geophysikalischen Instrumenten zu untersuchen. Für die Untersuchung wurden folgende Instrumente verwendet: Das Sedimentecholot SES2000, das Fischecholot EK60, ein Magnetometer, das Fächerlot für die Bathymetrie, und die „Mini GI-Gun mit Streamer", für seismische Messungen. Alle Instrumente zeichneten die Daten simultan auf und lieferten wichtige Informationen über bspw. Meeresbodenbeschaffenheit, sedimentäre Formationen und magnetische Anomalien. Die Daten wurden an Bord vorab mit mehreren Computern ausgewertet. Ein weiterer wichtiger Aspekt, insbesondere für die Studenten, den Ablauf einer solchen Reise kennenzulernen. Die sechs Studenten wurden in zweier Gruppen eingeteilt, daraus ergaben sich dann drei Gruppen. Es gab zwei Wachen am Tag die jeweils vier Stunden lang waren. Ein Beispiel für dieses Schichtsystem wäre eine Schicht die zwischen 8:00 Uhr morgens und 12:00 Uhr mittags stattfinden und zwölf Stunden später zwischen 20:00 Uhr und 0:00 Uhr. Während dieser Schichten wurden die Messungen alle 15 Minuten in ein Protokoll geschrieben. Ebenso wurde alle 15 Minuten der Druck der Mini GI-Gun überprüft und vor jeder Schicht wurden zudem die Kompressor Daten notiert. Neben den Schichten, wurden die Messdaten von den Studenten prozessiert und zusätzlich ein „Decksplan" der ALKOR angefertigt. Die Daten werden für das kommende WISE 2019/20 im Rahmen der Lehrveranstaltungen verwendet. Es ist wichtig mit den zugrundeliegenden Daten Aussagen über die Geologie von Jasmund zu treffen und diese für die Lehre zu nutzen.

2 Participants

2.1 Principal Investigators

Name	Institution
Schwenk, Tilmann, Dr.	GeoB
Frederichs, Thomas, Dr.	GeoB

2.2 Scientific Party

Name	Discipline	Institution
Schwenk, Tilmann, Dr.	Marine Geophysics / Chief Scientist	GeoB
Frederichs, Thomas, Dr.	Marine Geophysics	GeoB
Bergmann, Fenna, Dr.	Marine Geophysics	GeoB
Gehrmann, Anna, Dr.	Marine Geophysics	UniG
Brune, Rouven	Marine Geophysics	GeoB
Albrecht, Philip	Student	GeoB
Bugenings, Alexander	Student	GeoB
Lampe, Marco	Student	GeoB
Schraad, Jan	Student	GeoB
Seeliger, Julian	Student	GeoB
Warnken, Niklas	Student	GeoB
Schwenk, Tilmann, Dr.	Marine Geophysics / Chief Scientist	GeoB

2.3 Participating Institutions

GeoB Faculty of Geosciences, University Bremen
UniG Institute for Geography and Geologiy, University Greifswald

3 Research Program

3.1 Description of the Work Area

The Leg proceed around the coastline of Jasmund and from the coastal region to the Arkona Basin. Jasmund has steep shore formations build by a glacial process. These formation includes boulder clay, which belongs to the till formation, or chalk formations like the “Königsstuhl”. The underground is struck by sandy deposits. Consequently, the marine subsurface offshore Jasmund and in the Arkona basin is dominated by glacio-tectonic processes.

3.2 Aims of the Cruise

The main aim of the cruise to demonstrate the students the acquisition of all kind of marine geophysical data, including hydroacoustic data by means of a swathsounder and sediment echosounder, multichannel seismic data, magnetic data and CTD casts. To teach the students the first interpretation of such data sets, but also the maintenance of the devices and the survey planning was another major aim of the cruise. The main scientific aim was the surveying of the offshore prolongation of the glacio-tectonic structures around the Jasmund Peninsula to support an ongoing project at the University of Greifswald.

3.3 Agenda of the Cruise

First, hydroacoustic, seismic and magnetic data were gathered on several profiles around Jasmund, thereby the orientation of the profiles were located perpendicular to the suspected glacio-tectonic structures. This survey was interrupted by long profiles to the East to the boundary of Denmark in order to image deeper tectonic structures there. Finally, the ship headed to the Arkona Basin to continue a survey from the legs before. Finally, at four stations the CTD were used to sample data from the water column..

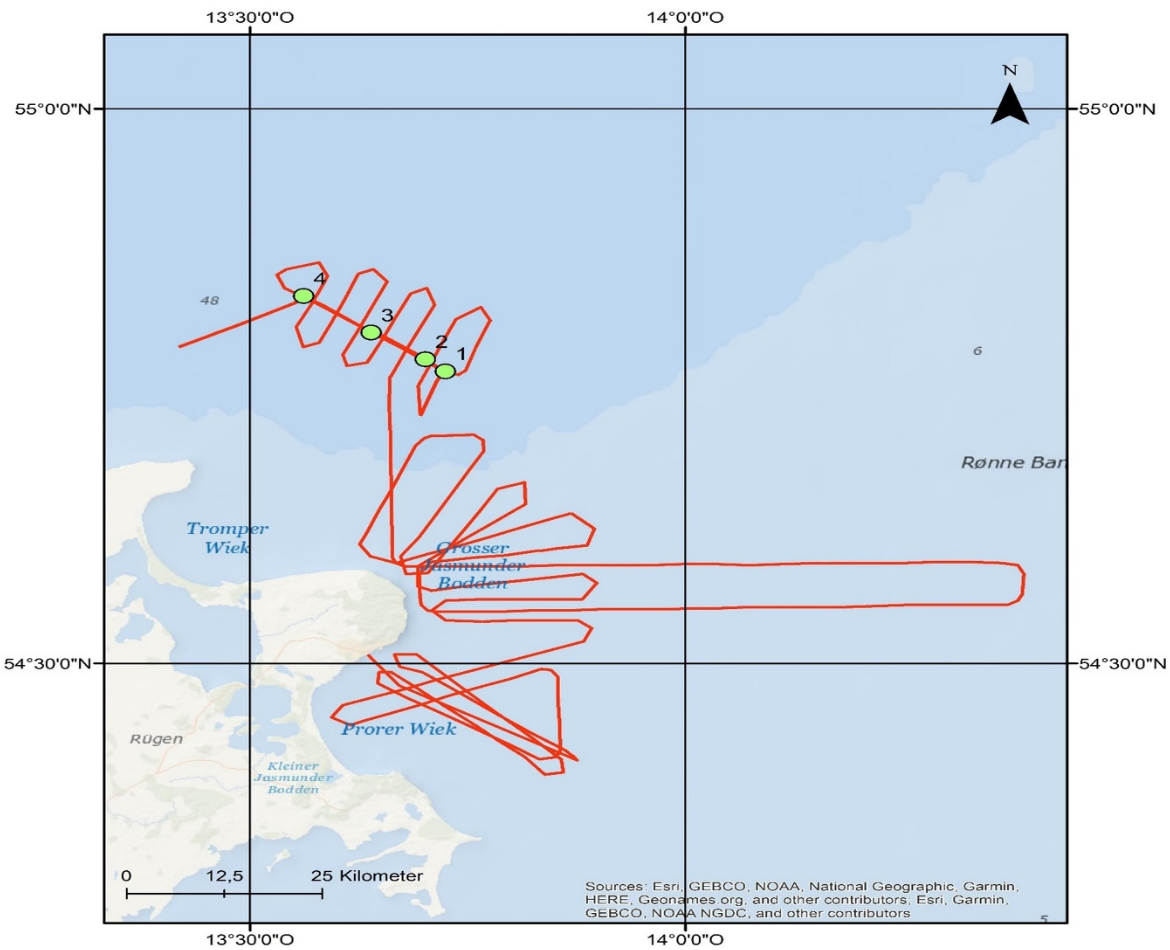

Fig. 3.1 Track chart of R/V ALKOR Cruise AL525/3 around the Jasmund Peninsular, east of Rügen, and in the Arkona Basin.

4 Narrative of the Cruise

The student group for the third leg from AL525 arrived at the ship on Monday the 12th of august 2019 in the afternoon. The vessel laid in the port of Sassnitz. After getting a guiding in from the vessels officer, we met in the dry laboratory. There, we got a schedule for the following days and the shifts were organized. Further the first two presentations from the students were held. The presentations were about the different measure devices and the geology of the Baltic Sea and especially the working area.

On the next day, Tuesday August 13 the ship started leaving the port of Sassnitz at 7 am with 6 bachelor students, 4 scientists from the University of Bremen and one guest scientist. At this point the SES system started recording data, starting with profile SES-GeoB19-269-pre. After finishing the last presentations, the streamer and Gi gun were deployed at around 10:00 am. After a successful test shoot the magnetic system was deployed. The recording started at 10:10 am with profile GeoB19-269-pre. The first profiles, GeoB19-269 to GeoB19-274 were recorded in the Prorer Wiek, a bay in the southeast of Rügen. After finishing profile GeoB19¬274 at around 8:20 pm, the vessel started heading northeast for profile GeoB19-275. From August 13 10:55 pm to August 14 1:55 pm the profiles GeoB19-276 to GeoB19-286 were recorded at the east and northeast of Jasmund. After that the two long profiles GeoB19-287 and GeoB19-289 were created. At around 11:45 pm the vessel headed north towards the Arkona basin. There the profiles GeoB19-291 -GeoB19-299 were recorded from August 15 1:40 am to 10:35 am.

After finishing those profiles, the data acquisition was stopped. The ALKOR turned and headed again to the northwest-southeast profile in the Arkona basin. Along this profile four CTD measurements were accomplished. The first one was taken on August 15 at 12:42 am at 54°45.41 N and 13°43.46 E, the second one at 1.07 pm at 54°46.41 N 13°42.08 E, the third at 1:38 pm at 54°47.92 N and 13°38.34 E and the last one at 2:19 pm at 54°47.94 N and 13°33. 7 E.

During the travel time the streamer, the GI gun and the magnetic fish were retreived. Furthermore, the whole measuring devices were cleaned and dismantled. Also, the dry and wet laboratory were cleaned. After finishing the CTD measurements the ship headed towards Kiel. On August 16 at around 8 am the ship arrived at the port of Kiel. There, the whole equipment was loaded into a truck and brought back to the University of Bremen

While two of the six students had their observe shift, the other were doing other tasks. The desk plan was created on August 13. Other tasks were for example converting the recorded data or doing backups.

None of the gathered data were deeply analyzed or interpreted. However, they were used for first analysis, for example if there is gas in the sediment, which is typical for the Baltic Sea, or for glacio-marine structures. The seismic data will be processed and analyzed in the lecture seismic exploration, which will be held in the winter semester 2019/20. The weather conditions were acceptable the whole time with little waves and none too few rain. Further there were no massive technical issues. Only the multichannel seismic software MaMuCS crashed several times.

5 Preliminary Results

5.1 Magnetic Survey

The magnetic surveys were carried out with a SeaSPY 2 total field magnetometer (SeaSPY2 Operation Manual). Through the tow cable spool it was connected with the transceiver unit which delivered the measured data to one computer in the laboratory. By that the data, mainly the field magnitude and the depth of the magnetometer, could be observed as a graph and was automatically saved. For every second one value of the field magnitude was saved.

The towfish unit contains an Overhauser magnetometer sensor. To have a compromise between a short distance to the seabed for a precise measurement and a sufficient distance to prevent damaging the device was kept about 5 to 10 meters higher than the seabed. Therefore, it was necessary to constantly control the depth of the magnetometer and the seabed. Furthermore the magnetometer was operated on starboard to prevent a collision with the GI-Gun. While going straightforward the distance between the devices was sufficient but while going in a curve the devices had to be watched.

Generally, just a limited number of significant anomalies could be found. The major part stays at an almost equal level in terms of Magnetic field with a value of about 50,350 nT. Little magnetic anomalies can be found regularly, e.g. Fig. 5.1.

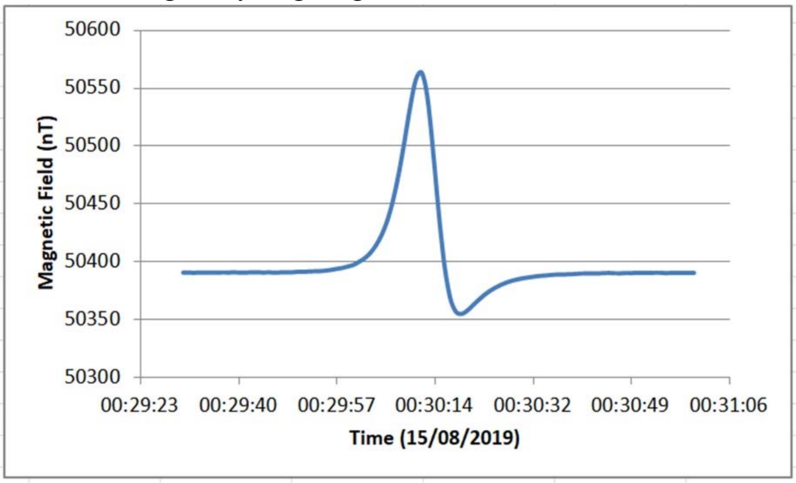

Fig. 5.1 Small magnetic anomaly, probably caused by a small metallic object. For location, see Figure 3.4 (yellow dot).

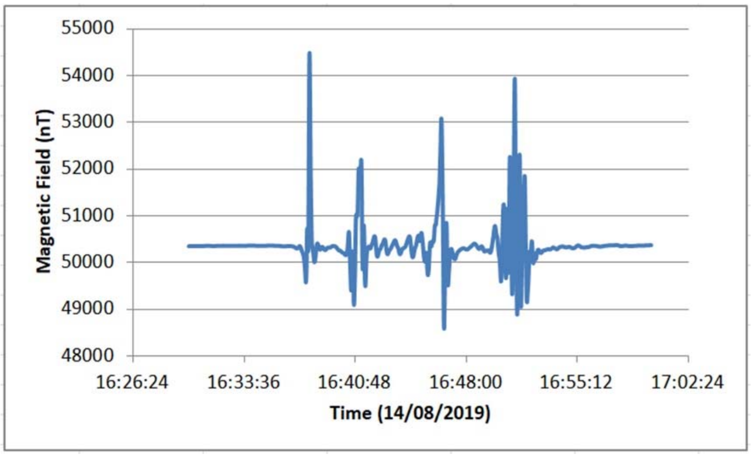

Fig. 5.2 Succession of pronounced anomalies. For location, see Fig. 3.4 (green line).

In one case bigger anomalies could be found (see Fig. 5.2). The reason for such an anomaly could be a large structure like a shipwreck. To find out what the particular reason for this anomaly is further information from the seismic data, navigation data and hydroacoustic data has to be compared.

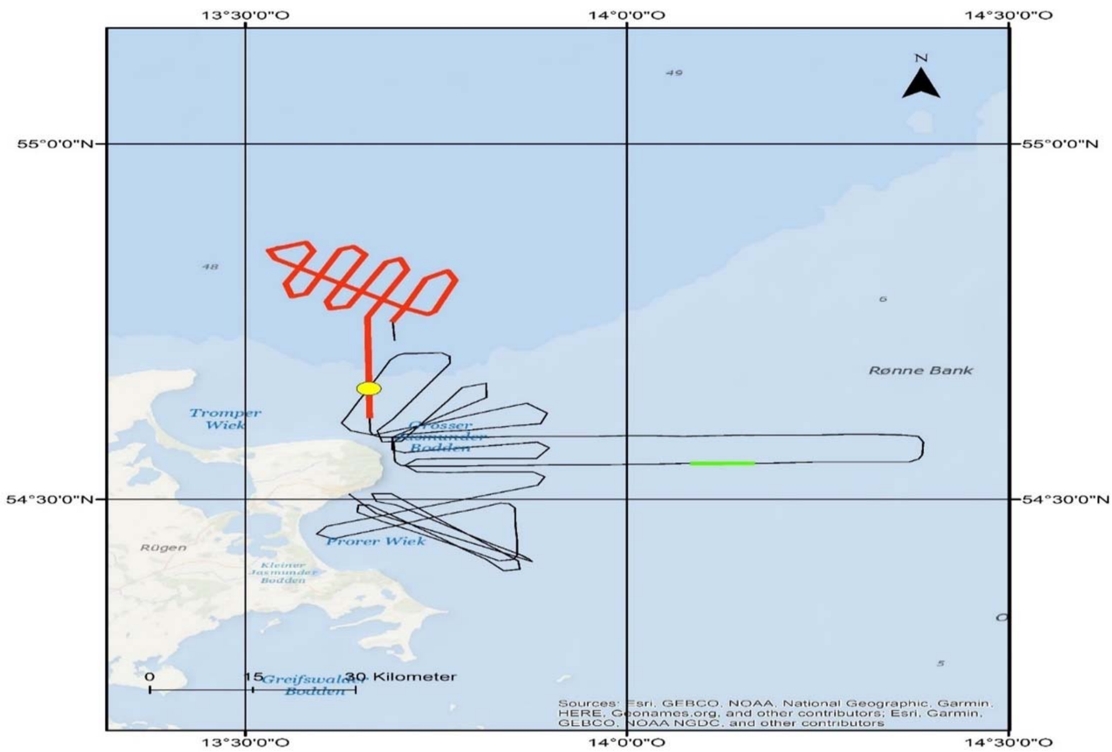

Fig. 5.3 Map showing the location of the shown examples of the magnetic data in Figs. 3.2 (yellow dot) and 3.3 (green line).

5.2 EK60 Echo Sounder

The F.S. ALKOR is equipped with a permanently installed Simrad EK60 echo sounder system. While this system is mainly intended to be used in fishery research operations, it was used as a means of water column imaging on this cruise. The system is capable of running up to seven frequencies (ranging from 18 to 710kHz) simultaneously with each frequency requiring a separate transducer/transceiver combination. On F.S. ALKOR only four transducer/transceiver combinations are installed, one being out of operation. All three available frequencies (38kHz, 70kHz, 120kHz) were used and recorded throughout the entire cruise.

Figure 5.4 displays an exemplary visualization of the acquired data using the 38 kHz. Assuming an average water sound speed of 1500m/s, the sea floor is clearly visible at an approximate depth of 40m. The stratification is of the water column is clearly visible by several reflectors representing changes in density steered by temperature and salinity.

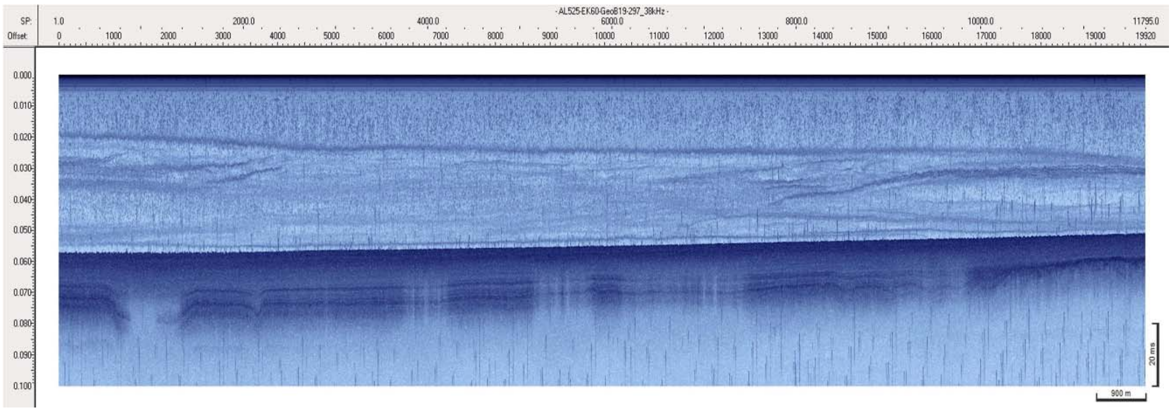

Fig. 5.4 EK60 data recorded on Profile GeoB19-297.

5.3 CTD

A multi water sampler and CTD (conductivity, temperature, depth) probe combination made by the manufacturer HYDRO BIOS was used in order to conduct measurements within the water column (MWS12 operation manual). While being lowered to the seafloor and back to surface, the mounted electric sensors measure water conductivity, temperature and depth. An onboard processing unit is used to calculate salinity, sound velocity, density, oxygen saturation and chlorophyll concentration based on the collected data. The device is equipped with twelve bottles, enabling it to take water samples from different depths in order to bring them to surface for further analysis.

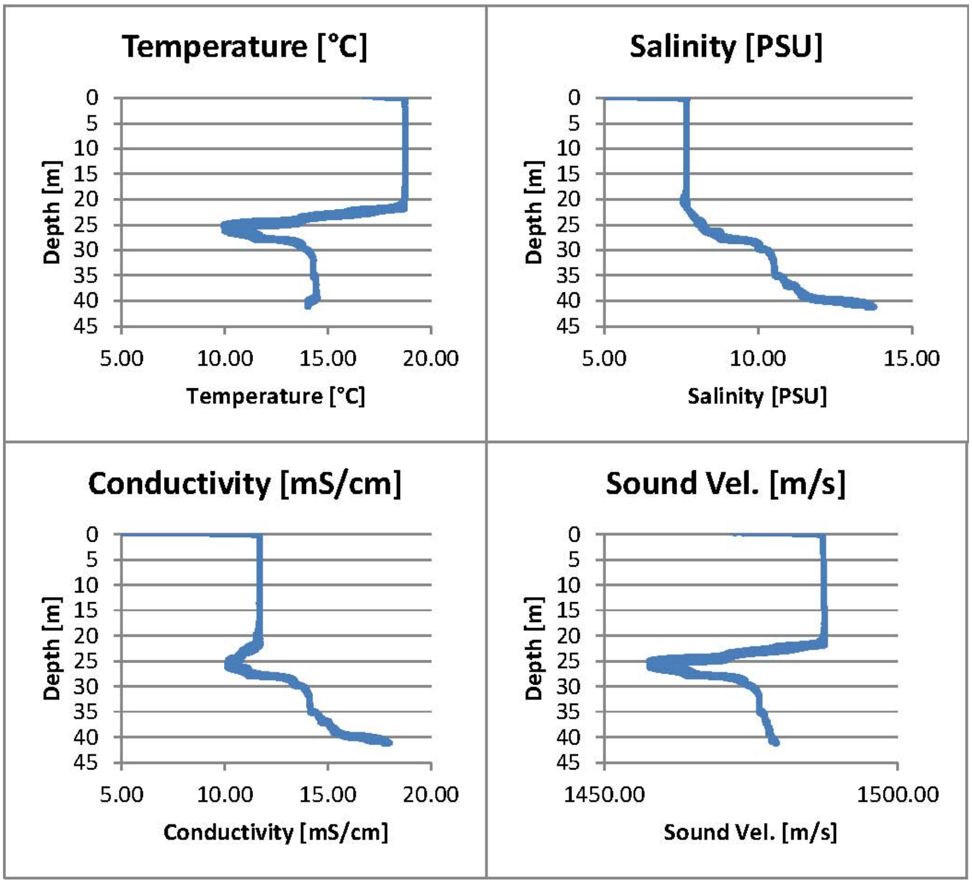

Fig. 5.5 CTD data from station CTD-1.

A total of four CTD runs was conducted roughly based on the information provided by EK60 Profile GeoB19-297. The assembly was lowered and raised with a winch speed of 0.3m/s to an average depth of 40m with the sensors running at a sampling rate of 1 Hz. Figure 5.5 provides an example of the acquired data and can roughly be correlated to the EK60 Profile GeoB19-297 as parameters change in the same water depths (20-25m) as main reflectors are visible in the water column (Fig. 5.4).

5.4 Sediment Echosounder SES2000

The SES "Sediment Echo sounder" is a special Type of echo sounding systems. Normally all echo sounding systems are based, of the sonar. The typical function of a sonar system is to use underwater sound propagation to navigate or to detect other objects under the water surface. In the case of echo sounding, it is used to determine water depth by transmitting sonic waves into the water column. There are a time interval between the emission and the return of a pulse and this is recorded. Thereby the water depth is determinates. To get the distance of the seafloor, the half time of the signals outgoing pulse to its return is multiplied by the speed of sonic in the water. The value of water sonic speed is approximately 1500 m/s. On the F.S. ALKOR research vessel the SES Innomar 2000 medium is installed. This is suitable for smaller vessels. It compensates the roll, pitch and yaw movements which come from the vessel by a "IMU" motion sensor and it can also adjust the angle of the sonic radiation by using a Beam-steering.

The parametric SES Innomar 2000 medium uses the parametric acoustical effect. Two sonic waves with nearly the same frequencies are transmitted into the water column. Both frequencies are transmitted at high sound pressure. These are the primary frequencies f1 and f2 and f2 is higher than f1. They interact in the water so there are new frequencies generated, called secondary frequencies. The transducer of the SES Innomar 2000 medium has a primary frequency of 100 kHz and a secondary frequency of 10 kHz. Every profile has been recorded with several frequencies in this case with the available frequencies 5 kHz, 10 kHz and 15 kHz. These frequencies are low enough to penetrate the seafloor. The advantage of a parametric echosounder is the much smaller emission cone (higher directivity) compared to conventional systems (Fig. 5.6).

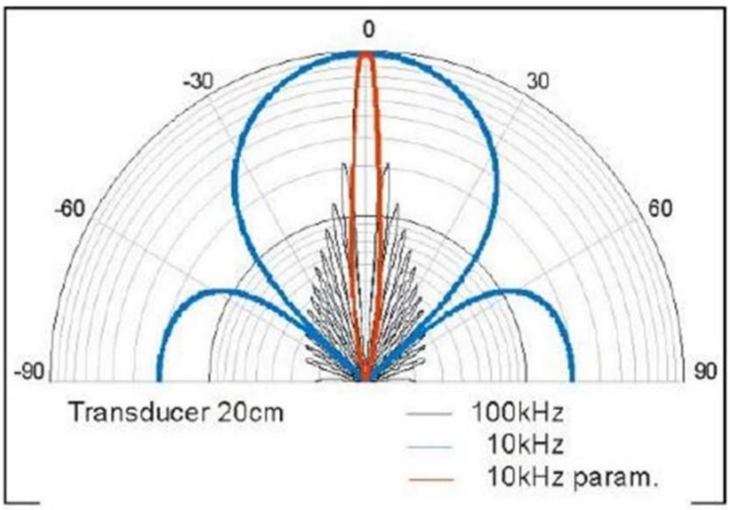

Fig. 5.6 Sketch demonstrating the better directivity of a 10 kHz parametric signal compared to a conventional echosounder. From SES 2000 Users Guide.

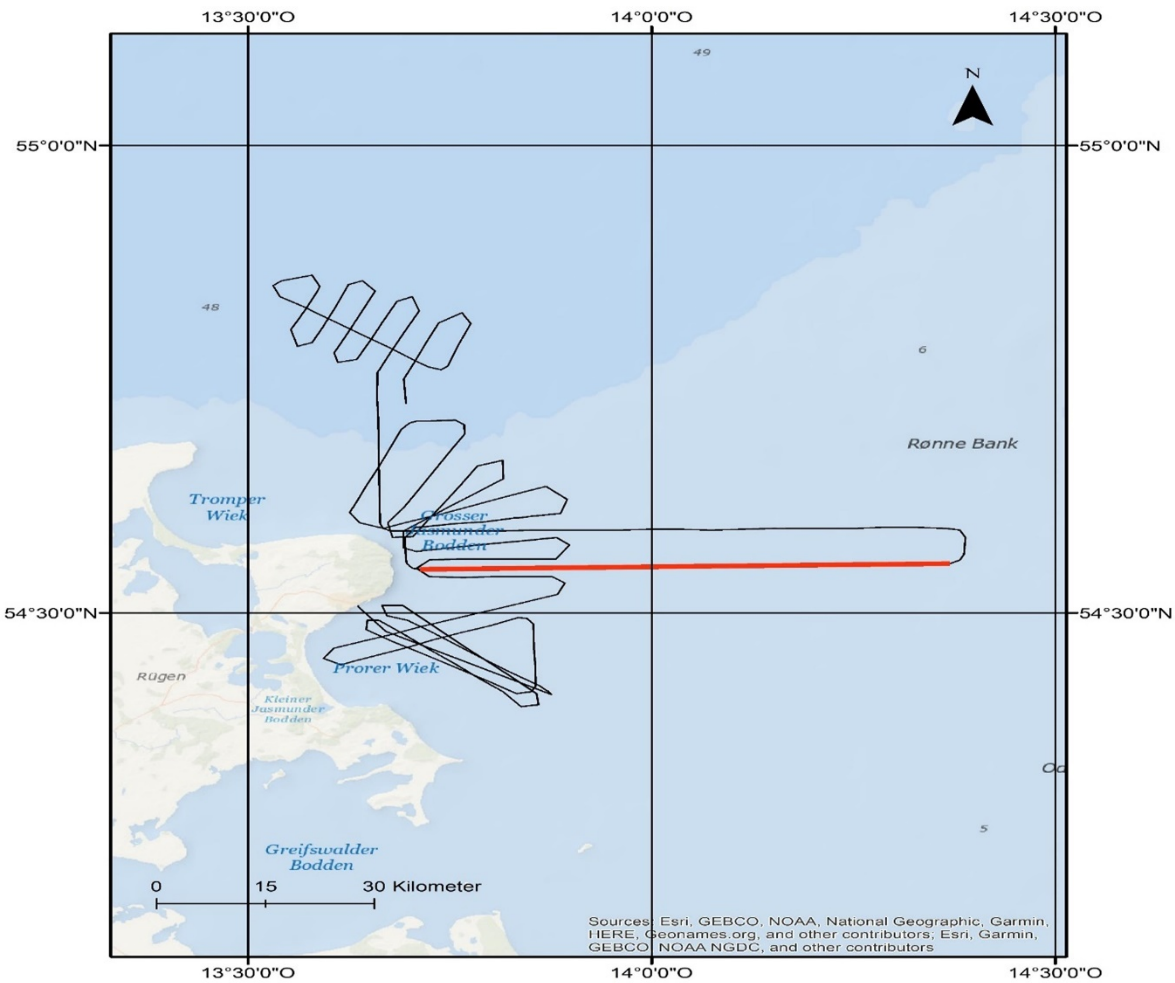

Fig. 5.7 Map showing the location of the SES data example in Figure 5.8.

The interesting profiles were those which were recorded in areas with, some anomalies like special deposits or other objects on the seafloor. Figure 5.8 shows a SES profile at a water depth of approximately 18 m spanning from Ruegen to the east until the boundary to Denmark. The upper, acoustic prolonged layer displays the sediment layer deposited probably in the Holocene which can be assumed to the chalk formation of the coastline of Jasmund. Beneath, some multiples are visible as well. The sub bottom is irregular with some ripples or faults in the middle of the profile. There are also some small elevations visible at the seafloor.

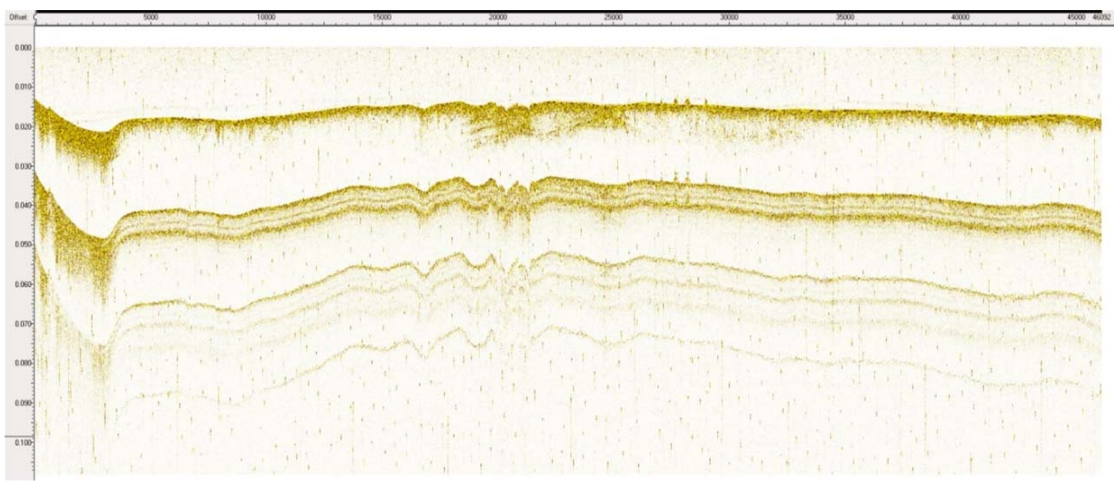

Fig. 5.8 SES data gathered on Profile GeoB19-287

These elevations are shown as close-up in Figure 5.9. The diffraction hyperbolae points to small structures at the seafloor. Taken the location it is most probable that these structures representing the Northstream pipeline.

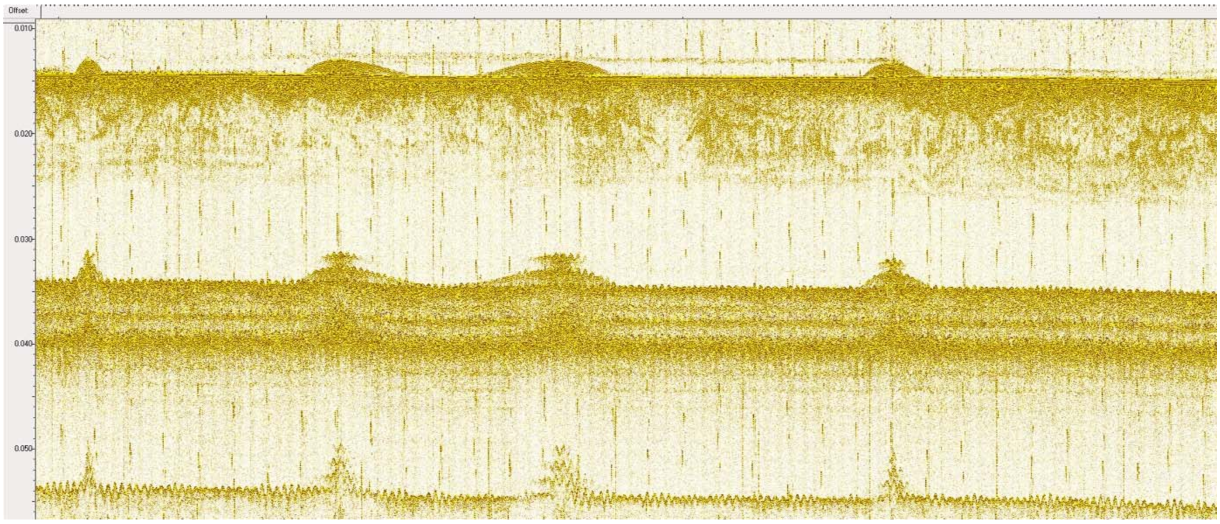

Fig. 5.9 Close up of SES data from Profile GeoB19-287 (Fig. 5.8).

5.5 Multibeam Bathymetry

Objectives

From the beginning of the cruise in Sassnitz until the end of it in Kiel, bathymetric measurements were conducted with a Reson SeaBat 7125 multibeam sonar. The processed data can be used to get a better overall image of the Seafloor and its depths in the south-western Baltic Sea. Also it will be used for the study group of the 5th semester as raw data. The systems were observed by Students in groups of two.

Placement and location

The Reson System was placed behind the Computer and connected via cable (see Fig. 5.11). Located next to the Computer was the motion sensor, which delivered data directly to the system. The motion sensor however was not perfectly calibrated. The GPS data was taken directly from the ship with an accuracy of approximately 10 m. The multibeam sonar itself was attached to a steel construction and lowered down the moonpool (open at the bottom) to fix it under the ship (see Fig. 5.10). The moonpool was 10 m away from the primary GPS sensor.

Operation

While the system was recording the Students in charge had to maintain the range window (yellow lines in Fig. 5.12) and if it was not centred correctly it had to be adjusted. The red line shows the depth at which the system sets the seafloor. The minimal and maximal depth can be scaled in the gates settings, in which we chose a 10m ranged window. The recording was paused and resumed in a consistent measure, since the data package is easier to handle if it is smaller (app. 200 mb). The system did run from the beginning until the end of the measurements, taken on this cruise. No problems occurred.

Fig. 5.10 Placement of the multibeam system under the ship. The construction is lifted above the moonpool.

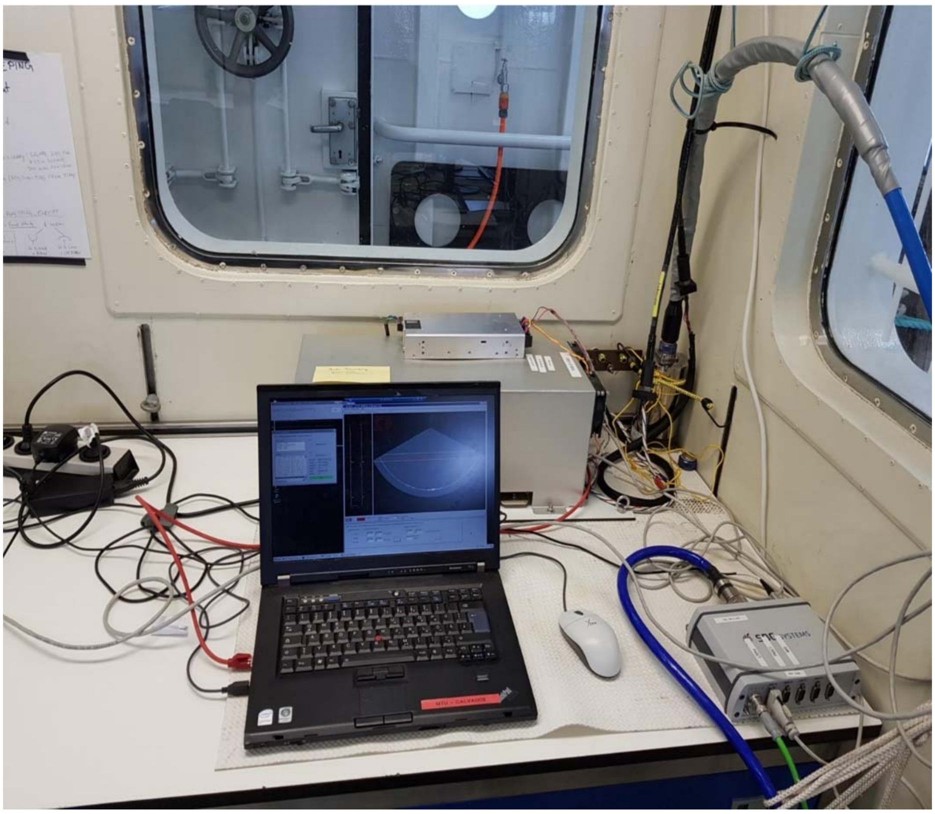

Fig. 5.11 Photo showing the Reson system (the silver box behind the Laptop). On the right side is the motion sensor visible (metallic cylinder) that was used to correct the ships movement during transmission and receiving of the sound energy.

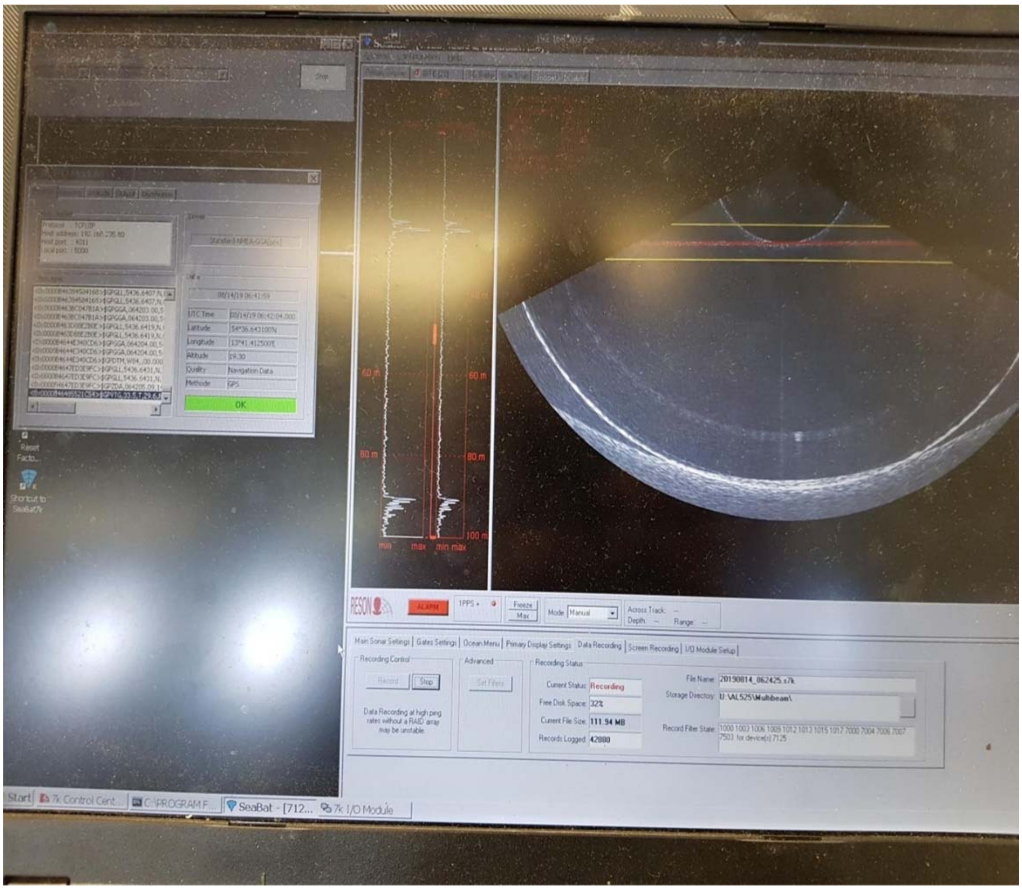

Fig. 5.12 Photo showing the acquisition software of the Reson system. The upper right panel visually displays each beam, with the estimated seabed at the red line. Underneath is the control penal for the system.

Settings

The system was set to run in equal angle (EA), which sets the opening range of each individual beam to the same angle. This was used because equal distance (ED) did not run smoothly on the Computer. The range of each beam is 100.0 m with a maximal rate of 3.0 p/s. The power was at 220.0 dB, gain at 83.0 dB and the pulse length at 300 us, all three are the highest possible settings. The gate control switch was set to Absolute and the minimum range to 0 with a maximum range of 80. The adaptive window size was set to 1 % for a better accuracy of the data. In the ocean menu the absorption was set to 80.0 dB/km with a spreading of 30.0 dB. Since there were no existing velocity profiles of the area we applied the value of 1490.0 m/s, which is the average value taken from CTD data of an earlier cruise. The window on the left side of the picture displays the Location of the measurements.

Results

Example of the bathymetric data gathered on the cruise is shown in Figure 5.13. The left side shows the colour table used to display the bathymetric data. Starting point of the Profile is 13:42:57 E, 54:32:20 N and it ends at 13:45:56 E, 54:32:18 N. In this example the middle part of the profile is significantly deeper than the parts on both sides.

Fig. 5.13 Data example from East of Rügen. For location, see Figure 5.14.

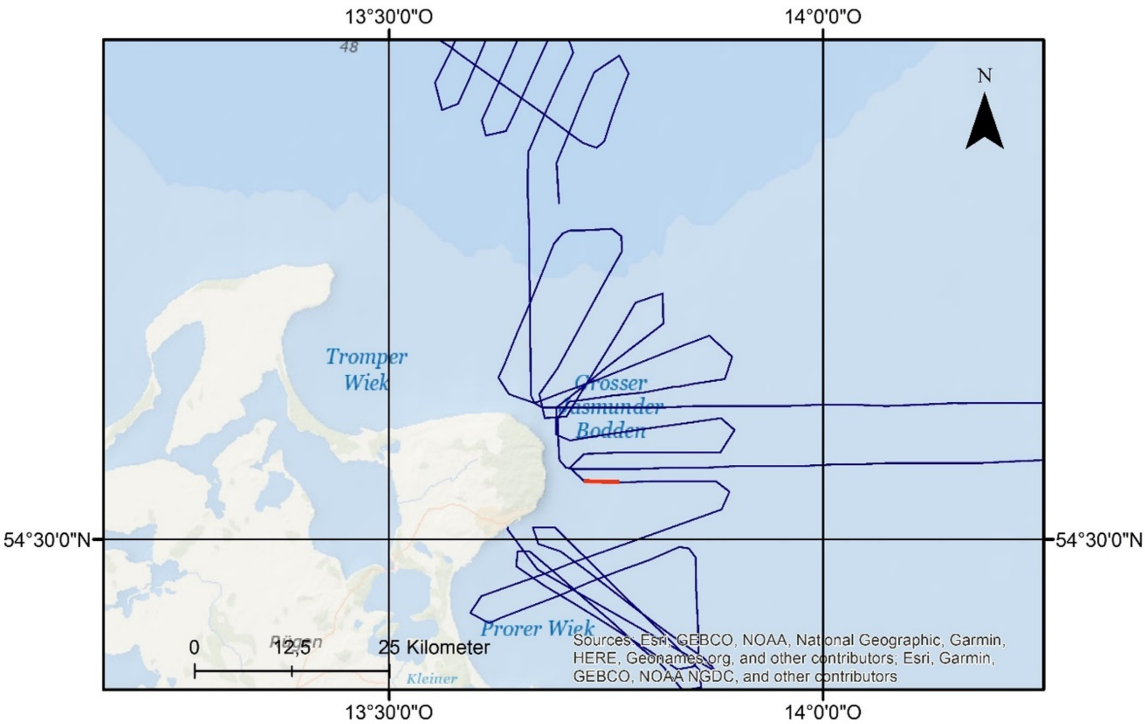

Fig. 5.14 Map showing the location of the data example presented in Figure 5.13.

5.6 Multichannel Seismic

The GeoB multichannel seismic equipment was installed on the Cruise AL525 to generate high resolution seismic data of the Baltic Sea on the one side and to establish the handling of seismic technology to the students of the University of Bremen on the other side. Because of the good weather conditions, a good data quality is assumed.

Source and compressor

During the whole seismic survey one seismic source was used, a mini GI-Gun was triggered in a time interval of 7 s between the shots. The source was constantly operated with a pressure of 120bar. One compressor was used to provide the mini GI-Gun and the velocity of the ship during the deployment was 2 kn. The mini GI-Gun was used in "true GI mode" that means both chambers (generator and injector) are the same size. The towing position of the mini GI-Gun is shown in Figure 5.15. Also, there is shown that the distance between the source and the seismic streamer is 4.8 m. The mini GI-Gun was hauled 20 m behind the ship in a water depth of 1 m.

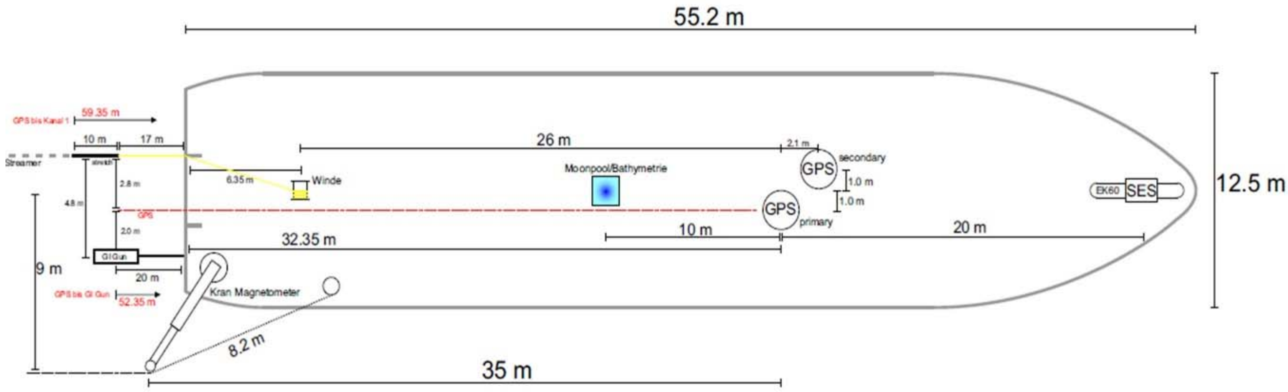

Fig. 5.15 Decksplan showing the towing geometry of all devices.

Streamer:

The seismic streamer with a total length of 225 m and in total 96 channel was placed on the rear. For better handling of the long cable unit, it was rolled up on a winch. Between channel 1 and 32 the distance is 1m. An exception is the offset among channel 32 and channel 33 which is 2.6 m. Henceforth until channel 64 the distance is 2m and from channel 64 to channel 96 the difference increases to 4m. Each channel represents a used hydrophone in the streamer. During the operation the streamer laid not completely straight. 6.75m slightly left from the heading of the ship, the streamer is placed on the ship to get the horizontal offset of 4.8m to the seismic source. After 27 m behind the ship the measuring hydrophone unit started (Fig. 5.15).

Bird controller

5 birds were utilized during the operation to control depth and direction. Each of the birds had a heading and depth sensor as well as adjustable wings. They were supervised and controlled in the seismic lab on a separated portable Pc in which the depth was set on 1 m. During the cruise the birds lost signal for a short period of time, but it does not emphasize as a bigger problem.

Data acquisition

The streamer as well as the GI Gun was connected with cables to the seismic lab in which the technology was supervised. For the seismic survey all ends and beginnings such as special happenings were recorded in a protocol. Also, if nothing happened the protocol had to be written on regularly basis of 15 minutes. For data recording, online visualisation and storage, the software MaMuCS (Marine MultiChannel Seismics) was installed to the PC. Also, the software visualizes the data for a first impression and stores received data in SEG-Y format. During the cruise MaMuCS crashed four times which was documented in the protocol. The total recording length was set to 2000 ms at a sample rate of 125 µs. In addition, the seismic lab had a device for triggering the mini GI-Gun to get a shot rate of 7 s. In total 33 multichannel seismic lines were shot during the cruise AL 525/3. The seismic source, created all those profiles, worked on the cruise AL 525/3 completely reliable. Onboard the collected profiles were roughly processed with the software package Vista. On Vista there were execute a number of predetermined steps to get a better seismic image and to create brute stacks of the recorded data. After the processing step the stacked data was loaded in the seismic interpretation system Kingdom Suite. This program helped to visualize the data in a geo-referenced system. After the survey all data was loaded on external hard disks

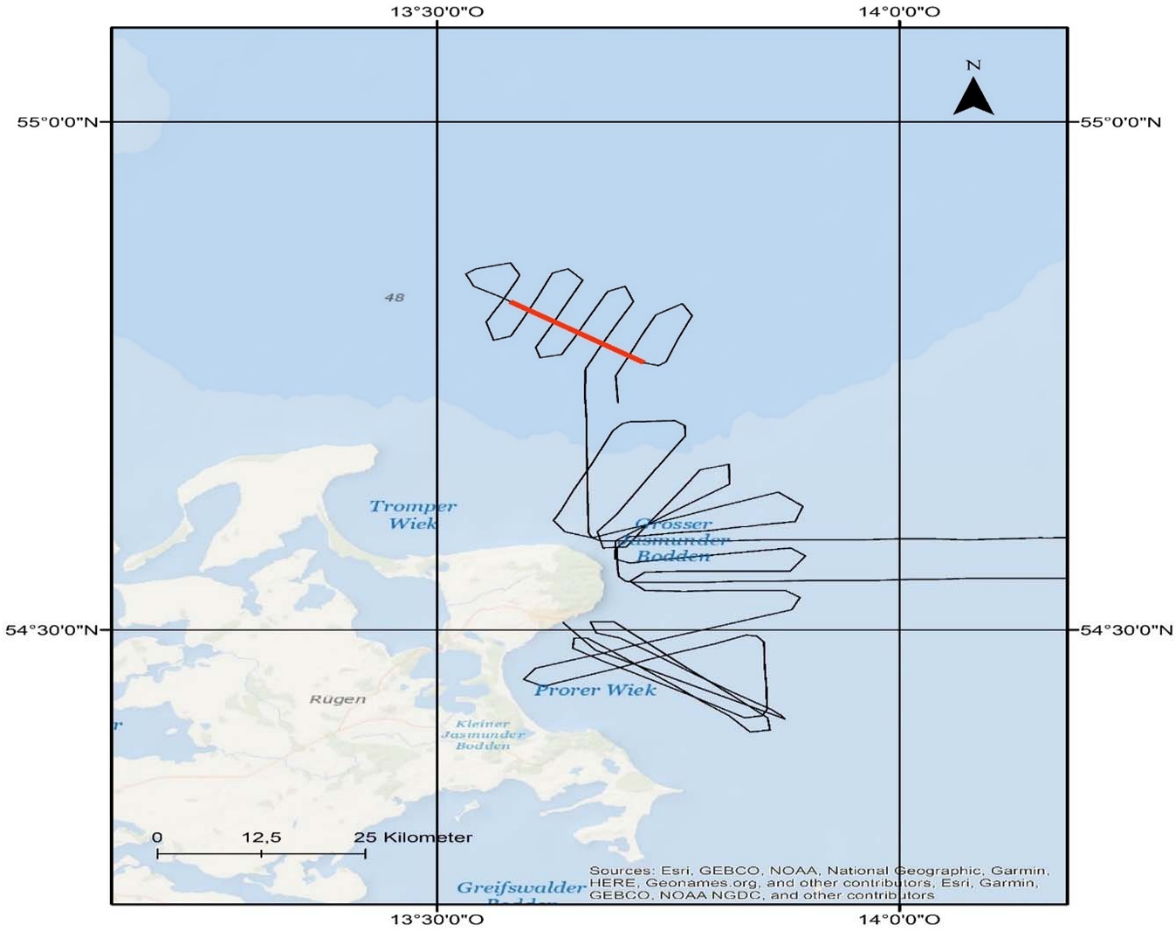

Fig. 5.16 Map showing the location of the seismic profile displayed in Figure 5.17

Preliminary results

The beginning of profile GeoB-297-B is located at the GPS-coordinate 54°50.34 (latitude) and 13°32.34 (longitude) and the end at the coordinates 54°43.43 (latitude) and 13°42.77 (longitude). The picture shows the seismic survey results loaded in the program Vista. On the left axis is TWT (two way travel time) and on axis above the shot number as well as the channel. The picture shows a maximal penetration depth of 600 ms, because after that distance the sea floor does not reflect at all. Consequently, it indicates that it is only possible to look 600 ms into the ground of the Baltic Sea. This corresponds to a depth of 400 m. From 60 ms until 200 ms the amplitude of the sea floor reflectors is very strong. Beneath 200 ms the illustration alternately displays stronger and weaker reflectors with a bigger cardinality by the stronger reflectors The morphology of the seafloor surface also indicates no bigger changes in the sea depth. The changes in reflectors indicate stratified sediments and therefore a change in sedimentation material. At shot number 104 there is an area of acoustic blanking.

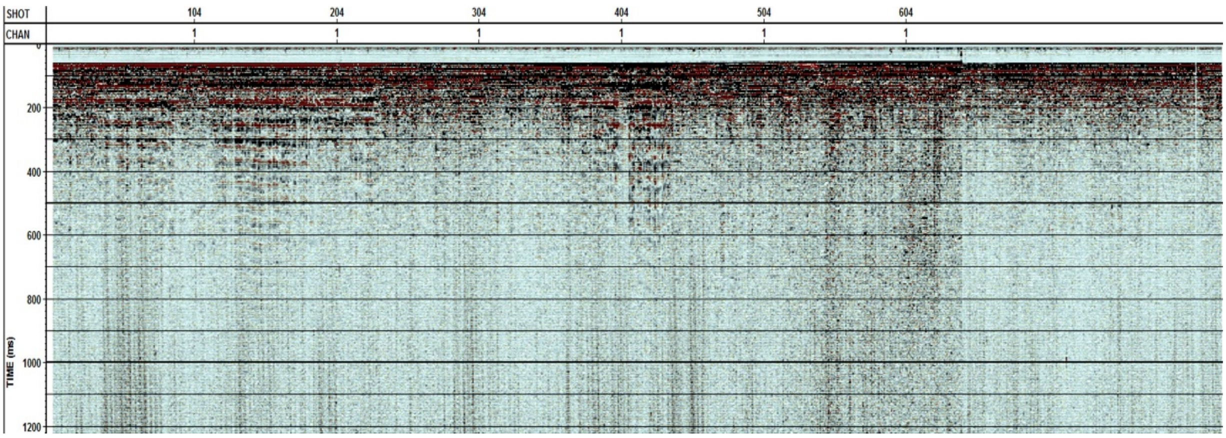

Fig. 5.17 Multichannel seismic data from Profile GeoB19-297.

6 Station List AL525/3

6.1 Overall Station List

Station No.		Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/ Recovery
AL525_	GeoB19-	2019		[UTC]	[°N]	[°W]	[m]	
18-1	269	13.08.	MCS, MB, SES, EK60, MAG	10:36	54°26.268	13°49.225	16	
18-1	270	13.08.	MCS, MB, SES, EK60, MAG	12:11	54°30.442	13°41.57	19	
18-1	271	13.08.	MCS, MB, SES, EK60, MAG	14:06	54°23.87	13°50.25	18	
18-1	272	13.08.	MCS, MB, SES, EK60, MAG	16:01	54°28.85	13°39.04	17	
18-1	273	13.08.	MCS, MB, SES, EK60, MAG	17:45	54°25.28	13°51.38	16	
18-1	274	13.08.	MCS, MB, SES, EK60, MAG	18:44	54°29.70	13°50.00	18	
18-1	275	13.08.	MCS, MB, SES, EK60, MAG	20:43	54°27.71	13°36.47	15	
18-1	276	13.08.	MCS, MB, SES, EK60, MAG	23:04	54°32.34	13°52.42	20	
18-1	277	14.08.	MCS, MB, SES, EK60, MAG	00:26	54°33.41	13°43.62	23	
18-1	278	14.08.	MCS, MB, SES, EK60, MAG	01:55	54°34.85	13°52.86	20	
18-1	279	14.08.	MCS, MB, SES, EK60, MAG	03:28	54°35.34	13°41.71	24	
18-1	280	14.08.	MCS, MB, SES, EK60, MAG	05:04	54°39.41	13°47.00	30	
18-1	281	14.08.	MCS, MB, SES, EK60, MAG	06:30	54°24.85	13°40.43	25	
18-1	282	14.08.	MCS, MB, SES, EK60, MAG	08:02	54°42.39	13°45.32	38	
18-1	283	14.08.	MCS, MB, SES, EK60, MAG	08:33	54°41.80	13°41.37	37	
18-1	284	14.08.	MCS, MB, SES, EK60, MAG	10:04	54°35.48	13°40.06	23	
18-1	285	14.08.	MCS, MB, SES, EK60, MAG	12:02	45°36.41	13°53.08	21	
18-1	286	14.08.	MCS, MB, SES, EK60, MAG	13:47	45°33.16	13°41.81	22	
18-1	287	14.08.	MCS, MB, SES, EK60, MAG	13:55	54°32.82	13°42.88	21	
18-1	288	14.08.	MCS, MB, SES, EK60, MAG	18:37	54°33.82	14°23.22	22	
18-1	289	14.08.	MCS, MB, SES, EK60, MAG	19:04	54°35.43	14°21.88	25	
18-1	290	14.08.	MCS, MB, SES, EK60, MAG	23:48	54°35.77	13°39.81	24	
18-1	291	15.08.	MCS, MB, SES, EK60, MAG	01:41	54°45.58	13°39.78	41	
18-1	292	15.08.	MCS, MB, SES, EK60, MAG	02:48	54°50.03	13°41.02	44	
18-1	293	15.08.	MCS, MB, SES, EK60, MAG	03:51	54°46.73	13°36.40	42	
18-1	294	15.08.	MCS, MB, SES, EK60, MAG	04:57	54°51.08	13°37.44	43	
18-1	295	15.08.	MCS, MB, SES, EK60, MAG	06:03	54°48.22	13°33.17	45	
18-1	296	15.08.	MCS, MB, SES, EK60, MAG	06:47	54°51.67	13°34.47	44	
18-1	297	15.08.	MCS, MB, SES, EK60, MAG	07:17	54°50.34	13°32.34	45	
18-1	298	15.08.	MCS, MB, SES, EK60, MAG	08:53	54°45.95	13°44.91	41	
18-1	299	15.08.	MCS, MB, SES, EK60, MAG	09:52	54°48.60	13°44.11	43	
19-1	CTD1	15.08.	CTD	12:42	54°45.41	13°43.46	41	
20-1	CTD2	15.08.	CTD	13:07	54°46.41	13°42.08	42	
21-1	CTD3	15.08.	CTD	13:38	54°47.92	13°38.34	43	
22-1	CTD4	15.08.	CTD	14:19	54°47.94	13°33.7	45	

7 Data and Sample Storage and Availability

Metadata and CSR were submitted to BSH/DOD after the cruise. Raw seismic and hydroacoustic data are stored in the data base of the Research Group "Marine Technology –Environmental Research" at Bremen University. Additionally, these data are stored in the central Green IT-Housing-Center of the University Bremen on servers belonging to the research group. All published data will be made freely available via PANGAEA immediately after publication. All data are made available on request after a moratorium of 3 years.

Table 8.1 Overview of data availability

Type	Database	Available	Free Access	Contact
Multichannel seismic and hydroacoustic data, CTD	Uni Bremen	20.08.2019	20.08.2022	Tilmann Schwenk FB5, Uni Bremen tschwenk@uni-bremen.del
Magnetics	Uni Bremen	20.08.2019	20.08.2022	Thomas Frederichs FB5, Uni Bremen frederichs@uni-bremen.de

8 Acknowledgements

We would like to thank the Captain and the entire crew from the cruise AL525 Leg 3 for all the support and accompaniment given during the Expedition.

9 References

Multi Water Sampler MWS 12, Operation Manual (Edition 01/19), HYDRO-BIOS Apparatebau GmbH

SeaSPY2 Operation Manual Revision 6.2 (2005), Marine Magnetics Corp

SeaBat7125 operator’s manual, RESON, version 3.00 (2006)

SES2000 Users Guide, Innomar Technologie GmbH, V 2.8 (June 2009)

10 Abbreviations

CTD – Conductivity Temperature Depth

MAG – Magnetics

MB – Multibeam

MCS – Multichannel Seismic

SES – Sediment Echosounder System