POS – 405

RV POSEIDON

Cruise Report

07th December 2010 – 22nd December 2010

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1. Abstract

Cruise POS-405 aims at testing new equipment developed within the SUGAR project. A new Seabeam SBE 3050 multibeam system by ELAC Nautik was hull-mounted to R/V POSEIDON during the recent dry dock refurbishment. This multibeam system is capable to record the water column and display gas bubbles in the water column image (WCI) viewer. Successful tests of the system were completed during bathymetric mapping of the upper reaches of the Danube canyon. The second newly developed system, a deep-towed multichannel seismic streamer was deployed for the first time. Elaborate system tests using a deep-sea cable and winch were completed and first seismic signals could be recorded. After an intermediate port call with exchange of scientific crew a new bottom towed controlled electromagnetic source system was also tested. For the first time a 700 m long receiver array was towed behind the bottom deployed transmitter.

Due to difficult weather conditions (wind speed up to 25 m/s) R/V POSEDION needed to stay with nose in wind and waves for a total of 3.5 days out of 15 working days. This limitation prevented intense profiling with the towed instruments as they could not be deployed and recovered in such rough conditions.

2. Introduction

The SUGAR project aims at developing technology and knowledge in the field of methane production from gas hydrates in combination with CO_2 storage. For this purpose the whole sequence from prospection, exploration, quantification, exploitation and transport is studied in various subprojects. Although gas hydrates are well known from almost every continental margin, not all findings are suitable as an economical reservoir. For such occurrences a gas hydrate zone with a thickness of at least several meters and a sufficient top layer for sealing purposes is required. From synthetic modelling it is known that thick hydrate layers typically evolve within a highly permeable sediment matrix with sufficient gas production.

To address the increased requirements in prospection and exploration technology new or improved geophysical equipment was developed. Among these are a new multibeam echosounder system, a new deep-towed multichannel seismic streamer and a new bottom-trawled electromagnetic system. All three systems should undergo their first field test during this cruise. The best calibration of new equipment can be done when a good knowledge of the region is available beforehand. Therefore a suitable location needed to be found, which could be reached within the overall travel schedule of RV POSEIDON. Under this aspect the Danube delta in the Black Sea was one of the possible target areas. Gas flares were mapped and published at the shelf break in front of the Bulgarian and Romanian coast. Most of them are located in water depth shallower than 700 m water, which is the upper limit of the gas hydrate stability field. Next to the Danube canyon (also known as Viteaz canyon) off the port of Constanta two areas with BSR features were known from various publications. Seismic images identified even multiple BSR events in the centre of this region. Therefore all features, which should be targets of investigation for the three systems were available within close distance.

Due to the limited amount of deck space available for all the equipment and the available berths on board of POSEIDON the cruise was split into two legs. Leg one started on 7th December with installation of the seismic equipment in the port of Constanta. A change of equipment and crew members took place on 15th Dec. again in Constanta, where the electromagnetic equipment was set up. Finally the cruise terminated on 22nd December in

Constanta, when all equipment of the electromagnetic group was shipped home. The multibeam measurements were undertaken during the entire duration of the cruise, as the system has recently been permanently installed on POSEIDON.

3. Cruise Narrative

06.12.2010
The group of five scientists from IFM-GEOMAR, two engineers from companies SEND Off-Shore and E+JE and the Ukrainian observer arrived at port of Constanta and boarded RV POSEIDON at 18:00 hrs.

07.12.2010
The day in port was scheduled for the installation of the scientific equipment in the laboratories. At about 10:00 hrs a delegation of the Maritime Hydrographic Directorate of Romania visited the vessel. After greeting words by captain Guenther the chief scientist reported about the SUGAR project to which the foreseen cruise POS-405 is related. After the talk the delegation was guided through the vessel. Special interest of the visitors was directed towards the operation and equipment of a multipurpose vessel. The tour terminated with a visit of the scientific labs. At 12:00 the delegation left the vessel. By that time the truck with remaining equipment shipped from Germany had arrived. The compressor container was lifted aboard together with additional boxes. The afternoon and evening hours were used to set up the laboratories. During the afternoon arrival of the remaining scientist from Bulgaria completed the scientific team.

08.12.2010
The foreseen departure at 09:00 was delayed due to a final visit of the port authorities to complete the ships papers. On 10:15 RV PSOEIDON left the port of Constanta and set course towards the first CTD station, some 120 nm away. A safety instruction for crew and scientists was undertaken in the afternoon. At 22:15 POSEIDON arrived at the CTD station in 1700 m water depth.

09.12.2010
After completion of the sound velocity profile the ship returned to shallow waters next to the shelf brake of the Danube canyon where the calibration of the ELAC multibeam and a first survey for gas bubble detection should be completed. During the calibration run it turned out that the multibeam data were off by about 180 m in along ship direction. Therefore the calibration could not be completed. Despite intensive search within the systems parameters and support from ELAC the error could not be located. Knowing that any correction could be applied to the recorded data afterwards the planned bathymetric survey was conducted.

10.12.2010
At 00:15 the first bathymetry map in the shallow waters of the Danube canyon was completed. POSEIDON set course to deeper waters from where BSR features are reported in the literature. This area was chosen as test site for the deep towed streamer and electromagnetic system. Therefore a detailed bathymetry map needed to be recorded beforehand. Unfortunately the weather turned bad and the mapping had to be interrupted after the first profile at 06:00. Wind speeds of up 20 m/s and high waves perturbed the bathymetric signals and did no longer allow sailing along dedicated courses.

11.12.2010
Unfortunately the weather report was right and the bad weather with wind speeds up to force 9 continued while POSEIDON sailed slowly in wind direction.

12.12.2010
Wind conditions improved slightly during the morning and the bathymetry profile was continued at 09:40. In the course of the day the deep-towed streamer was deployed from the aft deck of POSEIDON. This first semi-dry test proved the basic functioning of the streamer, data telemetry and deck QC systems.

13.12.2010
After further improvement of weather conditions the preparation of the deep tow could be continued on the aft deck in the morning hours. After mounting the pressure cylinders with the electronic components a final system test was completed. The depp-towed streamer was then deployed at 15:00. A GI airgun provided the acoustic signals for the multichannel streamer. After 40 min. a power failure occurred due to a broken umbilical cable and the system needed to be brought back on board. At 18:00 the cable was repaired and the system could be deployed again. After short prototype tests in the shallow bay of Kiel with only three hydrophone nodes this was the first time the whole system could be deployed. It was also the first time that real seismic signals were recorded and a proper test with all data routes and recording systems could be undertaken. After some time it was noticed that the current drain had significantly increased. The system started to become instable after variable time spans. The last hydrophone node did not deliver clear signals anymore; hence it was assumed that water has penetrated into the pressure cylinder. However, thanks the new design of system electronics the hydrophone chain continued operation. During the test program another node showed irregular seismic data and difficulties in depth determination. This behaviour allowed to test failure procedures and handshake control of the different computing systems under worst-case conditions. On the other hand the obvious failure did not allow proceeding with scientific valuable profiling. Therefore the system was recovered at 22:00. A manual inspection of all hydrophone nodes was required to identify the reason for the high power drain and the unstable signal and depth transmission of the intermediate node. It turned out that the last node indeed was full of water, which entered though one of the connectors. Obviously the connector was not perfectly screwed in and the sealing became leaky over time. The second failed node showed only a few drops of water in the housing, which seemed to have passed through the depth sensor. Therefore depth values were unstable while the seismic signal still could be transmitted.

14.12.10
Due to the weather conditions with already rising wind speeds RV POSEDION need to leave the working area latest at 17:00 to complete the transit to Constanta in due time. It was planed to exchange scientific crew and equipment for the second part of the cruise. With respect to the already increasing wave height it was decided not to redeploy the deep-towed streamer system. It was decided to continue with data transmission tests and adjustments of power levels while the system was set up on board with the deep sea cable connected, i.e. conditions that are not available at home in the laboratory. During the morning wind speed and wave height increased again. At 14:30 wind speeds (>13 m/s) and wave height did no longer allow to record useful multibeam bathymetry data. Therefore it was decided set course to Constanta. While unused equipment was already packed the deep-towed streamer was continuously operated on deck.

15.12.10
RV POSEIDON reached the pilot position at 09:00 and docked at 10:00 again in the port of Constanta. The new crew from BGR Hannover arrived at the vessel. All seismic equipment was unloaded by 13:00 and the deck space and laboratories were equipped with the electromagnetic system of BGR. At 16:00 technicians and scientists of the seismic crew left the vessel.

16.12.10
After clearing of all port documents RV POSEIDON could leave the port of Constanta for the second part of the SUGAR test cruise. While on its 90 nm passage towards the working area the wind increased again. By 14:00 wind speed was constantly well above 15 m/s and POSEIDON could proceed with 4 kn only. Due to the wave state the multibeam data were of no use nor could be thought of any deployment operation. Therefore it was decided to turn against wind and waves, waiting for improved conditions.

17.12.10
During the day wind speed increased as high as 27 m/s. In the evening hours it decreased below 15 m/s and it was decided to continue the approach of the working area.

18.12.10
By 04:00 POSEIDON reached the working area again. When preparing for a calibration run of the multibeam system a system failure of the Coda Octopus motion sensor required a reset of the unit and delayed the operation by 1 hour. In the following two short profiles were mapped with the multibeam and used to calculate the remaining calibration angles. Following the calibration POSEIDON headed for a second multibeam survey at the shoulders of the Danube canyon following the eastern and western rim of the shelf break. More than 20 active seep locations were mapped by our colleagues from Russia and Bulgaria in this region. Due to improving weather conditions the survey was interrupted at about 14:00 to allow a first test deployment of the controlled-source electromagnetic system (CSEM). The test profile was chosen on the shelf area some 5 nm south of the canyon in water depth of only about 130 m. Here the profile orientation could be chosen against the wind direction and the shallow water allowed rapid recovery when the wind speed increased as announced. The test deployment was completed by 17:30 just in time when wind speeds increased again to about 13 m/s. At 20:20 the multibeam survey was continued. Due to increasing wind speed (>17 m/s) and increasing wave state the survey need to be interrupted again at 23:15.

19.12.10
Weather conditions improved. Although still around 15 m/s direction changed to westerly winds and hence reduced wave state. The bathymetric survey was continued on 08:30. With steadily improving weather conditions the CSEM equipment could be deployed at 23:30.

20.12.10
Due to a 700 m long receiver array this procedure continued until 01:30, when all parts of the equipment were deployed. Measurements in trawl and start/stop mode continued until 08:50 in the morning. After complete recovery at 13:30 the bathymetric survey looking for gas flares at the flanks of the Danube canyon was continued.

21.12.10
At 05:00 in the morning a new test sequence with the CSEM equipment interrupted the bathymetry profiling. Conductivity tests and frequency tests were completed during the day. After recovery of the CSEM the remaining bathymetry profiles were recorded until midnight.

22.12.10
At 00:00 all profiles were covered and POSEIDON set course towards Constanta. At 10:20 POSEIDON docked in the port of Constanta where the SUGAR test cruise terminated with unloading all scientific gear.

4. Crew

a) Ships crew

No.	Rank	Name	First Name
1	Kapitän	Günther	Matthias
2	1. Naut. Off.	Griese	Theo
3	Naut. WO	Hänsel	Alexander
4	I. techn. Off.	Stange	Hans-Otto
5	II. techn. Off	Hagedorn	Günther
6	Bootsmann	Mischker	Joachim
7	Matrose	Wagner	Knut
8	Matrose	Peters	Ralf
9	Matrose	Meiling	Ralf
10	Matrose	Rauh	Bernd
11	Matrose	Wilga	Hans-Joachim
12	MotM	Engel	Rüdiger
13	Elektriker	Polter	Rüdiger
14	Koch	Falk	Volkhardt
15	Steward	Gerischewski	Bernd

b) Scientifc crew – Leg 1

No.	Name & Given name	Function onboard
1	Bialas, Joerg	Chief scientist
2	Papenberg, Cord	Multibeam
3	Klaucke, Ingo	DeepTow
4	Wollatz-Vogt, Martin	Electronics
5	Schleisiek, Klaus	Electronics
6	Mansdorf, Steffen	Compressor
7	Lettmann, Arno	Watchkeeper
8	Myhaylyuk, Stanislav	Observer Ukraine
9	Vasilev, Atanas	Observer Bulgaria

c) Scientifc crew – Leg 2

No.	Name & Given name	Function onboard
1	Bialas, Joerg	Chief scientist
2	Papenberg, Cord	Multibeam
3	Schwalenberg, Katrin	CSEM
4	Engels, Martin	CSEM
5	Deppe, Joachim	Technician
6	Wallrich Olaf	Technician
7	Myhaylyuk, Stanislav	Observer Ukraine
8	Vasilev, Atanas	Observer Bulgaria

5. Equipment to be tested

a) L3-ELAC Nautik SBE 3050 Multibeam

In the course of the SUGAR project a new multibeam bathymetry system was developed and tested during the cruise for its capability to record and visualize full swath water column data (WCI-data) in order to detect and map gas flares rising from the seafloor into the water column.

The SeaBeam SBE 3050 multibeam system by ELAC Nautik was recently built into the hull of RV POSEIDON. For this purpose a gondola was fixed underneath the hull of POSEIDON, which gave space for the transducers and provides best protection against bubble disturbances. Due to size limitations the transducer arrays were chosen in a 1.5° by 2° dimension. The SeaBeam 3050 is the latest generation of mid and shallow water multibeam bathymetric sonar systems from L-3 Communications ELAC Nautik GmbH. The new multi-ping technology of the SeaBeam 3050 allows a higher maximum survey speed without loosing 100% bottom coverage by creating two swaths per ping cycle. The system operates in the 50 kHz frequency band in water depths ranging from 3 m below the transducers to approx. 3,000 m.

Gondola with Multibeam transducers

The system can be utilized at survey speeds of up to 14 knots. It has an across-ship swath wide of up to 140 degrees. A maximum of 386 reception beams is provided for each multi-ping. The SeaBeam 3050 uses a transmit technique, which fully compensates for vessel pitch and yaw motion, recorded by the CodaOctopus motion sensor F180 (see below) and which is integrated into the system's network. The compensation is achieved by splitting the transmit fan in several sectors which can be steered individually. This technique achieves full motion compensation and guarantees a stable straight coverage under the vessel. The SeaBeam 3050 generates sonar data for wide-swath contour charts, backscatter data for seabed sediment classification, raw data for water column imaging (WCI) and sidescan data for side-scan images.

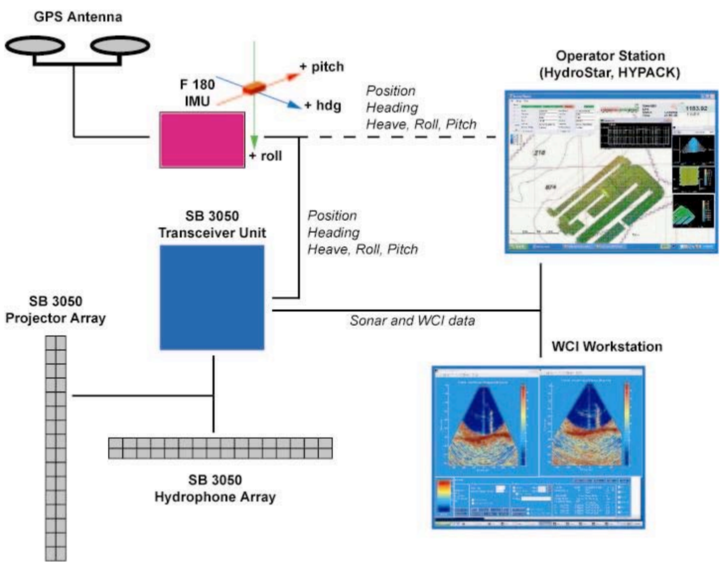

Figure 5a.1: Data flow of the sonar system, motion sensor and operating PC.

The F180 Inertial Attitude and Positioning System from CodaOctopus is integrated into the sonar system network, making precision measurements of vessel attitude (including heading), dynamics and geographical position for use in compensating the vessel motion for hydrographic surveying. The system is a multi-sensor system consisting of an inertial measurement unit (IMU), built up of three solid-state gyros and three inertial grade accelerometers, and two survey grade GPS receivers.

b) DeepTow Multichannel Streamer

With standard surface streamers the lateral resolution is reduced with increasing water depth. Using a deep-towed streamer could provide a constant improved resolution as the receiver array is towed about 100 meters above the seafloor (Fig. 5b.1). Due to the drag of the deep sea cable in the water the tow fish is expected to be 2 to 2.5 times the water depth offset behind the vessel. Operating a standard GI airgun as sound source this allows undershooting of high reflective seafloor elements (e.g. carbonate crusts). Therefore the DeepTow provides the opportunity to resolve reflection interfaces in regions where standard surface streamers can image blanking areas only. With the source still at the sea surface and the receiver deployed at depth the raypath for the sound emission is no longer symmetric and hence the concept of CDP stacking does not hold any more. Therefore full waveform migration need to be applied to integrate all streamer channels into one seismic section.

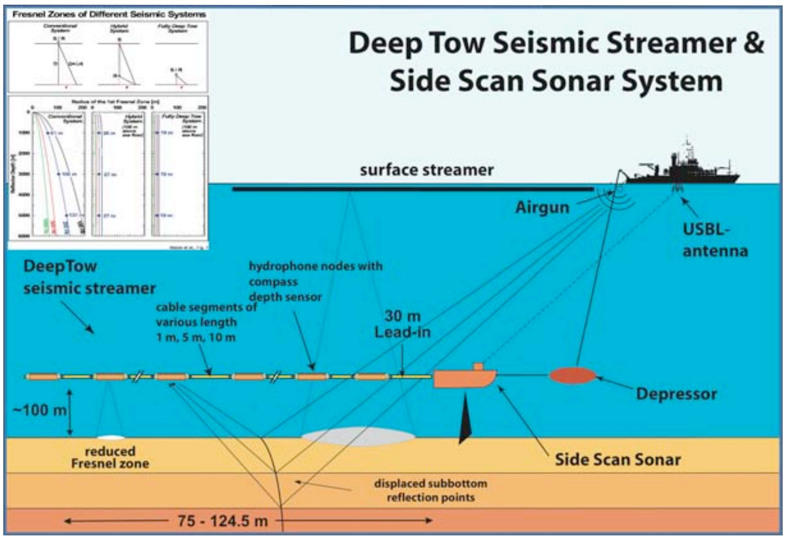

Figure 5b.1: Scetch of the DeepTow system with multichannel streamer and Sidescan

The deep towed multichannel streamer is a custom made new development designed by companies SEND Off-shore, Hamburg, and KUM, Kiel. It comprises of single hydrophone modules and modular cable connections (Fig. 5b.2). From a so-called Top-PC (TPC) Ethernet connections to the Bottom-PC (BPC) in the tow fish and the GeoEel seismic QC recording system from Geometrics are connected. In addition the sidescan sonar PCs in the tow fish and on board the vessel are connected via the TPC, BPC and the modems of the telemetry system (Fig. 5c.3). The TPC runs a control program for the deep towed streamer. Here all parameters (shot interval, record length, etc.) are specified and submitted to the streamer and the recording system. Moreover the control program displays heading and depth distribution of the hydrophones and other statistical system information. During

Figure 5b.2: Photgraph of the streamer hydrophones and cable segments during setup of the multichannel chain.

profiling a GPS based time code is interpreted to generate the wanted shot interval and to distribute the trigger signal to all external systems and the streamer at depth. Depending on the bandwidth of the towing cable a certain number of hydrophone data can be transmitted real-time via the cable on board. The hydrophone nodes are equipped with a compass and a depth sensor. During operation the USBL system POSIDONIA is used to track the position of the towfish. From this data base exact positions for each hydrophone at each shot time can be calculated.

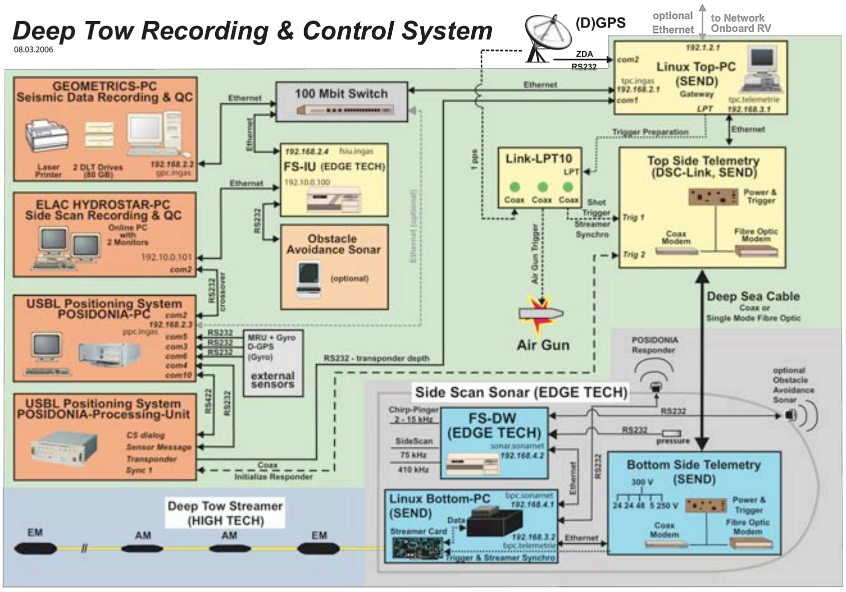

Figure 5c.3: Overview of the data connections within the DeepTow control system

c) Bottom towed Controlled Source Electromagnetic System

Marine electromagnetic methods are used to derive bulk resistivity of the sub-seafloor sediment sections, which can be helpful to evaluate the nature of the pore fluid. Natural hydrocarbons like oil, gas and gas hydrate are electrically resistive in contrast to the conductive seawater filling pore space under normal conditions. Active or controlled source electromagnetic (CSEM) methods are used when the shallow seafloor down to some hundred meter depths is investigated. Together with seismic profiling CSEM is the only remote method covering the entire gas hydrate stability zone. The two methods provide complementary information: structure from seismic data, bulk properties from CSEM data.

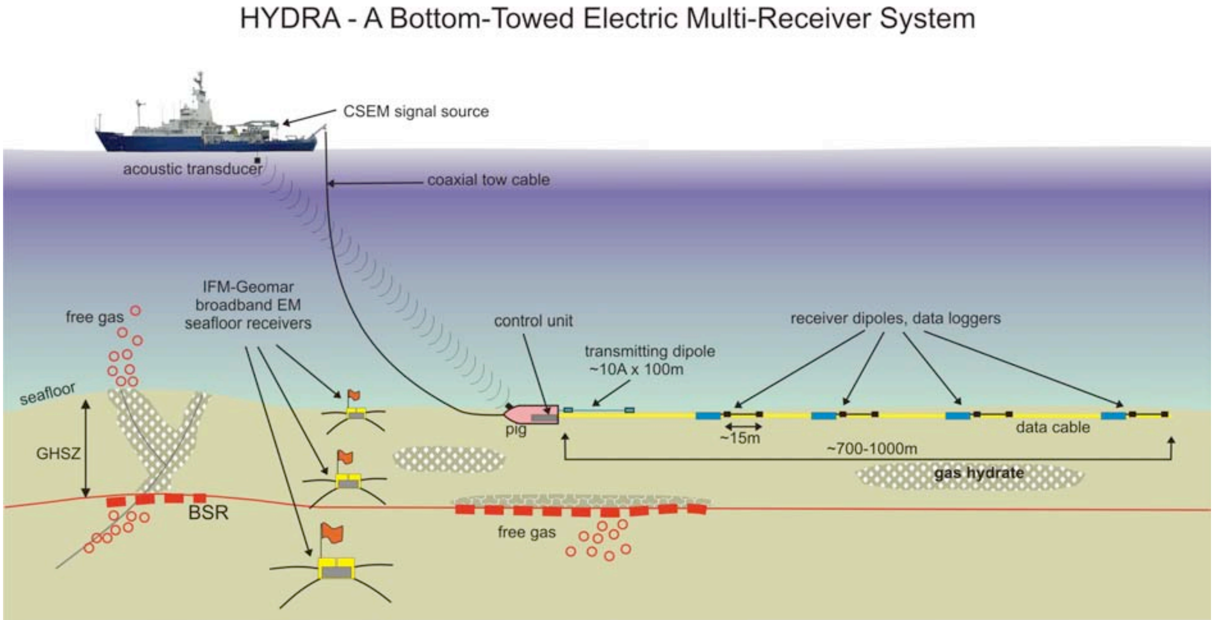

Figure 5c.1 Set-up of the towed BGR marine CSEM System. Also shown are IFM-Geomar ocean bottom EM receivers.

BGR has developed a new bottom-towed marine CSEM system as part of the SUGAR project (Figure 5c.1). The design is based on a previous system from the University of Toronto, Canada. HYDRA is a modular system that consists of an up to 1000m long data cable that links a 100m long transmitting dipole and four modular electrical receiving dipoles at increasing offsets. The whole system is towed in-line along profiles at the seafloor behind a plough called 'pig'. The source signal is generated by a current transmitter onboard the vessel and is sent down to the transmitting dipole on the seafloor via the coaxial deep-tow cable. The pig hosts the control unit which sends a timing pulse along the data cable to synchronize the receiving units and records the current signal. It also hosts an acoustic transponder to locate the seafloor position of the system and a CTD sensor to measure seawater conductivity and velocity.

Figure 5c.2 The 'Pig': Instrument carrier and depressor.

Figure 5c.3 CSEM Transmitter.

The current transmitter has two output ranges for shallow (40A, 200V) and deep water applications (15A, 1000V). The signal form is typically a square wave with a period between 1 and 4 seconds, but any signal i.e. sine, ramp can be applied. Each receiver records the transient decay of the transmitted signal through the ambient seafloor and seawater. Amplitude and signal form depend on the seafloor resistivity and can be analyzed for sediment properties such as gas hydrate or fluid content.

Figure 5c.4 Receiver Units and frames (floor) in the lab.

The system is deployed over the aft deck starting with the last receiver unit. Finally the pig is picked up with the A-frame and deployed. Then the system is slowly lowered to the seafloor paying out the deep tow cable. Because the POSEIDON does not have an adequate deep tow cable a mobile hydraulic winch with 4000m coaxial cable was supplied by NOC (National Oceanographic Centre, Southampton, UK). As a role of thumb three times the water depth is paid out to keep the system on the seafloor while towing along the profile. To avoid tangling on the seafloor the ship has to move forward when the last receiver has touched the seafloor.

Ship speed should match pay-out speed of the winch or be slightly higher (~1knot ship speed, ≤30m/min winch speed).

Data are collected and stored locally on 4GB micro SD cards at each receiver unit at a sampling frequency of 10 kHz. Each receiver unit is battery powered with a lifetime of about 36h. The units are synchronized with 1pps signal sent from the control unit along the data cable to the receiver units. Data are available on recovery through an USB connection. Housekeeping data, i.e. compass, 3 axis orientation sensor, and temperature, are recorded every second.

6. Work performed and results

a) L3-ELAC Nautik SBE 3050 Multibeam

One prerequisite of multibeam bathymetry surveys is the exact knowledge of the water sound velocity. Therefore we deployed a CDT at 31:17 E and 43:42 N in a water depth of 1600 m (Fig. 6.a.1), which would well cover the foreseen survey depth. The table was extended to 2000 m depth with an interpolated value of 1505 m/s.

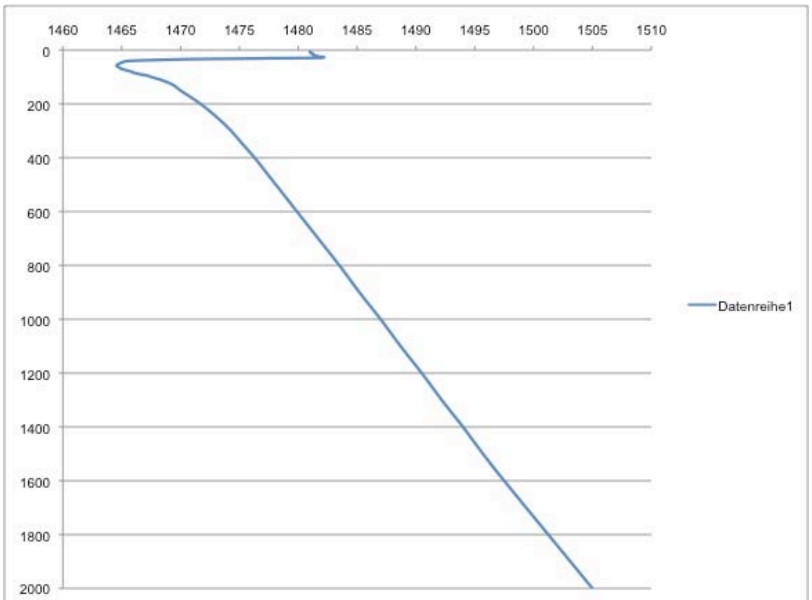

Figure 6a.1: Sound velocity profile calculated from CTD cast
CTD measurements reached 1600 m water depth. The graph was extended to 2000 m water depth by an interpolated value.

During a first calibration run it was observed that the multibeam data were displayed in the HydroSweep software package with an offset of about 180 m, corresponding to a time delay of 72 sec. Due to this delay no proper calibration could be calculated. Despite intensive search in all system parameters no reason could be found for this error. As HydroSweep allows full recalibration in post processing it was decided to continue with a first survey next to the shelf break where gas bubble expulsion was reported (Fig. 6a.2).

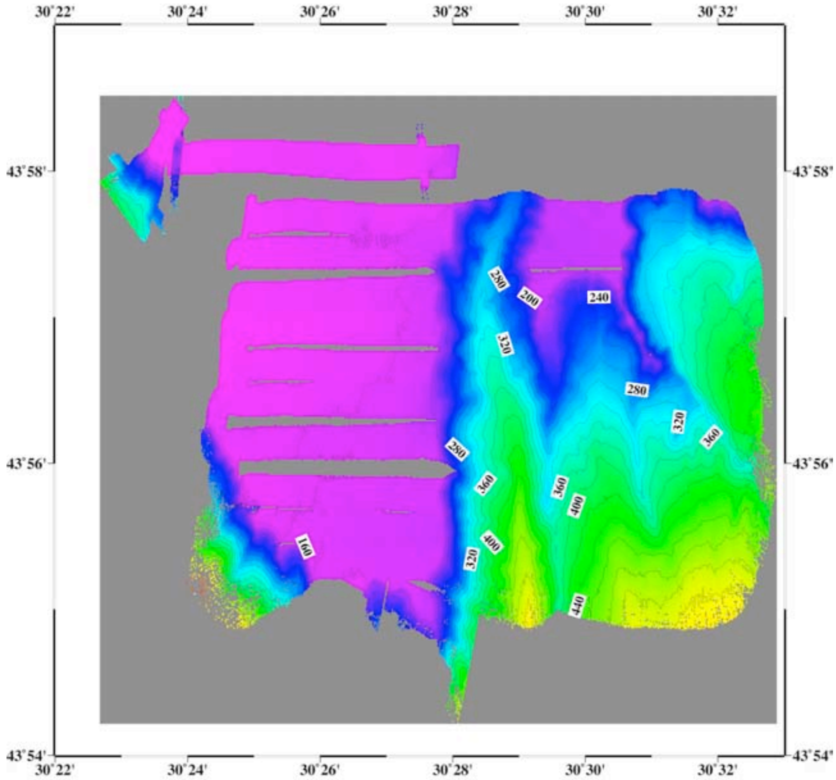

Figure 6a.2: Shelf area East of the Danube canyon

Unfortunately no bubble echoes were detected in the water column images of the multibeam system, since the water-column viewer (WCI-Viewer) worked only sporadically in online-mode, due to the heavy data load. Meanwhile software and data handling routines were further improved and networked between the various PC systems.

In preparation for a deployment of the deep towed streamer a second area was mapped with the multibeam system. From this area (BSR North) a wide distribution of a BSR reflection has been reported in various publications. Shortly after beginning mapping, the survey was interrupted due to strong northerly winds, which forced the vessel to veer off for a northerly course for one day. The bathymetric work continued after the weather calmed down and the target area could be mapped successfully (Fig.6a.3).

A second survey, dedicated to image and map gas flares, was conducted at the shelf break. Here the survey area was targeted at the flanks of the Danube Canyon (Fig. 6a.4), roughly 5 km west of the first survey area. An additional calibration was applied first to correct for possible inaccurate roll, pitch and yaw angles. Unfortunately, mapping of the Danube Canyon had to be interrupted again due to bad weather, but could be continued 12 hours later with success. On a track starting from the northern flank of the canyon, across the valley and following the southern flank of the canyon, numerous gas flares of different shapes were visible on the online WCI-viewer (Fig. 6a.5). This example shows the great advantage of multibeam techniques in flare imaging, because swath systems are able to detect flares offline to the centre beam. A single-beam system would have missed the flare, shown in Figure 6a.5. A newly developed post-processing sequence of a wider range of WCI-data was tested earlies and already found this specific area promising for possible flare bursts.

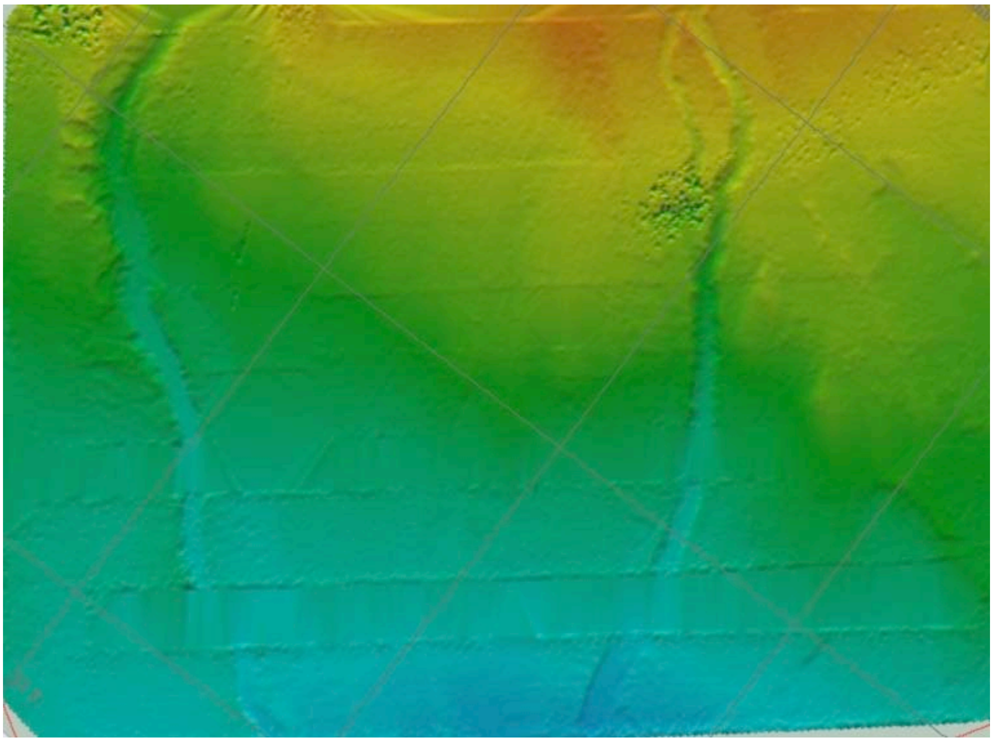

Figure 6a.3: Screenshot of raw bathymetry data showing the area of the planned deeptow deployment (BSR North)

This area with intense bubble expulsion was revisited for a detailed study. Four track lines across an area of numerous seeps were mapped radial in order to ensonify the water column at different angles. In a later stage, these data will improve the post-processing algorithm to detect flare motion. While continuing to map the Danube Canyon, the online water column monitor showed almost no flare activity on the eastern flank of the canyon. It seems that most active seeps are limited to the western part of the canyon. However, a large amount of data could not be monitored online. Gas flares, other than at the positions marked in figure 6a5 (left), are most likely to be detected during post-processing of the whole data set.

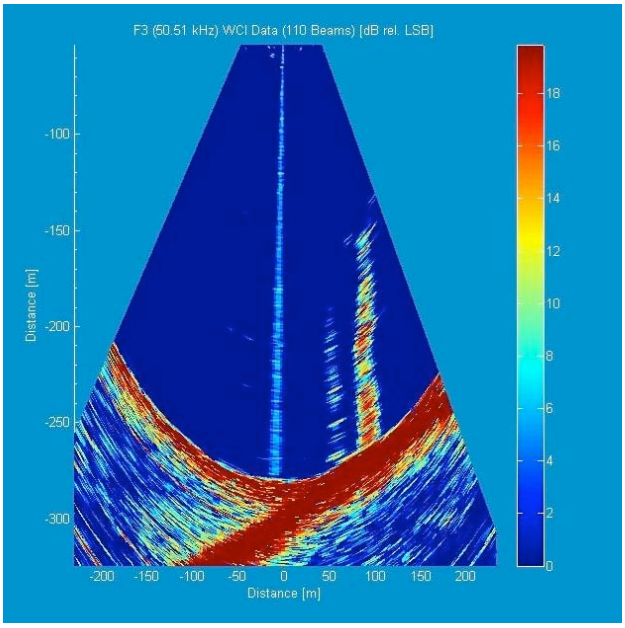

Figure 6a.4: Gas flares rising from the seafloor, imaged online by the WCI-viewer

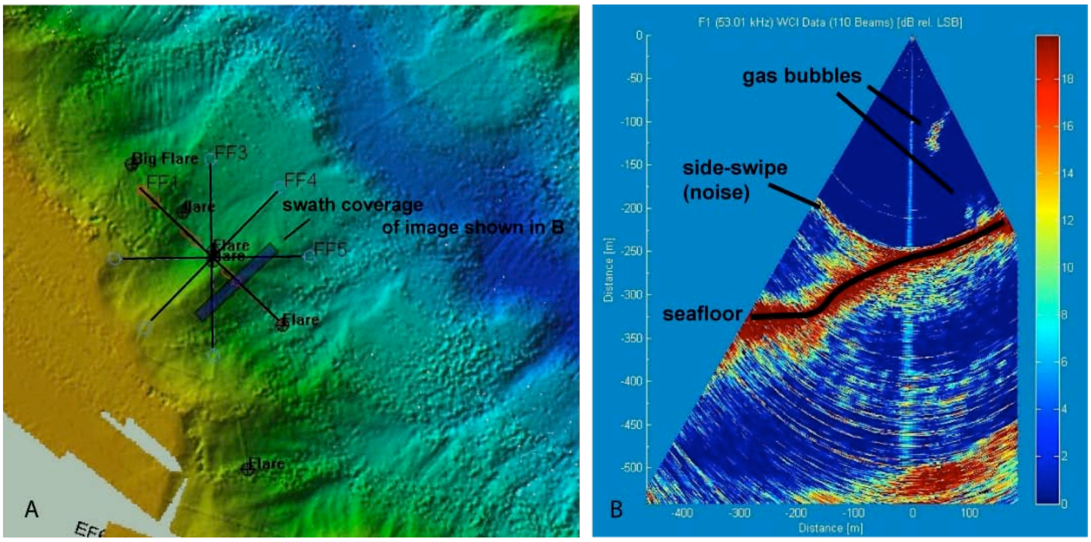

Figure 6a.5: (A)Radial tracks across a seep field to image gas flares at different azimuths and (B) acoustic image of rising gas bubbles in the water column.

b) DeepTow Multichannel Streamer

After intensive laboratory tests of the electronic boards the DeepTow streamer was completely mounted on board RV POSEIDON the first time. A list with hydrophones and remarks is given in the Appendix. After set up of a local network with control PCs, data storage and QC computers dry tests of the entire system were undertaken. It was the first time that all electronics could be tested with a 4 km long deep sea cable included in the transmission route. After adjustment of several threshold values in the data transmission modems and power supply a first deployment was undertaken right from the aft deck of RV POSEIDON. Amplitude adjustments and continuity tests were performed during these first deployment trials. After a time gap due to difficult weather conditions a full deployment was performed the next day. The streamer was lowered to about 200 m water depth and a small GI airgun was used to provide seismic signals, firing every 7 sec. Further adjustments were undertaken and system control parameters tested. Unfortunately it turned out that one of the hydrophone nodes seemed to have become leaky. Although the streamer did continue to work the power drain increased from 0.5 A to about 1 A. As a result the power supply in the streamer chain was reduced to limit values and some of the nodes started to behave unstable. Flow control and data transmission by the DSL modems was affected as well. Still resets of the system enabled to continue with tests and adjustment of the system and network parameters. A continuous operation as required for a scientific profiling could not be established without physically exchanging the damaged node. The system was consequently recovered after the main tests were completed. Due to decreasing weather conditions a re-deployment was not possible. Nevertheless replacement of the broken node on deck enabled a continuous noise record of the system during the night. Inspection of the broken node showed that one of the connector bulkheads was not properly mounted and caused flooding of the pressure tube. A second hydrophone node showed water penetration through the depth transducer sealing. Fortunately only limited amount of water entered the cylinder and the main electronic board was still operating keeping the entire chain alive.

c) Bottom towed Controlled Source Electromagnetic System

The CSEM system was deployed three times during the second leg. A bad weather period during the first half of the week was used to carry out final assemblies and run final tests in the laboratory. The following tests have been performed during these deployments:

- Deployment of the complete set-up with 4 receiver units in deep water
- Deployment of 3 receiver units in shallow water
- Transmission of the source signal from the shipboard transmitter via the deep tow coaxial cable to the transmitter dipole on the seafloor.
- Transmission of different wave forms (square, sine, ramp) and signal amplitudes (13 A max)
- Acoustic positioning of the pig from the ship using an acoustic transducer and a deck unit.
- CTD recording in the pig
- Noise recording on the seafloor while towing
- Noise recording on the seafloor while stationary
- Signal recording on the seafloor while towing
- Signal recording on the seafloor in stop and go mode
- Calibration while array is hanging in the water
- Loop test with pig and TX dipole in the water and open end of first data cable segment back on board.

Table 1 shows the deployment times and details.

Results:
All three deployments have been successfully. All equipment has been safely deployed and recovered. Data have been collected with all recording devices. The handling of the equipment on board was safe and satisfactory. Prior to the CSEM experiments the profile conditions were monitored with the Multibeam system to make sure the CSEM system can be safely deployed. A new spooling device was used to unreel and coil the 100m to 340m long cable segment. However, the spooling device does not have enough power to haul the complete array in from the water. A capstan was used to deploy and recover the cable segments and the spooling device was only used for coiling.

Nr.	**Deployment date and UTC time (local time + 2h)**	**Set-up**	**Profile Coordinates**	**Average Water Depth**
1	18.12.2010 Start: 16:52 End: 21:02	Pig – TX – RU1 Offset: T-R1: 156.13m	Start: 43:50.95N / 30:13.54E End: 43:56.11N / 30:18.47	107m
2	20.12.2010 Start: 03:30 End: 14:40	Pig – TX – RU1 – RU2 – RU3 – RU4 Offsets: T-R1: 151.08m T-R2: 253.90m T-R3: 396.76m T-R4: 745.03m	Start: 43:28.33N / 30:38.94E End: 43:55.19N / 30:21.42	1350m
3	21.12.2010 Start: 11:20 End: 19:00	Pig – TX – RU1 – RU2 – RU3 Offsets: T-R1: 151.08m T-R2: 253.90m T-R3: 399.50m	Start: 43:52.79N / 30:14.39E End: 43:53.38N / 30:20.93	106m

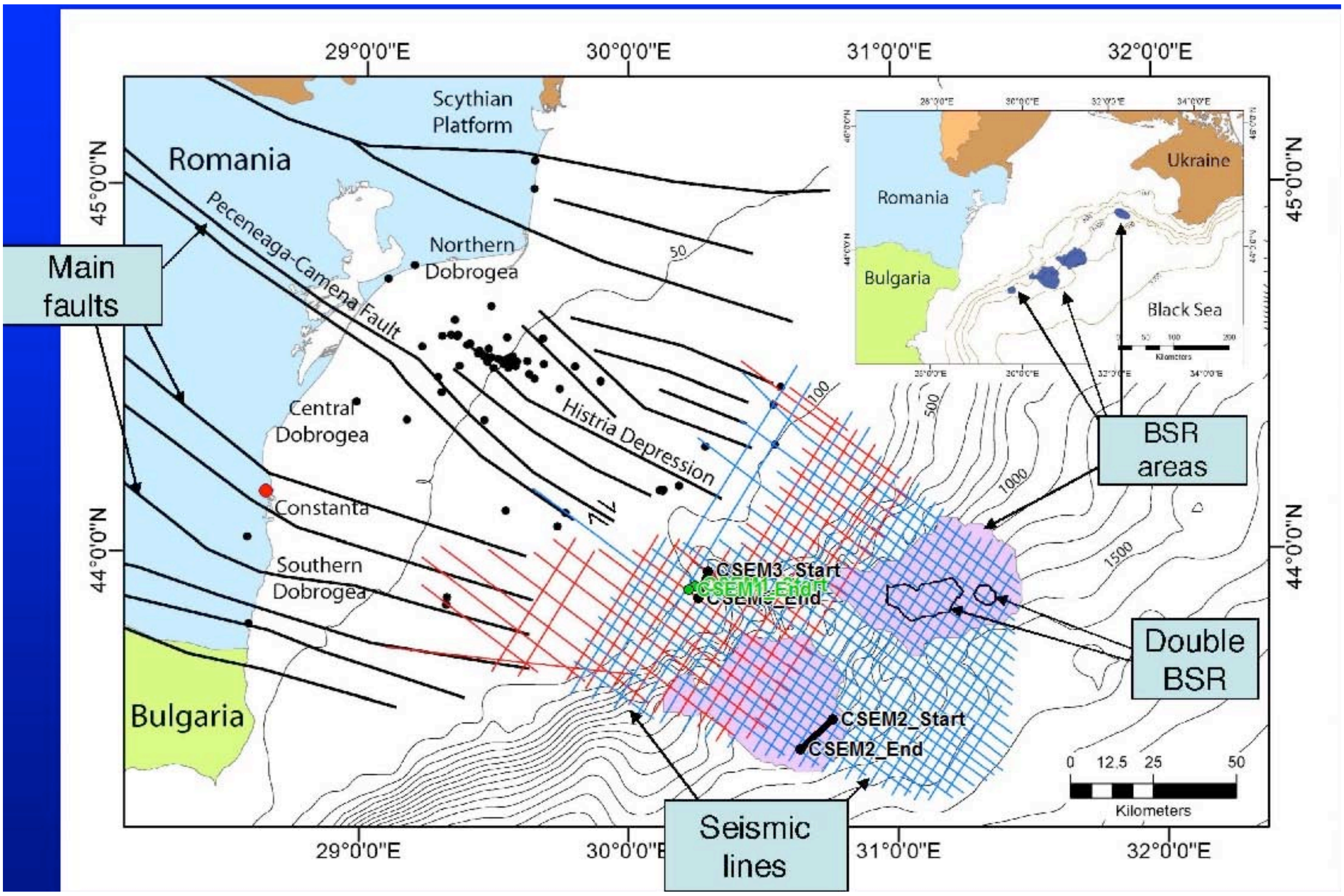

Figure 65c.1: Overview map of the survey area with CSEM profiles (modified after Baristeas, 2008)

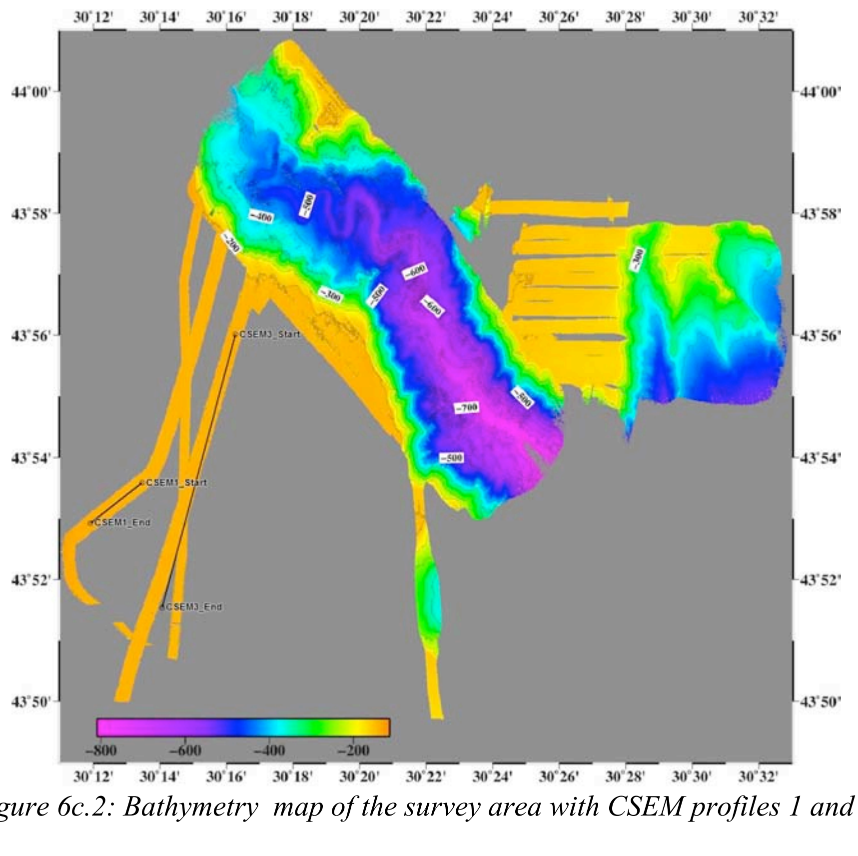

Figure 6c.2: Bathymetry map of the survey area with CSEM profiles 1 and 3.

Deployment 1:
Due to weather conditions and a short time slot only one receiver was used and the deployment was performed in shallow water for a quick recovery in case of sudden weather changes. Different signal forms and amplitudes were applied. The transmitter was unintentionally shutting down at signal amplitudes greater than 8A because the resistance of the tow cable was too low. The load (a heater with 8 sauna heating elements) which is used to run the transmitter in the laboratory was put in series between the transmitter and the tow cable and the transmitter was able to output amplitudes up to 13A.
The transmitted signal which is also displayed and recorded in the lab during the deployment is prone to the unstable electricity supply of the ship. Different grounding tests of the signal driver box showed best results when the signal driver box was grounded to the housing of the transmitter.

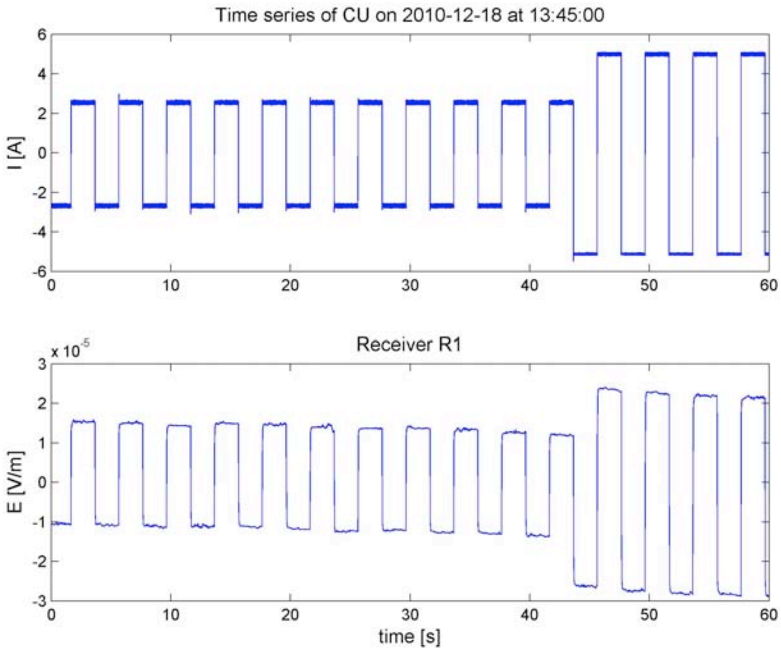

Figure 6c.3: Time series example of the first deployment with Receiver 1. The amplitude was increased within this one minute time window. The data which are recorded at 10 kHz have been averaged and decimated to 1250 Hz.

Deployment 2:
The second deployment was performed in deep water with all 4 receiver units. This was the first deep water deployment of a towed seafloor CSEM system with an overall lengths of more than 800m length. Data have been recorded with all units. Similar to the first deployment, the transmitted waveform can be recovered from the receiver data. However, the noise level was high at RU1, RU2, and RU3. The data quality was much better at RU4, even though the offset was bigger and the signal has smaller amplitude. The first three receivers are parallel to the data cable and are distorted by noise from the transmitter which is passed on along the data cable to the receiver electronics or receiver dipoles. The last receiver is only attached to rope. Data quality will improve by post-processing i.e. filtering and stacking.
While useful data were collected when the array was moving with the first 3 receivers at shorter offsets, data quality improves considerably when the array is stationary on the seafloor. Therefore a stop and go mode is preferred where the ship keeps position and an extra cable length is paid out to keep the array stationary, is alternating with the mode where the ship moves slowly forward at a speed of 1-1.5 knots and the extra length is recovered.

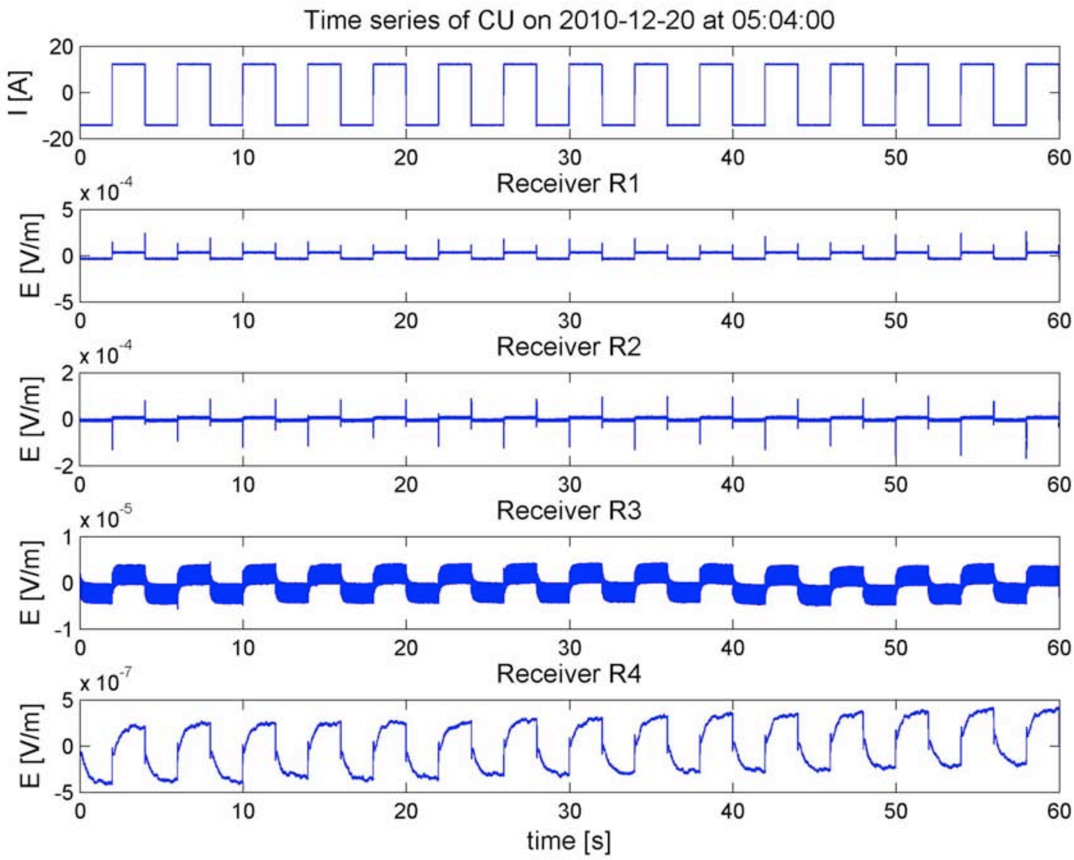

Figure 6c.3: Time series example of the second deployment with 4 Receiver Units (stationary). The data are averaged from 10kHz to 1250Hz. The square wave form is visible at all receivers, but the noise level (including spikes at polarity changes for R1 & R2) is high, except for the last receiver which was not parallel to the data cable.

Loop Test:

We suspected that noise is transported inside the receiver electronic with the digital ground line which was previously connected to the shields (3, 6, 12) of the twisted pairs for the two deployments. To reduce the noise level digital ground was moved to an inner pin (4) (and Rx to 7,8) for the first data cable segment prior to the third deployment. The shields (3,6,12) were floating.

To test what noise signals do propagate along the data cable to the receiver units and may cause the beats and distortion in the data a loop of the pig and the first cable segment with the transmitter dipole was deployed as displayed in Fig. 5c.4 The rear end of the first data cable segment was fixed on board under the A-frame. The transmitter was turned on and the signals between pins were displayed on a handheld scope. The advantage of the scope is that much higher frequencies can be observed. The transmitted square wave signal was clearly visible. However, a dominant wavelet occurs at a frequency around 33 kHz. This distortion is most prominent on the outer shield (9) and is reduced by a factor 2 on the inner shields and another factor 10 on the inner line.

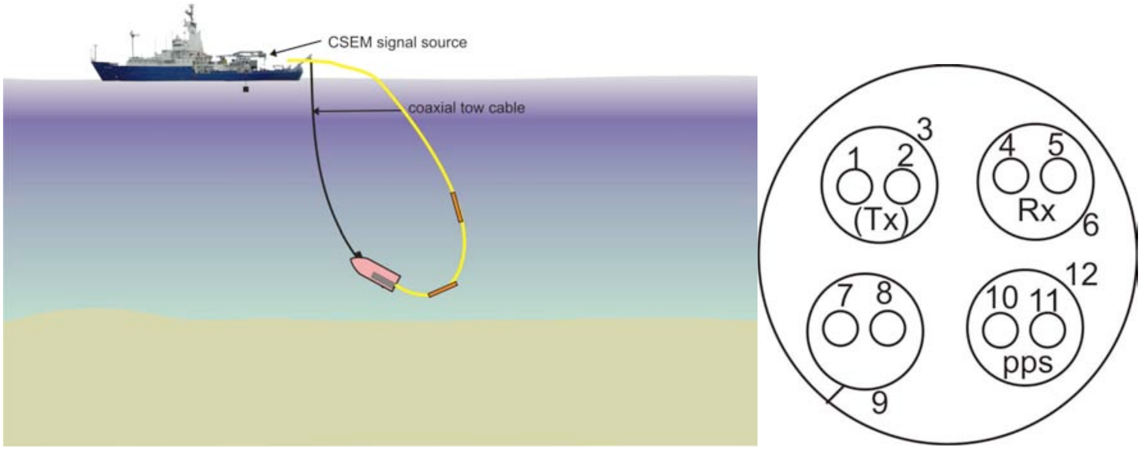

Figure 6c.4: Sketch of the loop test, and configuration of the data cable

Deployment 3:
The last deployment was carried out in shallow water with three receiver units (RU1, RU2, RU3). Data have been recorded with all units. Different wave forms and signal amplitudes were applied. Data were collected in stop and go modus. A first inspection of the data showed the noise level was reduced by moving digital ground to an inner conductor. During deployment 2 data quality of the last receivers was only sufficient while stationary on site – now all receiver data are useful even when moving.

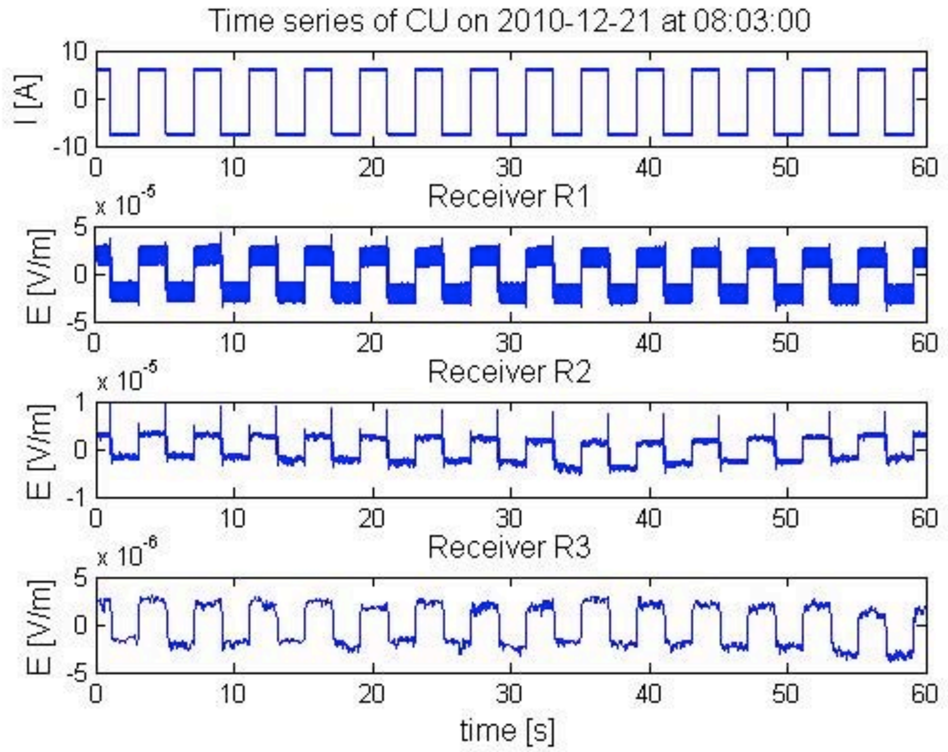

Figure 6c.5: Time Series example of the third deployment with 3 Receiver Units while moving. Due to the wire connection modification, data quality improved significantly: spikes at polarity changes decreased and all receiver data are useful even when moving the system.

7. Acknowledgements

Our thanks go to the captain and crew of R/V POSEIDON. The outstanding support of the crew was a major contribution to the successful operation. Substantial advice during first tests with new equipment was a contribution to the safe and successful application. Cruise POS-405 was granted through BMBF project SUGAR TP-Z (03F0687A).

8. Appendix

No. of Hydrophone	Cable offset	Serial No.	Remarks
1	1m	10	
2	1m	30	Hydrophon hoher Offset
3	1m	27	
4	5m	33	
5	1m	23	
6	1m	29	
7	1m	37	
8	5m	25	
9	1m	38	
10	1m	8	
11	1m	28	Am nächsten Tag ersetzt durch 14, 28 war aber von innen nicht feucht. Kabelproblem??
12	10m	21	
13	1m	22	
14	1m	11	
15	1m	44	
16	1m	40	Hydrophon hoher Offset
17	10m	20	
18	1m	18	Hydrophon hoher Offset
19	1m	2	
20	1m	15	
21	1m	9	Hydrophon hoher Offset, Drucksensor ausgefallen. Der Knoten hatte offensichtlich über den Drucksensor ein wenig Wasser gezogen, ein Sensoranschluss war völlig abkorrodiert, der schiffswärtige Deckel (Hydrophonseite) hatte Korrosionslöcher. Die Elektronik scheint aber ansonsten nicht nass geworden zu sein, der Knoten arbeitete auch bis zuletzt in der Kette.
22	10m	17 39	Beim ersten Aussetzen (170m) ausgefallen - die Isolierfolie war von Kondenswasser überzogen, die Elektronik sah ansonsten trocken aus. Durch 39 ersetzt für die letzten Tests an Deck
23	1m	35	
24	1m	32	
25	1m	3	
26	1m	36	
27	Ende	26 6	Beim ersten Einsatz (170m) ausgefallen Drucksensor ließ sich schon vor dem ersten Einsatz nicht mehr richtig kalibrieren. Offset von mehreren Metern. Der Stecker auf der Hydrophonseite war nicht festgezogen, Zylinder voll Wasser, Elektronik korrodiert, Titanzylinder bräunlich verfärbt. Durch 6 ersetzt für die letzten Tests an Deck

Table with the streamer configuration and test remarks