Cruise Report

ALKOR 412

22.03.13-08.04.13

(Kiel, Germany - Kiel, Germany)

GEOMAR Helmholtz Centre for Ocean Research Kiel

Dr. Peter Linke and cruise participants

June 2013

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1. Introduction

P. Linke

Cruise 412 of the German research vessel ALKOR (22.03.-08.04.13) was conducted in the framework of the EU project ECO2. The project, supported by a team of international collaborators, investigates the potential environmental impact of the storage of carbon dioxide (CO_2) in the sediments. This is being performed at existing CO_2 storage sites in the North Sea and the Barents Sea paired with a comparison of natural gas emissions at the seafloor. The first target of the cruise was the Norwegian Utsira sand stone formation, which has been used since 1996 for CO_2 storage in parallel to gas production. Already in 2011 during the first ECO2 cruise, initial investigations on potential gas emission sites were conducted on board the ALKOR, followed by 4 cruises in 2012 with the RVs HEINCKE, G.O. SARS, JAMES COOK and CELTIC EXPLORER. The expeditions complement each other to efficiently use valuable ship time. At this time, on board the ALKOR were the ROV PHOCA, one lander, a video-guided CTD as well as a 4 m-long vibro corer. With this instrumentation selected sediment and water samples were obtained to close gaps in the data obtained so far. In addition to the Utsira formation, the so-called blowout crater in the British sector of the North Sea was investigated, where high quantities of methane have been emitted for more than 20 years following a failed drill attempt. Ideally, this unplanned long-term release experiment can be used to estimate how much methane is emitted from the seafloor and its resultant distribution in the water column. The challenge of the cruise in this season of the year was to investigate a late winter situation where a stratification of the water column is not established yet and where larger volumes of the greenhouse gas might escape into the atmosphere.

Fig. 1.1: View on the Sleipner platform.

2. *Cruise narrative*

P. Linke

23.03.13 The vessel left the GEOMAR pier at Kiel's east shore at 07:00 (UTC = LT + 1 h) heading towards the Great Belt and the Skagerrak. During the transit the instrumentation and the laboratories were installed. Due to the cold temperatures the sea spray and water washed on deck was freezing on the instrumentation (Fig. 2.1).

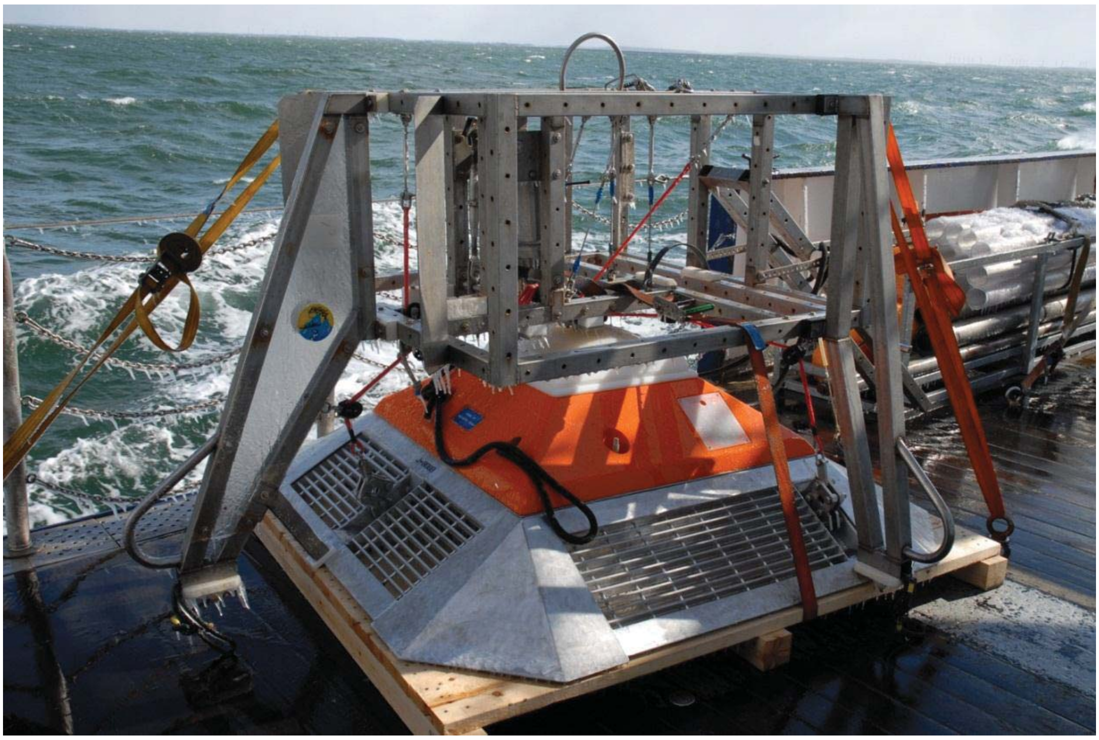

Fig. 2.1: Ice covered trawl-resistant lander with launcher on deck.

24.03.13 The transit to the first working area was interrupted in Norwegian waters as a leak and malfunction in the heating system was detected. After several trials by the ship's crew to repair this damage it was decided to steam towards Frederikshavn (DK) where the vessel arrived in the morning of the next day.

25.03.13 The leak in the heating system was repaired in the ship yard. Furthermore, the harbor stay was used to test the reaction time of the Picarro system and to prepare the lander deployment. The vessel left the harbor at 16:45 to continue the transit to the first working area in the UK sector of the North Sea.

26.03.13 The vessel arrived at site 22/4b at 20:00 and station work started with a horizontally towed CTD cast in 85 m water depth. During the night two grids each covering 1 km^2 with the crater in the center were performed to measure the CH_4 and CO_2 concentration in the atmosphere at 22 and 1 m above the sea surface.

27.03.13 In the morning, the trawl-resistant lander was deployed by a video-guided launcher at the northern rim of the crater. During the next deployment of the launcher a methane sensor with external battery supply was deployed in the vicinity of the lander. Both instruments were connected by a line for recovery during the subsequent ROV dive. During the dive gas and water samples were taken in the crater and next to the methane sensor. After recovery of the ROV, two additional horizontal CTD surveys were conducted in 40 and 10 m water depth. As the reference station had to be abandoned due to technical problems with the CTD we steamed slowly towards the second working area "Sleipner".

28.03.13 Here, at the “Hugin fracture” about 25 km northeast of the Sleipner platform, station work included two subsequent ROV dives to obtain additional push cores to the samples obtained during cruise CE12010 in summer 2012. A long CTD survey close to the bottom was conducted until midnight to measure the CO_2 concentration in the bottom water.

29.03.13 At 13:30, the vessel arrived in the port of Stavanger. One of the ROV pilots was exchanged against a technician to operate the vibro corer.

30.03.13 In the morning, the vibro corer was installed and tested on board the vessel. After this, the response time of the Picarro system was tested by injection of methane into the tubing installed in the mast of the vessel which left the harbor at 15:00 to steam back into the working area.

31.03.13 During the night at 02:00 the clock was set to summer time (LT = UTC + 2 h). Upon arrival, the vibro corer was deployed at the Hugin fracture followed by 2 ROV dives and another vibro corer deployment. In the evening a long near-bottom CTD profile was conducted.

01.04.13 Two replicate vibro corer deployments were performed followed by another CTD cast, which continued the profile started the day before. After this, a ROV dive was conducted.

02.04.13 In the morning, 3 replicate deployments with the vibro corer were conducted until the last one hit the desired bacterial mat as shown by increased concentration in hydrogen sulfide in the pore water. The 7th ROV dive was conducted with push coring at a ring of bacteria mats which will be the target for the next vibro corer deployment.

03.04.13 The ROV was deployed at a seismic chimney south of the Sleipner platform, which was subsequently sampled by vibro corer. The second ROV dive was conducted at a smaller seismic chimney, which was inspected for visible signs of fluid or gas discharge. However, at both seismic features no manifestation was visible or detectable in the sonar.

04.04.13 In the morning, 3 replicate vibro corer deployments were performed at the Hugin fracture. After successful recovery the instrument was taken apart. A last horizontal CTD survey next to the Sleipner platform was conducted crossing the subsurface reservoir and abandoned well 15/9-13. After this, station work in this working area was terminated and the vessel steamed towards site 22/4b.

05.04.13 During the night wind peaked up to 11 m/s and a CTD cast was performed at a reference station next to the blowout site. The acoustic release of the lander was activated but the floatation unit did not appear on the surface even after replicated trials from different directions. As the weather was too rough for the deployment of the ROV, the Video CTD was equipped with a hook and deployed next to the crater. During the bottom-near casts the connecting line between lander and sensor package was visible and the lander itself, where the recovery line was entangled with the bottom weight jeopardizing the ascend of the floatation unit. Finally, we were able to catch the connecting line with the hook and after recovery of the CTD, the mooring floated up and was recovered without any damage. After this, station work was terminated and the vessel steamed back in direction of the German island Helgoland, which we passed around midnight of the next day.

06.04.13 During the transit the instrumentation was disassembled and packed into boxes.

07.04.13 The vessel arrived at the locks of Brunsbüttel at 06:00 and started the passage through Kiel canal. The measurement with the Picarro was terminated at 07:00. Laboratories were cleaned and boxes were prepared for demobilization on deck. The vessel arrived at the locks of Holtenau at 14:00 and reached the GEOMAR pier on the east shore at 14:30 where the cruise ended.

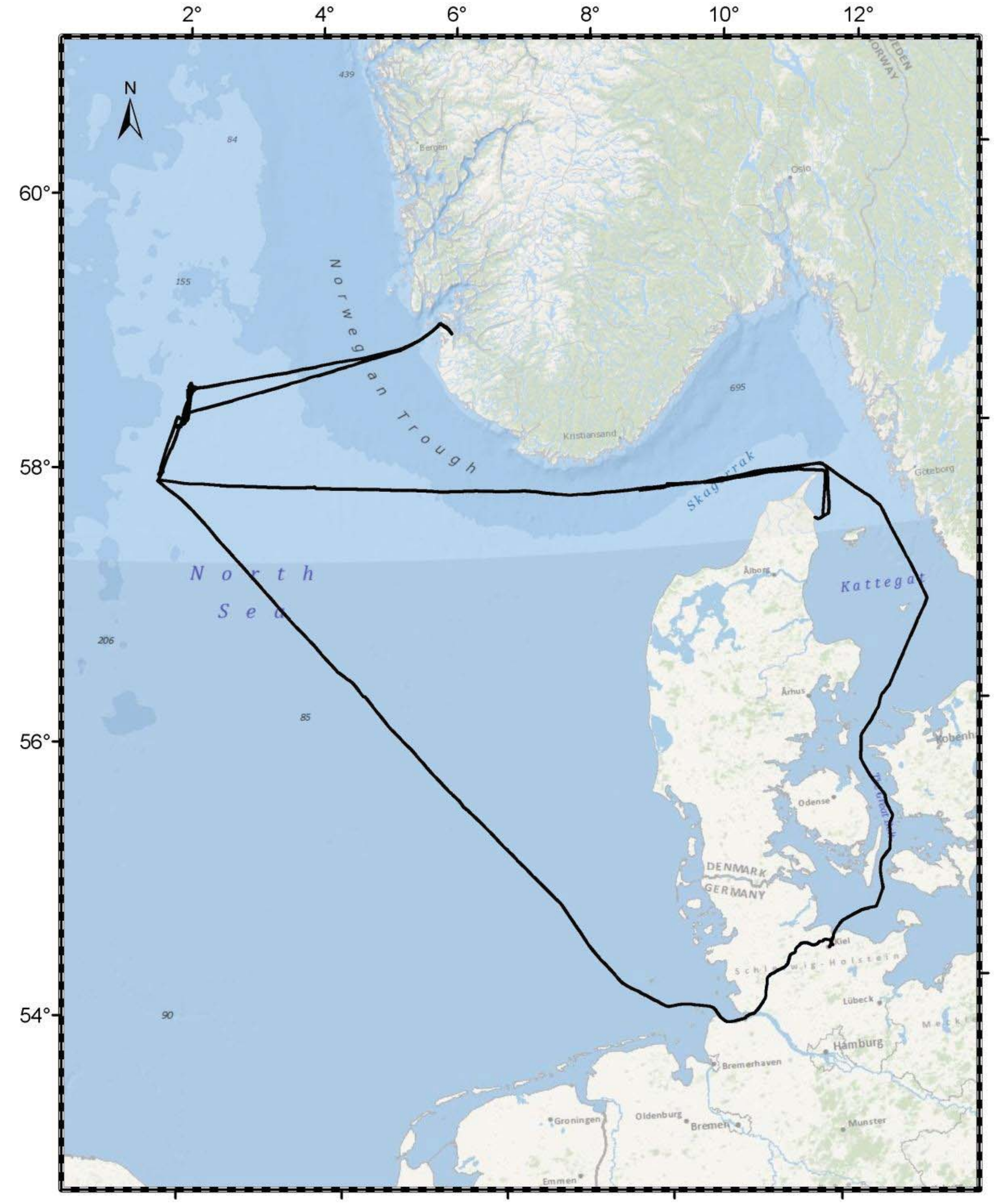

Fig. 2.2: Cruise track of cruise AL412.

3. *Participants*

	Name	Function	Institute
1	Linke, Peter	Chief scientist, ROV	GEOMAR
2	Schmidt, Mark	CTD, Sensors	GEOMAR
3	Schroller, Dirk	Pore water, Vibro corer	GEOMAR
4	Vielstädte, Lisa	Pore water	GEOMAR
5	Cherednichenko, Sergiy	Video	GEOMAR
6	Bodenbinder, Andrea	Dissolved gases	GEOMAR
7	Dibbern, Maike	Pore water	GEOMAR
8	Cuno, Patrik / Frahm, Andreas	ROV / Vibro corer	GEOMAR / IOW
9	Pieper, Martin	ROV	GEOMAR
10	Hennke, Jan	ROV	GEOMAR
11	Huusmann, Hannes	ROV	GEOMAR
12	Bodendorfer, Matthias	ROV	GEOMAR

Fig. 3.1: Crew picture of cruise AL412 with favorite weather on the way home after work is done.

4. *Preliminary Results*

4.1. *Water/gas sampling and hydrographic monitoring*

M. Schmidt, P. Linke, A. Bodenbinder, S. Cherednichenko

Sampling areas

Sleipner

During ALKOR cruise AL412 we investigated the hydrographic parameters (T, S, O_2, pH, DIC) and pCO_2 and CH_4 concentrations of water masses by CTD casts and towed CTDs at the Sleipner site.

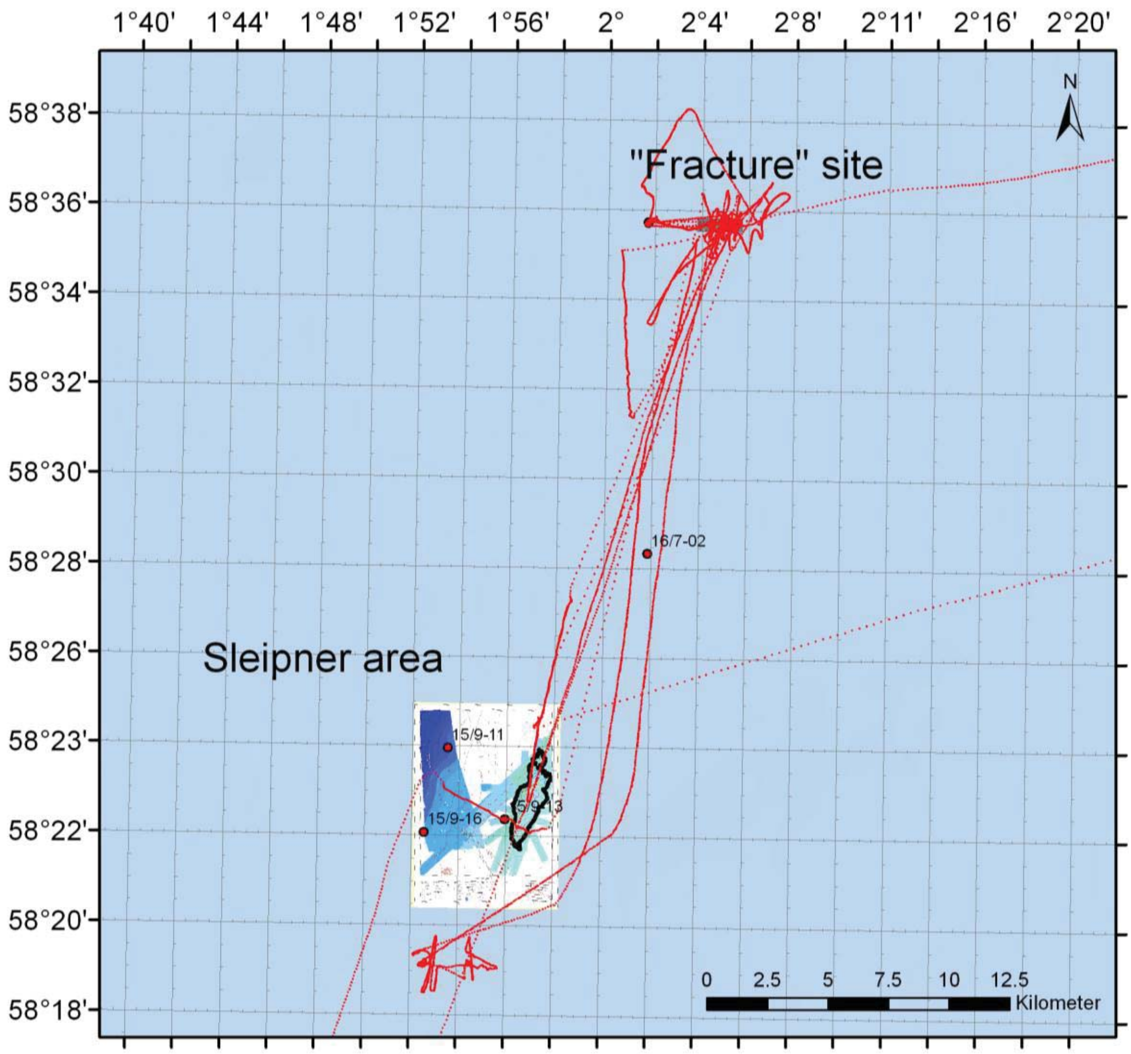

Fig. 4.1.1 Sampling areas Sleipner Vest and the "Hugin Fracture" site. Red dotted line marks the AL412 cruise track.

Well 22-4b ("Blowout")

To study the lateral and vertical distribution of dissolved methane and other trace gases at the "Blowout" site several towed CTD tracks were conducted at selected water depths. Moreover, one CTD cast was performed at a "background" reference station north-east of the well site 22-4b.

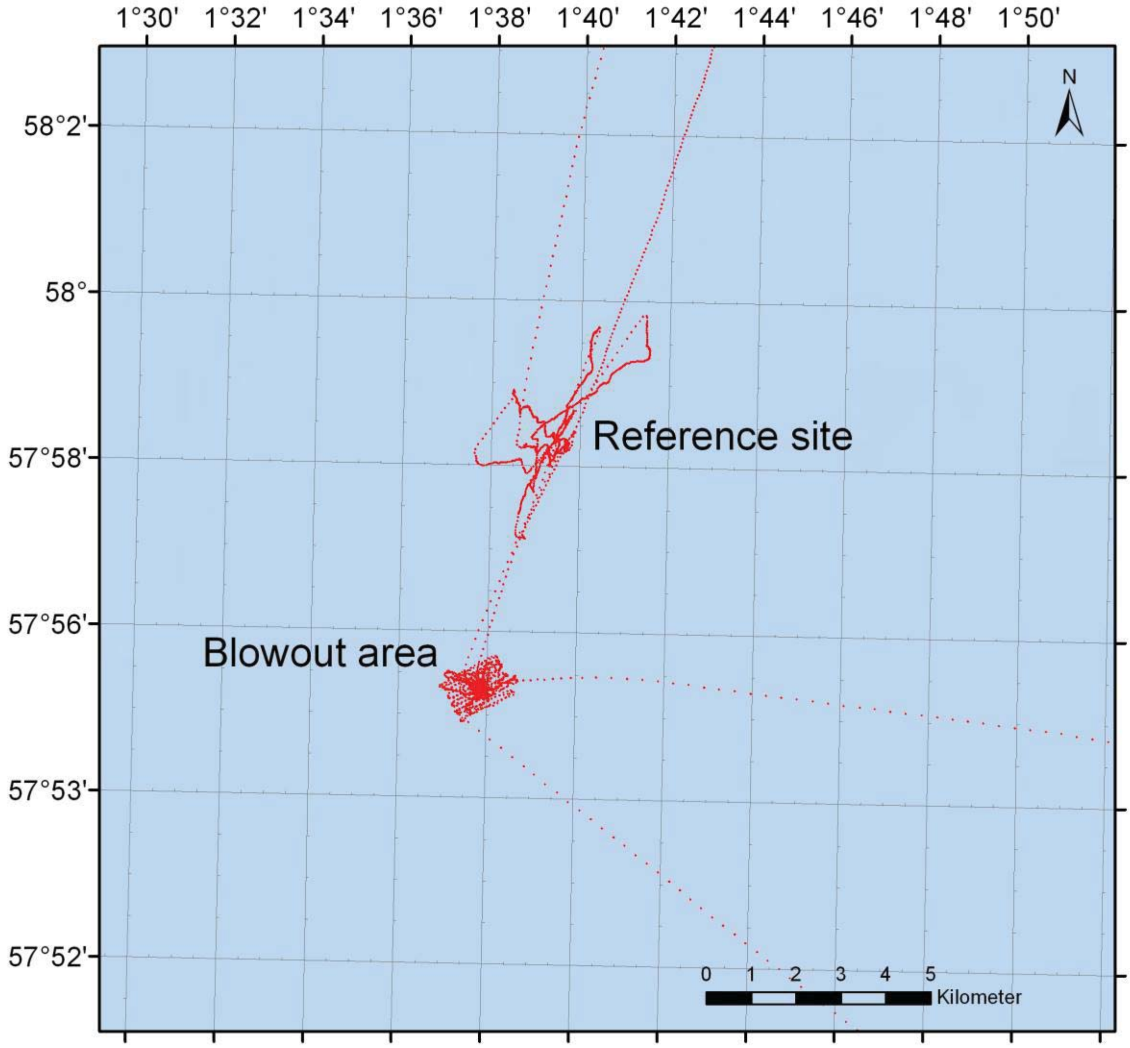

Fig. 4.1.2: Sampling areas "Blowout" and "Reference" site. AL412 cruise track is indicated by red dots.

"Multi-purpose" rosette

A newly designed Water Sampler Rosette system (Linke et al., 2012) was used to study dissolved gas concentrations at selected water depths between 10 to 120 m in the North Sea. The system was towed with ground speed of 0.3-1 knots by using winch 1 from the starboard site of RV ALKOR (Fig. 4.1.3). The water depths were controlled by pressure readings of the attached Seabird CTD (SBE9plus). The digital video system providing real-time monitoring of the seafloor was also used to control the distance to the seafloor in "bottom view" mode.

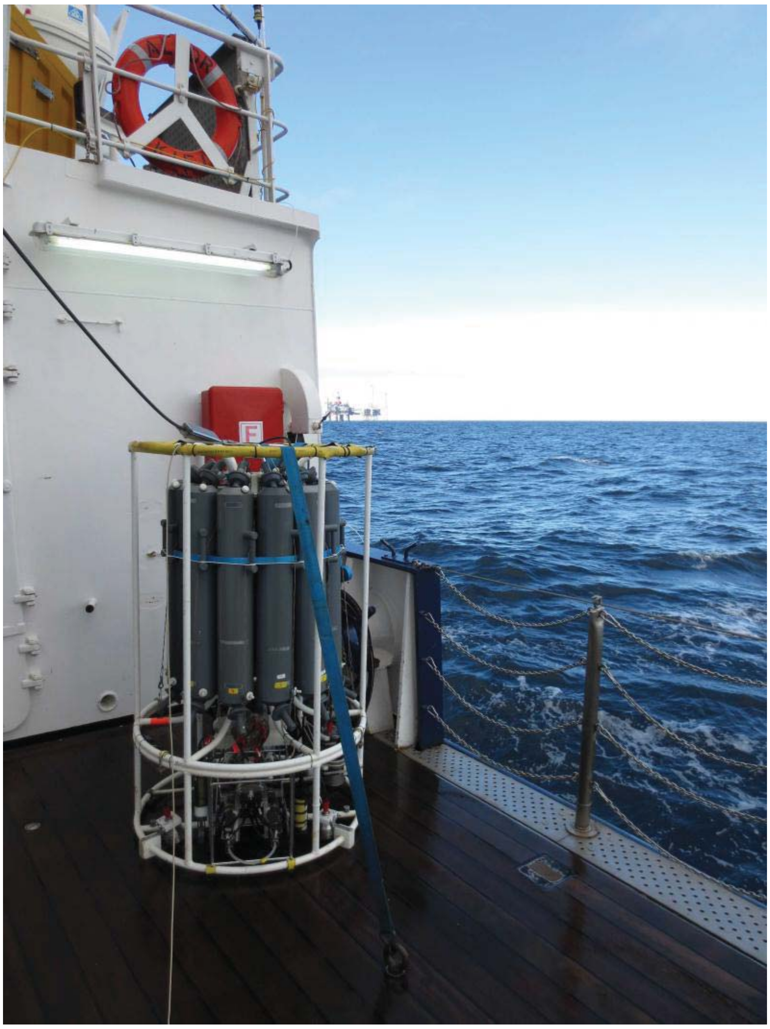

Fig. 4.1.3: Water Sampler (12 x 10 L Niskin) Rosette including SBE9plus CTD, pH sensor (SBE27), and HydroC/CH_4/CO_2 sensor package (Contros Systems and Solutions GmbH) with additional power pack; HD-Video camera and light sources are attached to the lower part of the frame and controlled by external telemetry (Sea and Sun Technology) via coaxial cable.

SBE9plus CTD

The SBE 9plus underwater unit was equipped with 2 pressure sensors, 2 temperature sensors, 2 oxygen sensors and 2 conductivity sensors. The decks unit SBE11plus provided power supply and online data control. Data collection was performed with SEASAVE software (version 4.21). CTD data were recorded with 24 Hz. GPS position data was logged parallel to the CTD data from an external GPS device mounted near the CTD winch. Two analogue channels at the SBE underwater unit were needed for external sensor reading (pH-, CO_2-/CH_4-sensor). The distance between CTD and the seafloor was controlled by video observation and bottom alarm unit. Hydrocasts and hydrographic data from towed CTDs were processed by using SBE software SBE7.21d. Usually data files of 1 second bins were created from raw data files and exported to ASCII.

SBE27-pH/O.R.P. sensor

The sensor (SBE27-0198) combines a pressure balanced glass-electrode, Ag/AgCl reference probe, and a platinum O.R.P. electrode (1200 m rated). The recent calibration equation provided by Seabird is used in the output data files.

HydroC-CH_4/CO_2 sensors

The HydroC instrument package capable of measuring pCO_2, and methane in situ (Contros, Systems and Solutions GmbH, Germany), is mounted to the Video-CTD frame. The sensor package is powered by an external NiMH-power unit (~10h/sensor at ~6°C water temperature). The sensors (CH_4, CO_2) store internal high resolution binary data, moreover, the sensors are also connected to the SBE9plus unit by serial cable and analogue data signals (0-5 V) are recorded online during CTD stations. The sensors analogue data is stored in the SBE data file.

Water sampling for dissolved gas and DIC measurements

Niskin water samplers were fired at selected depth and locations during CTD tracks and casts. Video observation and online sensor data (CH_4 and CO_2 data) were helpful to locate gas seepage locations and to decide where to fire the Niskin bottles. After CTD recovery, 100 ml of seawater was transferred bubble-free from each Niskin bottle into 100 ml glass vials, closed after sampling by rubber stoppers and crimped with aluminium caps. A helium-headspace was given to the closed vials by a syringe replacing 5 ml of seawater. The liquid samples were also poisoned by adding $HgCl_2$-solution and stored at 4°C. Concentrations of methane in the headspace (Tab. 1) were measured in onshore laboratories at GEOMAR. For dissolved inorganic carbon (DIC), and alkalinity titration seawater samples were transferred from Niskin bottles to 500 ml Schott glass bottles (listed samples in Tab. 4.1.2). The bottles were closed, after adding 100 µl saturated $HgCl_2$-solution, with a greased glass stopper leaving a head space of about 3-5 ml. The DIC and alkalinity determinations will be conducted at GEOMAR laboratories. pCO_2 calculations will be performed according to Dickson et al., 2007. A sample list presenting also the respective CTD data is shown in table 4.1.2.

Gas bubble sampler

Pressure retaining gas samplers (see Rehder and Schneider von Deimling, 2008 for details) were used to collect gas bubbles at the seafloor at ambient pressure (~9 bar). The sampler (inner tube volume of 62 ml) is submerged with an open valve. The water filled sampler is placed on top of a bubble stream and is hold in position by the main manipulator arm until the funnel is filled with gas. The valve is then closed by using the second arm of the ROV. After recovery of the pressure retaining sampler it is connected by the SwageLok adapter to a vacuum apparatus equipped with pressure gauge. Subsamples of high-pressured gas are released into pre-evacuated sample volumes (i.e. 20 and 100 ml glass vials), under controlled pressure (i.e. ~1020 mbar).

Onboard atmospheric gas measurements

Atmospheric trace gas concentrations (CH_4, CO_2, H_2O) were measured by using a Cavity Ring-Down Spectrometer (CRDS) built by Picarro. Filtered air was pumped by an external pump, through a Teflon tube, from above the vessels bridge and from 1 m above the sea surface, respectively, to the measuring device (Fig. 4.1.4). Concentration data is recorded with 2 Hz. Dry mole fraction of CH_4 and CO_2 is calculated and stored in 1 h-separated files. Precision of <3 ppb and <250 ppb is given for CH_4 and CO_2, respectively.

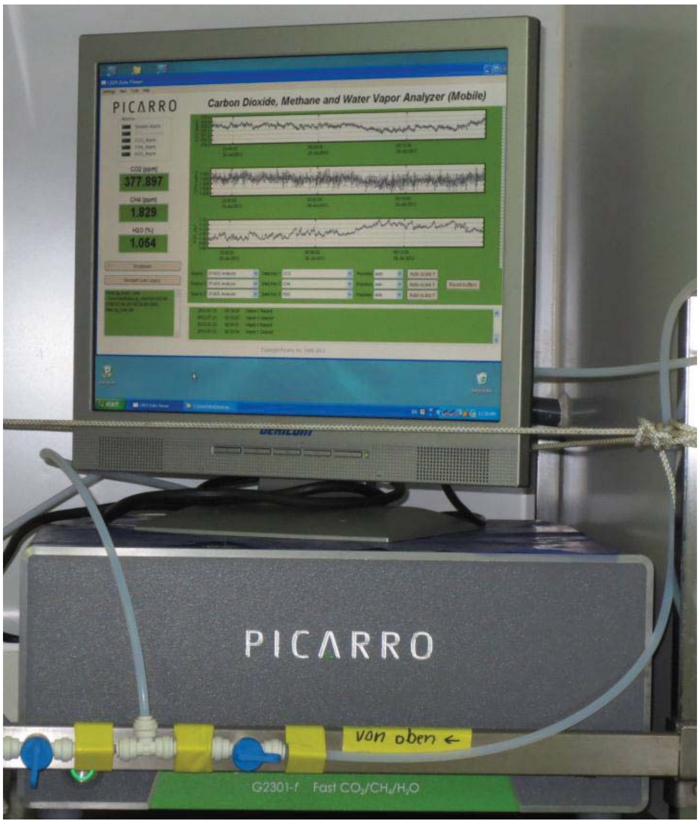

Fig. 4.1.4: CO_2, CH_4, H_2O gas analyser "Picarro G2301-f" installed onboard RV ALKOR.

Preliminary results

Sleipner Vest

Four towed CTD tracks were conducted at the Sleipner area (Figs. 4.1.5-4.1.8). CTD measurements at a speed of 0.3-1 knots two meters above seafloor showed no significant variations in temperature (4.97 - 5.56°C), salinity (35.13 - 35.19 PSU), pH (7.91 - 7.95), or oxygen (98 - 100% Sat.) at water depths between 75 and 87 m in the covered area (Figs. 4.1.5-4.1.8).

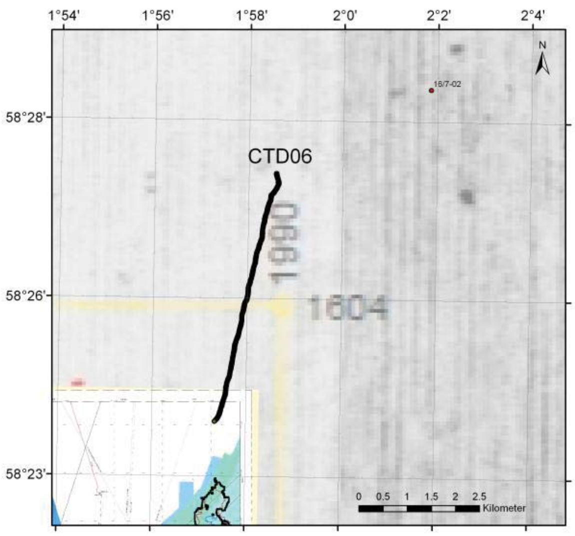

Fig. 4.1.5: Map of CTD06 track (black line).

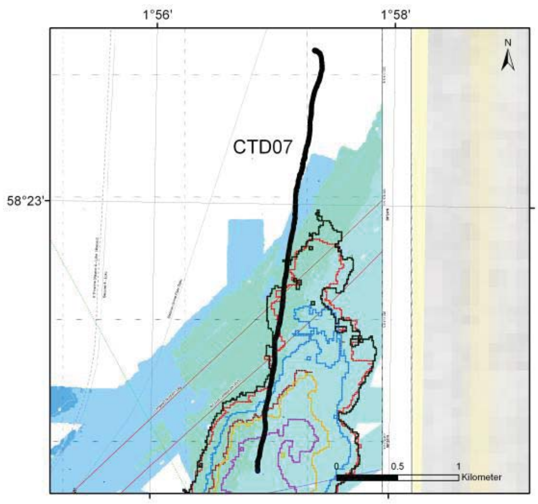

Fig. 4.1.6: CTD07 track.

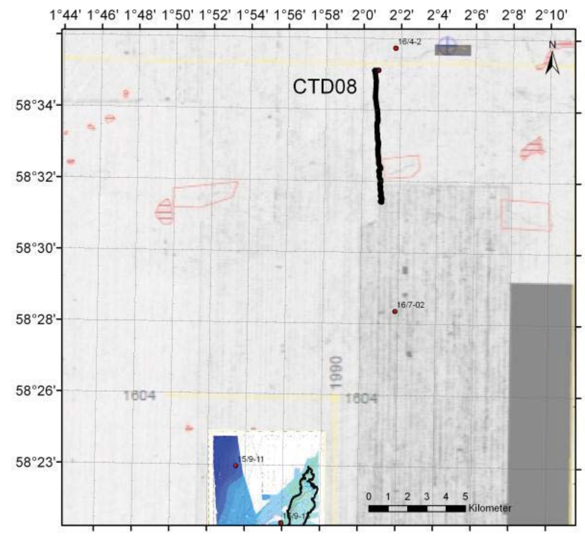

Fig. 4.1.7: CTD08 track.

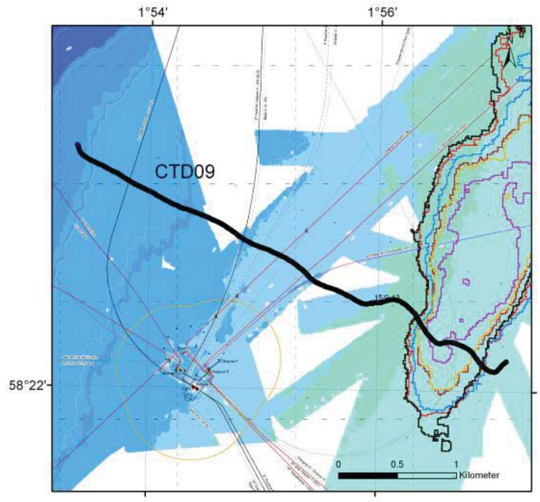

Fig. 4.1.8: CTD09 track.

In summary, pCO_2 concentrations of about 355 µatm (Figs. 4.1.9 and 4.1.10) were measured by the HydroC-CO_2 sensor which was attached to the CTD at ~2 m above the seafloor. A slight decrease of pCO_2 to 340 µatm can be measured in surface waters during up- and downcast of the sensor.

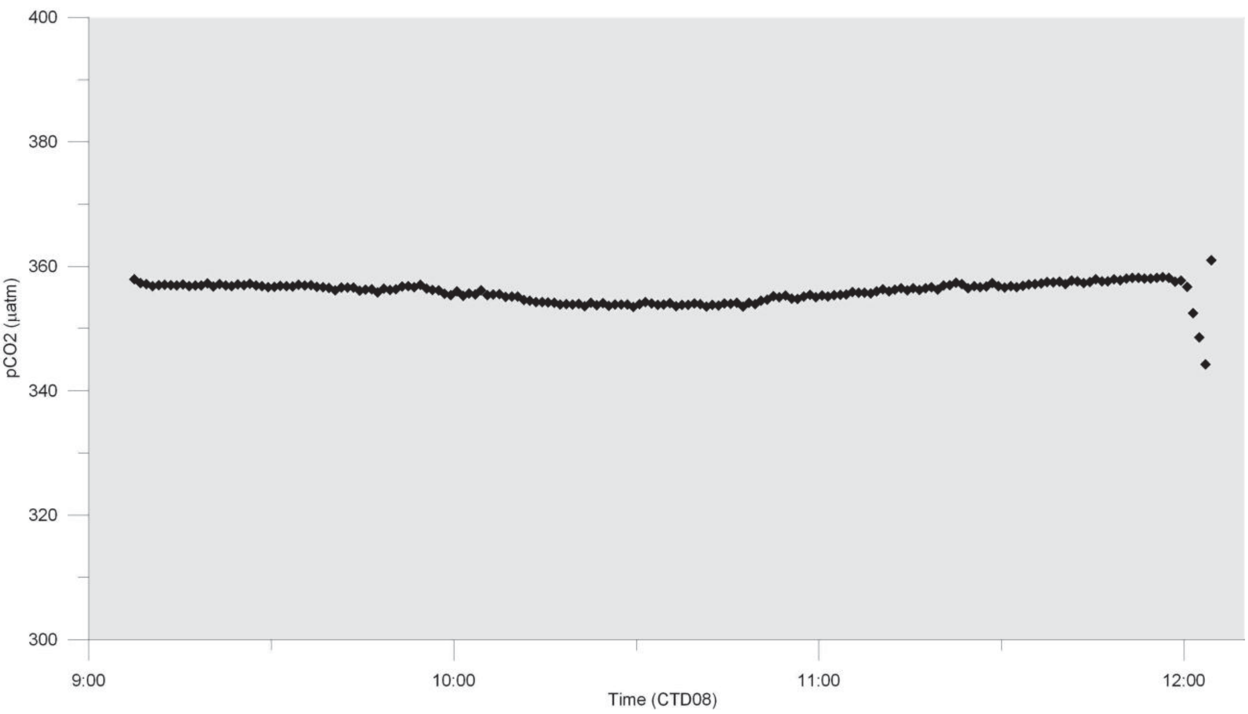

Fig. 4.1.9: pCO_2 concentrations determined by HydroC-CO_2 sensor during towed CTD08 (south-west of "fracture" area; towed at water depths of about 87 m). Note the slightly lowering of pCO_2 during uplift at the end of the track.

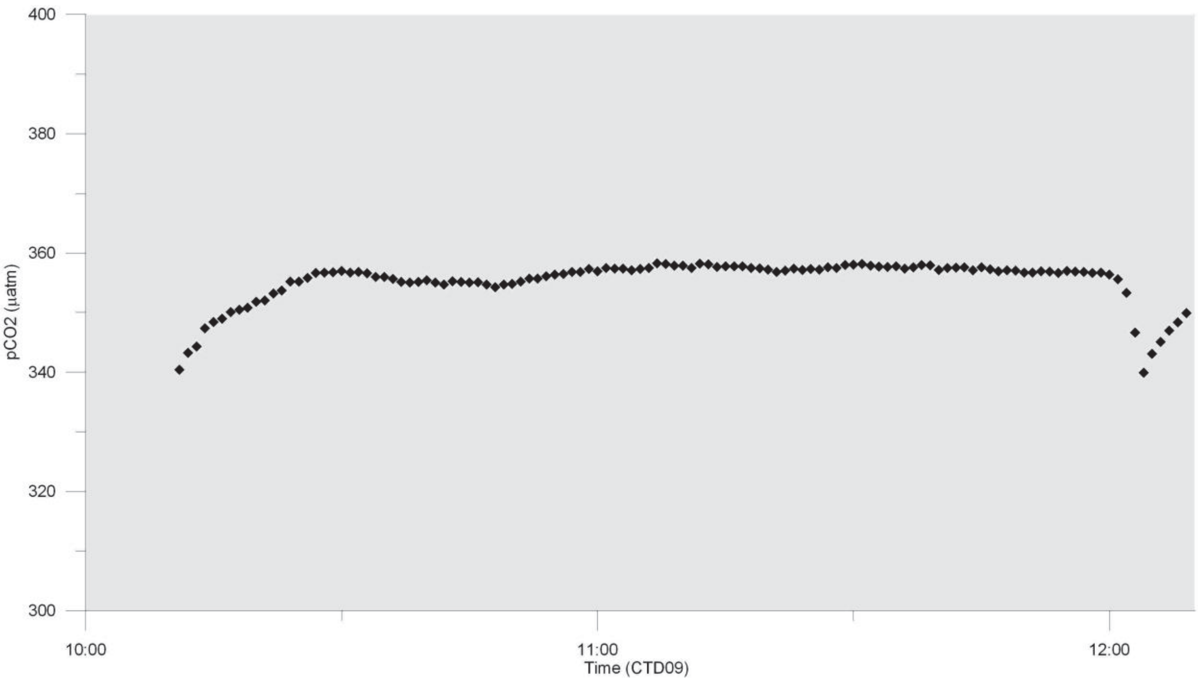

Fig. 4.1.10: pCO_2 concentrations determined by HydroC-CO_2 sensor during towed CTD09 (north of Sleipner platform; towed at water depths of about 81 m).

Well 22/4-b ("Blowout")

Three towed CTDs (Figs 4.1.11-4.1.14) were conducted at selected water depths in the area of the blowout site (well 22/4-b, UK EEZ). In order to monitor dissolved gas concentrations in the water column during late winter/early spring conditions Niskin bottles were triggered every 10-20 minutes during the towed CTD tracks (Tab. 4.1.1). A reference site located far from the blowout (CTD10 in Fig. 4.1.14) was selected to measure methane concentrations at different water depths.

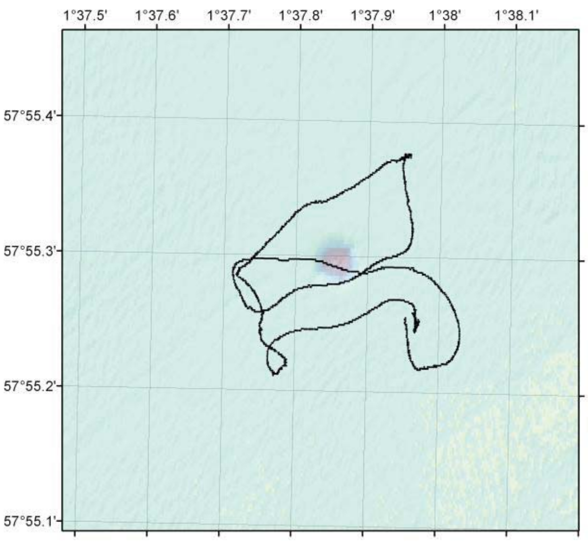

Fig. 4.1.11: CTD02 track at 85 mbsl.

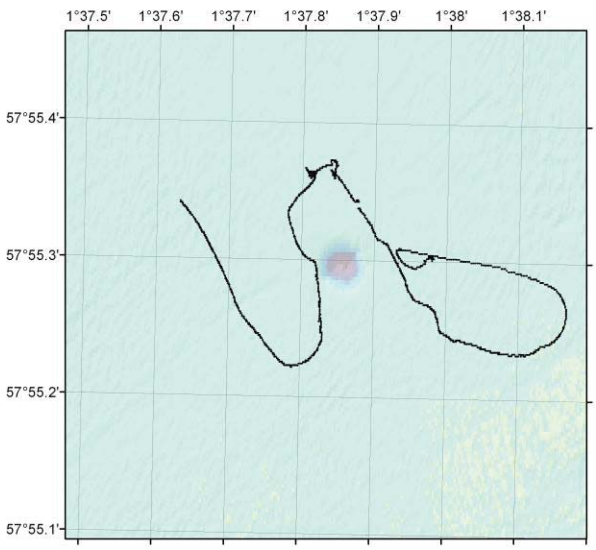

Fig. 4.1.12: CTD03 track at 44 mbsl.

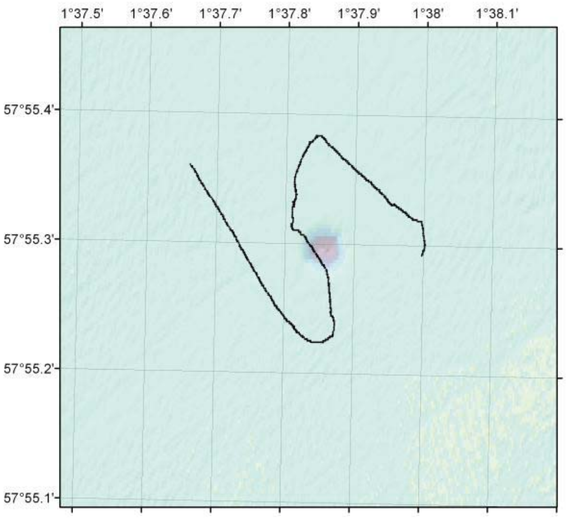

Fig. 4.1.13: CTD04 track at 10 mbsl.

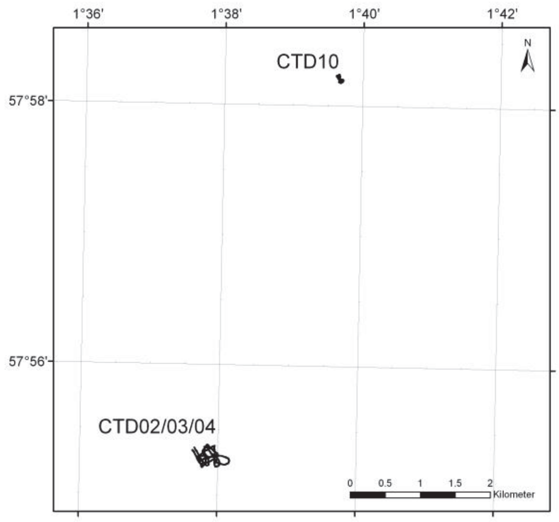

Fig. 4.1.14: Map of CTDs 02/03/04 and 10 (selected reference site).

Methane concentrations, which were measured by headspace gas chromatography range between 4 and 10,000 nM. Results from the discrete water sampling and continuous CH_4-monitoring by sensor (HydroC) measurements will be combined with oceanographic data (ADCP, CTD) and atmospheric data (Picarro) to evaluate the actual seepage situation without stratification of the water column (Fig. 4.1.15).

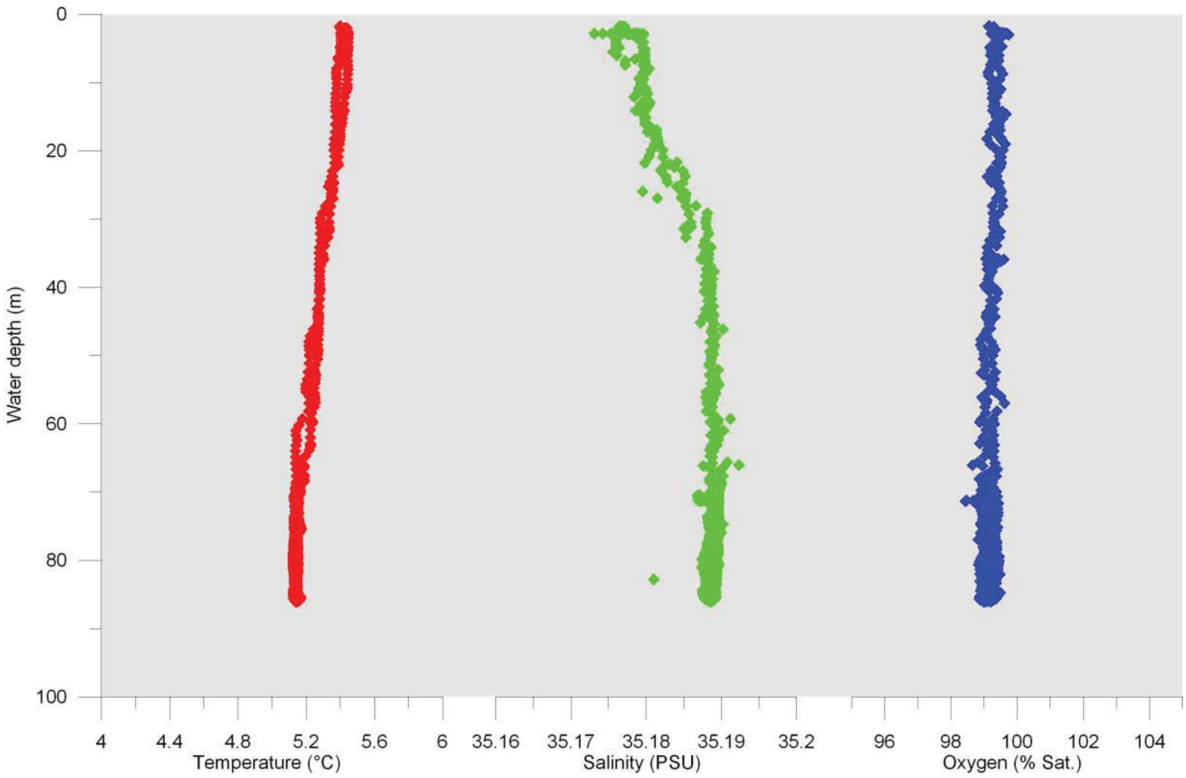

Fig. 4.1.15: Up- and down-cast of CTD02 indicates a well-mixed water column in the central North Sea during cruise AL412.

Table 4.1.1: CH_4 data from Niskin bottle samples (CTD, ROV).

Gear No.	Niskin No.	CH_4 in headspace (ppmV)
CTD 2 (85m)	NiBo 1	2.2
CTD 2 (85m)	NiBo 2	1.8
CTD 2 (85m)	NiBo 3	1.7
CTD 2 (85m)	NiBo 4	2.1
CTD 2 (85m)	NiBo 4	2.3
CTD 2 (85m)	NiBo 5	2.2
CTD 2 (85m)	NiBo 6	1.2
CTD 2 (85m)	NiBo 7	13.8
CTD 2 (85m)	NiBo 8	11.3
CTD 2 (85m)	NiBo 9	2.2
CTD 2 (85m)	NiBo 10	3.2
CTD 2 (85m)	NiBo 11	3.1
CTD 2 (85m)	NiBo 12	160.4
CTD 2 (85m)	NiBo 12	160.5
CTD 3 (40m)	NiBo 1	11.9
CTD 3 (40m)	NiBo 2	14.7
CTD 3 (40m)	NiBo 3	15.6
CTD 3 (40m)	NiBo 4	15.2
CTD 3 (40m)	NiBo 5	14.4
CTD 3 (40m)	NiBo 6	672.2
CTD 3 (40m)	NiBo 7	3258.5
CTD 3 (40m)	NiBo 8	12.9
CTD 3 (40m)	NiBo 9	12.6

Gear No.	Niskin No.	CH_4 in headspace (ppmV)
VCTD 6 (82m)	NiBo 1	1.6
VCTD 6 (82m)	NiBo 2	1.5
VCTD 6 (82m)	NiBo 3	1.8
VCTD 6 (82m)	NiBo 4	1.5
VCTD 6 (82m)	NiBo 5	1.6
VCTD 6 (82m)	NiBo 6	1.4
VCTD 6 (82m)	NiBo 7	1.6
VCTD 6 (82m)	NiBo 8	1.5
VCTD 6 (82m)	NiBo 9	1.2
VCTD 6 (82m)	NiBo 10	1.3
VCTD 6 (82m)	NiBo 11	1.3
VCTD 6 (82m)	NiBo 12	1.5
VCTD 9	NiBo 9	14.3
VCTD 9	NiBo 10	15.4
VCTD 7	NiBo 1	12.6
VCTD 7	NiBo 2	15.4
VCTD 7	NiBo 3	14.7
VCTD 7	NiBo 4	14.4
VCTD 7	NiBo 5	13.9
VCTD 7	NiBo 6	9.5
VCTD 7	NiBo 7	9.1
VCTD 7	NiBo 8	7.6
VCTD 8	NiBo 1	1.7

Gear No.	Niskin No.	CH_4 in headspace (ppmV)
CTD 3 (40m)	NiBo 10	72.5
CTD 3 (40m)	NiBo 11	77.3
CTD 3 (40m)	NiBo 12	8.8
CTD 4 (10m)	NiBo 1	22.1
CTD 4 (10m)	NiBo 1	22.0
CTD 4 (10m)	NiBo 2	26.8
CTD 4 (10m)	NiBo 3	13.6
CTD 4 (10m)	NiBo 4	69.7
CTD 4 (10m)	NiBo 5	8.9
CTD 4 (10m)	NiBo 6	12.2
CTD 4 (10m)	NiBo 7	35.8
CTD 4 (10m)	NiBo 8	118.2
CTD 4 (10m)	NiBo 9	176.4
CTD 4 (10m)	NiBo 10	126.3
CTD 4 (10m)	NiBo 11	263.6
CTD 4 (10m)	NiBo 12	410.7
CTD 10	NiBo 1	5.2
CTD 10	NiBo 2	15.1
CTD 10	NiBo 3	169.4
CTD 10	NiBo 4	22.0
CTD 10	NiBo 5	12.2
CTD 10	NiBo 6	11.3
CTD 10	NiBo 7	7.7
CTD 10	NiBo 8	10.4

Gear No.	Niskin No.	CH_4 in headspace (ppmV)
VCTD 8	NiBo 2	4.7
VCTD 8	NiBo 3	6.6
VCTD 8	NiBo 4	8.3
VCTD 8	NiBo 5	6.9
VCTD 8	NiBo 6	6.1
VCTD 8	NiBo 7	5.9
VCTD 8	NiBo 8	6.0
VCTD 9	NiBo 1	1.7
VCTD 9	NiBo 2	8.2
VCTD 9	NiBo 3	10.4
VCTD 9	NiBo 4	20.4
VCTD 9	NiBo 5	9.5
VCTD 9	NiBo 6	5.4
VCTD 9	NiBo 7	3.7
VCTD 9	NiBo 8	4.3
ROV1	NiBo 1 (2529)	14736.4
ROV1	NiBo 2 (2537)	1100.1
ROV1	NiBo 3 (2534)	91.4
ROV 8	NiBo 3 (2534)	2135.5

Table 4.1.2: DIC sample list.

Station No.	Device No.	Niskin No.	Temperature (°C)	Water depth (db)	Salinity (PSU)
Sta.121	VCTD 2	NiBo 1	5.1413	85.871	35.1886
		NiBo 8	5.1375	81.296	35.1886
Sta.127	VCTD 3	NiBo 1	5.2584	43.847	35.1893
		NiBo 7	5.2484	44.445	35.1893
Sta.128	VCTD 4	NiBo 12	5.4015	13.676	35.1885
Sta.132	VCTD 6	NiBo 1	5.5638	80.241	35.1678
		NiBo 2	5.5205	79.959	35.174
		NiBo 3	5.5093	82.298	35.1758
		NiBo 4	5.4805	81.249	35.1802
		NiBo 5	5.437	82.017	35.1856
		NiBo 6	5.4207	81.644	35.1875
		NiBo 12	5.3552	80.033	35.1932
Sta.137	VCTD 7	NiBo 2	5.1845	81.884	35.1839
		NiBo 5	5.1846	79.7	35.1841
		NiBo 8	5.1397	78.317	35.1778
Sta.140	VCTD 8	NiBo 8	5.4659	93.127	35.1801
Sta.155	VCTD 9	NiBo 2	5.1009	78.436	35.1533
		NiBo 7	5.0786	81.438	35.1529
		NiBo 8	5.3459	28.061	35.1764
		NiBo 10	5.4424	4.787	35.1699

4.2 ROV deployments

M. Pieper, M. Bodendorfer, P. Cuno, J. Hennke, H. Huusmann

The work class ROV PHOCA was used for sampling of sediments, gas and bottom water, for obtaining on-line readings of a CH_4- and a CO_2-sensor, and for deployment and recovery of autonomous instruments. It was the first deployment of ROV PHOCA from board RV ALKOR and proved to be very successful.

ROV PHOCA is a 3000 m rated deep diving platform manufactured by SubAtlantic FET, Aberdeen, Scotland. It is based on commercially available ROVs, but customized to our demands, e.g. being truly mobile. ROV PHOCA has previously been operated from the medium sized German research vessel RV POSEIDON. As an electric work class ROV of the type Comanche, this is build No. 21. ROV PHOCA is based at the Helmholtz Centre for Marine Sciences GEOMAR in Kiel, Germany.

For shallow-water applications, a 28 mm Aramid mantled cable (neutrally buoyant tether, 500m) is used, which is paid in and out manually, using a capstan winch (Fig. 4.2.1).

For underwater navigation, a mobile ORE system was used with an autonomous transponder mounted on the light rack of the ROV.

ROV PHOCA is equipped with a tool skid onto which a variety of tools to customers demand can be mounted (Fig. 4.2.2).

Fig. 4.2.1: Deck-setup of cabling, capstan winch and laid out tether cable on upper deck of RV ALKOR (Photo: ROV Team GEOMAR)

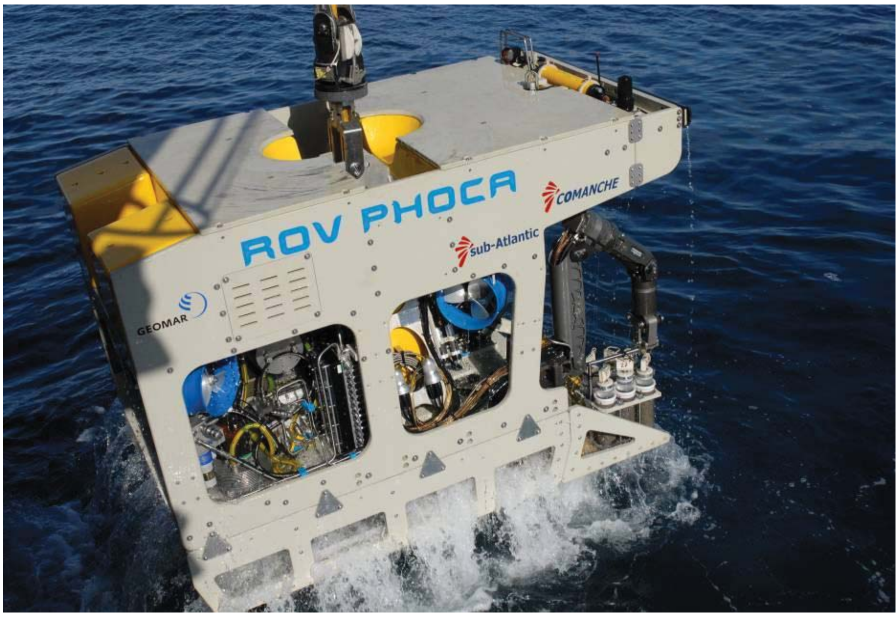

Fig. 4.2.2: ROV PHOCA during recovery; carrying a six-pack with push cores on its porch.

Short description of ROV activities during AL412

Including this cruise, ROV PHOCA has accomplished 31 dives during 3 missions. During AL412, 10 scientific dives (Tab. 4.2.1) were completed. Maximum diving depth was 117 m and maximum bottom time was 2:53 hours. In total, bottom time accumulated to approx. 22 hours (total dive time 28 hours).

Table 4.2.1: ROV station list AL412

Station Number CE12010	Dive No.	Date (UTC)	Time Start (UTC)	At Bottom (UTC)	Off Bottom (UTC)	Time End (surface) (UTC)	Location	Depth (m)	ROV Bottom Time
Harbor test	21	22.03.2013	Kiel						
126ROV01	22	27.03.2013	11:07	11:34	13:35	14:02	Blowout	117	02:01
130ROV02	23	28.03.2013	07:37	07:55	10:48	11:13	Sleipner	90	02:53
131ROV03	24	28.03.2013	14:40	14:50	17:08	17:27	Sleipner	90	02:18
134ROV04	25	31.03.2013	07:20	07:34	10:41	10:57	Sleipner	92	03:07
135ROV05	26	31.03.2013	12:30	12:49	14:27	14:45	Sleipner	93	01:38
141ROV06	27	01.04.2013	12:43	12:57	14:47	15:00	Sleipner	92	01:50
145ROV07	28	02.04.2013	08:28	08:40	10:20	10:40	Sleipner	92	01:40
146ROV08	29	02.04.2013	12:12	12:37	13:59	14:10	Sleipner	94	01:22
148ROV09	30	03.04.2013	06:05	06:18	08:53	09:05	Sleipner	82	02:35
151ROV10	31	03.04.2013	12:20	12:38	15:30	15:40	Sleipner	83	02:52
Total: 10 scientific dives									22:16 h

ROV PHOCA was deployed at different stations in the Norwegian and the British Sector of the North Sea. At the first and most southerly working area, the “Blowout” site, ROV PHOCA located the trawl-resistant lander (Fig. 4.2.3a) as well as a sensor package (Fig. 4.2.3b) and connected both with a rope for later recovery using a hook-wire-construction. In addition, the ROV went to the bottom of the crater and sampled gas and bottom water.

The main goals for the second working area “Sleipner” were to revisit the “Hugin” fracture and an abandoned well and to survey two seismic chimneys south of the platform. At active seeping sites as indicated by bacterial mats, push cores were taken for further microbiological and geo-chemical investigations.

A gastight gas sampler was deployed by the ROV on different occasions to collect samples for methane and/or CO_2 analyses. Sensors for CH_4- and CO_2 measurements (both Contros) were mounted on the ROV and partly integrated into the ROVs telemetry system, allowing on-line readings for real time control of one sensor at time while the other recorded data internally.

Niskin bottles mounted on one of the drawers of the ROV were used to collect samples of ambient water as well as CH_4 and CO_2 enriched bottom water. More details on individual dives and respective scientific results are given in the scientific chapters of this report.

For more details on the ROV system please visit http://www.geomar /PHOCA

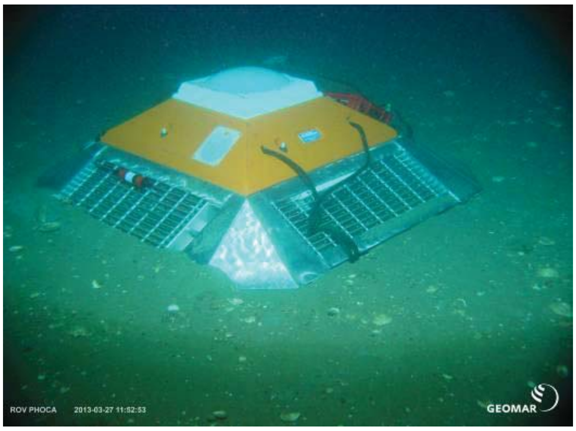

Fig. 4.2.3a: Trawl-resistant lander at the Blowout site.

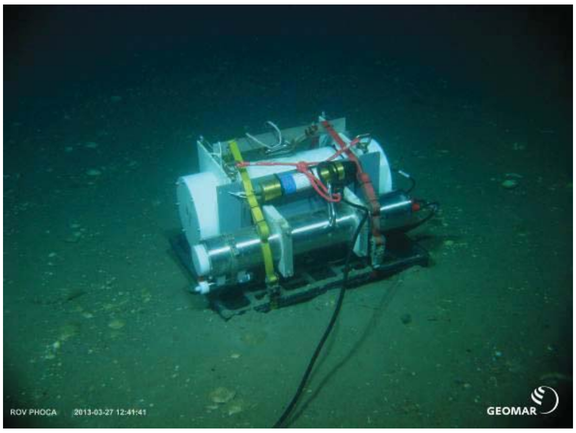

Fig. 4.2.3b: Sensor package at the Blowout site.

Fig. 4.2.3c: Pushcore sampling of bacterial mats at the Hugin fracture.

Fig. 4.2.3d: Wolffish snugging with a lander anchor weight at the Hugin fracture.

Tools that were installed on and deployed by ROV PHOCA during AL412:

- CTD real-time probe (GEOMAR) (permanent)
- Pushcores, in mobile “six-pack” (GEOMAR) (optional)
- 2 litre Niskin bottles (GEOMAR) (optional)
- CH_4 and CO_2 sensors (GEOMAR/Contros) (optional / integrated)
- Gas sampler (IOW) (optional)
- Additional sampling boxes (compartmented) (GEOMAR) (optional)
- Acoustic HOMER beacon markers (GEOMAR) (optional)

4.3 Lander operation

P. Linke, M. Schmidt, S. Cherednichenko

In order to investigate the discharge of dissolved and gaseous methane from the blowout crater in a late winter situation, a novel trawl resistant lander and a sensor package were deployed on the rim of the crater during the entire cruise. The lander was equipped with a 300 kHz ADCP (Teledyne), a storage CTD (SBE 37SM, SeaBird), and a hydrophone (icListen LF, Ocean Sonics) with internal data logger. For recovery the lander is equipped with an acoustic release which enables the floatation unit to detach from the lander base and ascend to the sea surface. It is connected to the base of the lander with a 300 m long line, which enables a recovery of the whole equipment as this contains the acoustic releaser (K/MT562, KUM), CTD, hydrophone and the weights. Furthermore, the base was equipped with two baskets which contained a 100 m long rope and a snap hook to connect the lander with the sensor package (Fig. 4.3.1).

The sensor package was equipped with the HISEM methane sensor and a large battery container (Fig. 4.3.2). Both instruments were deployed video-guided on the sea floor next to the crater rim by the modified launcher and were equipped with a beacon for acoustic relocation by the ROV (see chapter 4.2). During the first dive the pilots of the ROV were able to relocate and connect both instruments by the rope which enabled a combined recovery of the whole mooring after acoustic release.

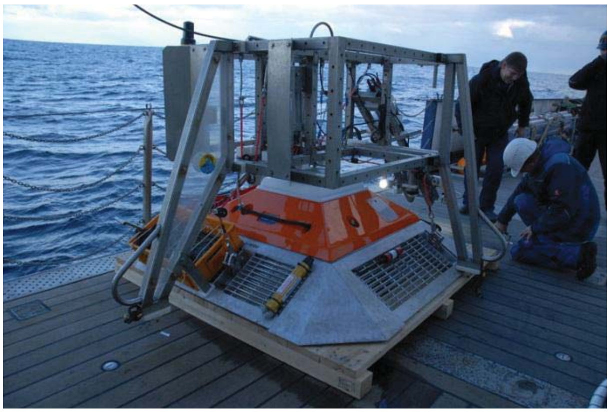

Fig. 4.3.1: Trawl resistant lander with launcher ready for deployment.

Fig. 4.3.2: Video-guided deployment of the sensor package.

Preliminary results

The mooring was deployed for 10 days with all units active during the entire deployment. The first analysis of the ADCP data depicts the tidal impact on the current velocity and direction (Fig. 4.3.3).

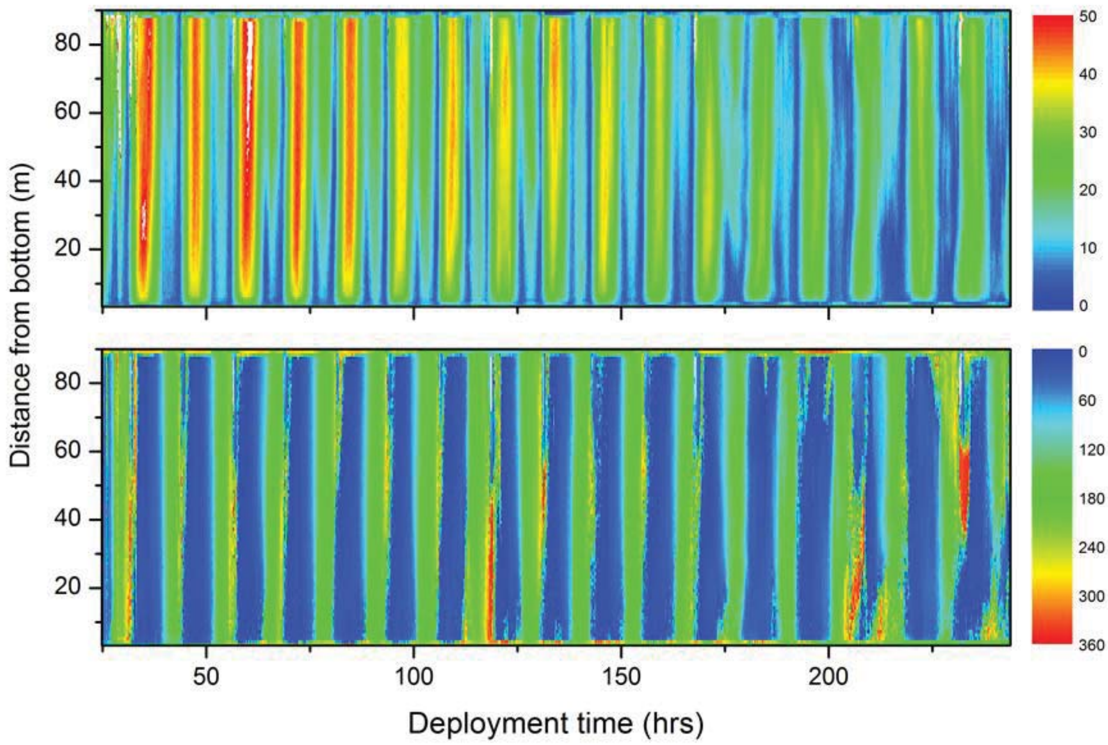

Fig. 4.3.3: Lander ADCP data: Velocity magnitude in cm/s (upper panel) and direction (lower panel).

The impact of the tides is also very apparent in the CTD (Fig. 4.3.4) and methane sensor data (Fig. 4.3.5).

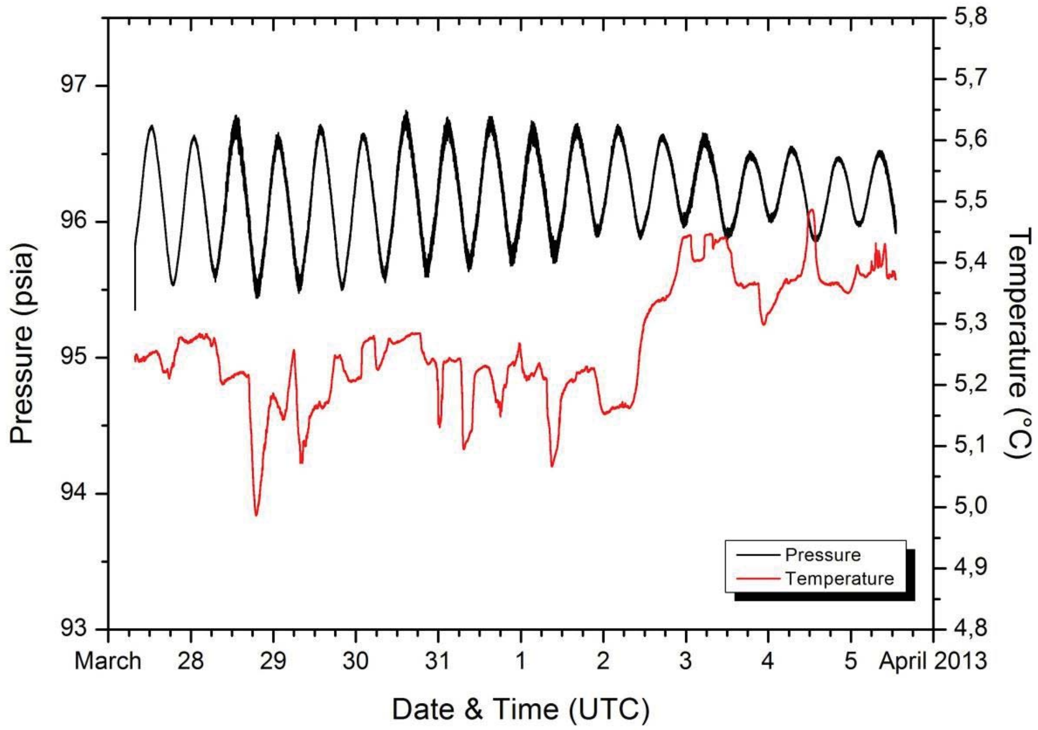

Fig. 4.3.4: Lander CTD data.

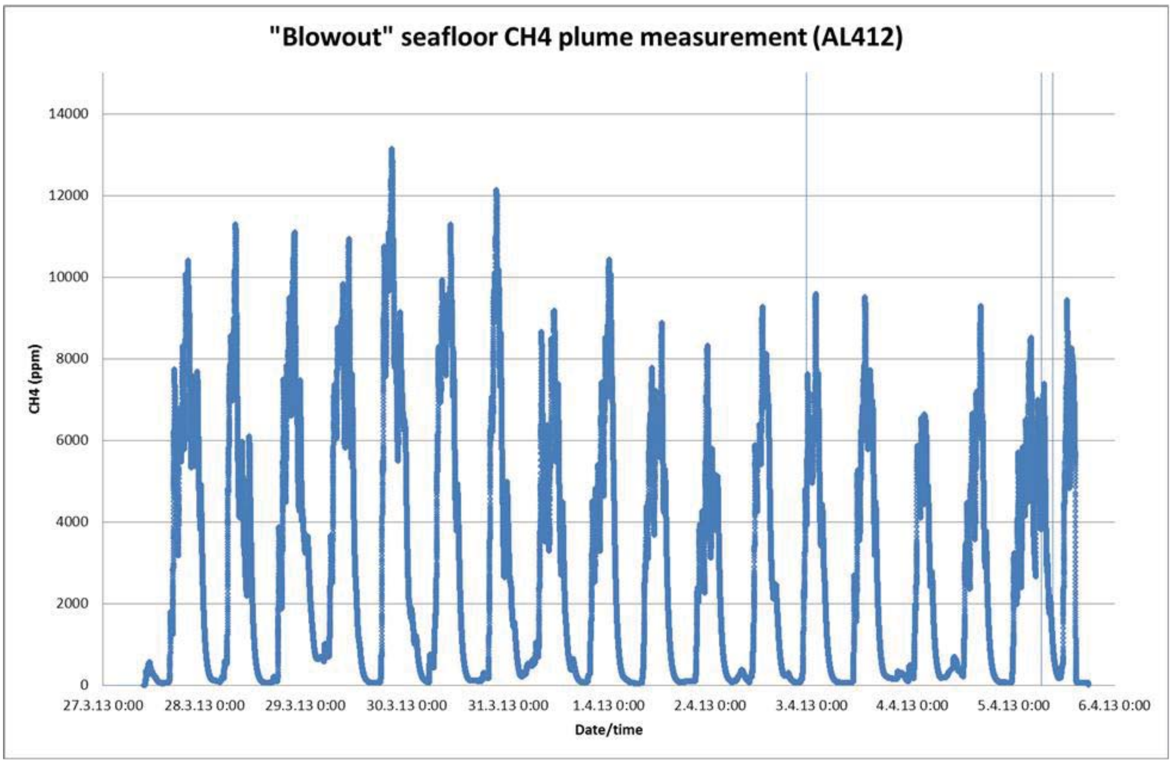

Fig. 4.3.5: Methane data recorded by the HISEM sensor.

The hydrophone recorded waveform and spectrum (FFT) data at 102.4 kHz bandwidth obtaining a total of 29.1 GB of data. These data are being analyzed at present to see whether the sound of the gas release from the crater has been recorded and whether this signal shows any correlation with the tidal impact like the other measurements (e.g. current direction).

4.4 Porewater and Sediment Geochemistry

D. Schroller, L. Vielstädte, M. Dibbern, A. Bodenbinder

On this follow-up cruise to the “Hugin” fracture north of the Sleipner CO_2 injection site, the geochemical work aims at collecting additional sediment samples in order to be able to constrain the source of the expelled fluids and the timing of its activity. In addition, the sediments above the seismic chimney structures south of the Sleipner platform were sampled for the first time to identify if these structures are indeed active pathways for upward fluid flow. On seismic similarity images the chimney-like structures are connecting the Utsira formation with the seafloor. The overarching goal at both study sites is to determine whether there is any connection to the CO_2 injection at Sleipner West into the Utsira formation.

Therefore, an extended geochemical dataset was collected on this cruise. This included onboard analyses of the collected samples for their content of NH_4^+, PO_4^{3-}, SiO_4^{4-}, H_2S, and total alkalinity. In addition sub-samples were taken for further shore-based analyses: DIC content and its $\delta^{13}C$ isotope ratio, dissolved metal cations, NO_3^-, SO_4^{2-}, Br^-, Cl^-, and I^- concentrations, dissolved hydrocarbon concentrations and their isotopic composition, isotopic ratios of Sr, Cl, Li, H, and O in the porewater, porosity and calcium carbonate, POC, PON, and total sulfur content of the solid phase (Tab. 4.4.1). At the fracture, additional samples were collected for ^{14}C-dating of the DIC, ^{210}Pb content of the sediment, and total Hg (THg) concentrations of the porewater and solid phase.

In total 16 cores were retrieved at 12 stations amounting to 298 sediment samples. At the fracture the most active fluid seepage spots and the reference station located on CE12010 were revisited. At the seismic chimneys sampling locations were selected based on available seismic similarity information from J. Karstens, GEOMAR.

Materials and Methods

Sediment and porewater sampling

Surface sediment samples were retrieved using ROV-operated pushcores (PC) and the 4 m–long vibro corer system (VC) of the Institute for Baltic Sea Research (IOW).

The sediments were extruded out of the PC plastic liners with a piston and cut into 0.5 to 1.5 cm thick slices. The porewater was separated from the sediment using a low-pressure squeezer (argon at 3-5 bar, sometimes up to 6.5 bar). While squeezing, the porewater was filtered through 0.45 µm regenerated cellulose Whatman filters and collected in recipient vessels. Porewater extraction from the sandy sediments by centrifugation was inefficient and consequently abandoned for the low-pressure squeezing. The porewater extraction from the first three VCs was also done with the low-pressure squeezer through 0.20 µm cellulose acetate Whatman filters. Unfortunately, this procedure yielded too little porewater volume and hence was substituted by rhizon sampling. Holes were drilled into the VC liners every 15-30 cm and the Rhizosphere rhizons (5 cm long, 0.38 cm in diameter) placed in those holes. Subsequent to the porewater extraction at on-deck temperatures of 5 °C, the porewater was filtered through 0.2 µm cellulose acetate filters and collected in recipient vessels. Afterwards the VC liners were cut in half and opened to sample about 5 ml of wet sediment between each of the porewater sampling depths for porosity, carbonate and CNS element analyses at the home laboratory. Additional 3 ml of wet sediment were subsampled with a cut-off syringe for headspace methane gas analyses.

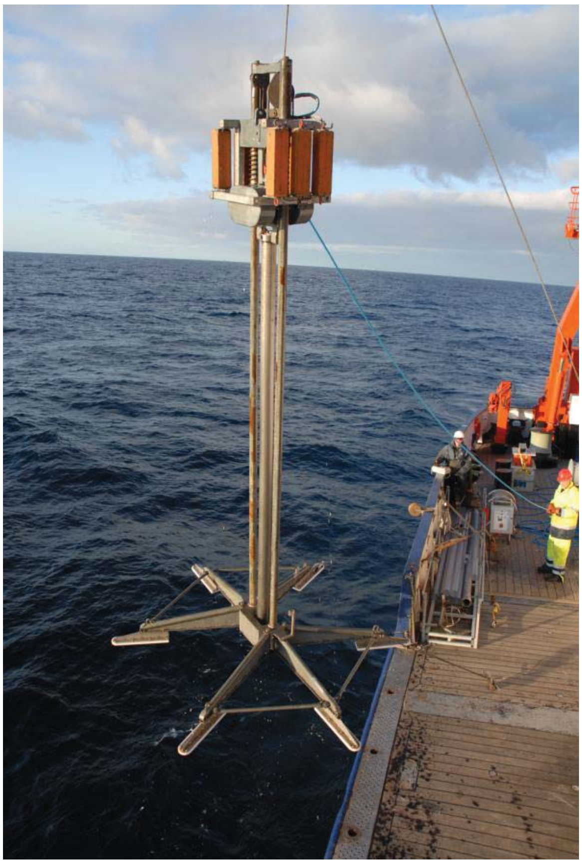

Fig. 4.4.1: Deployment of the vibrocorer.

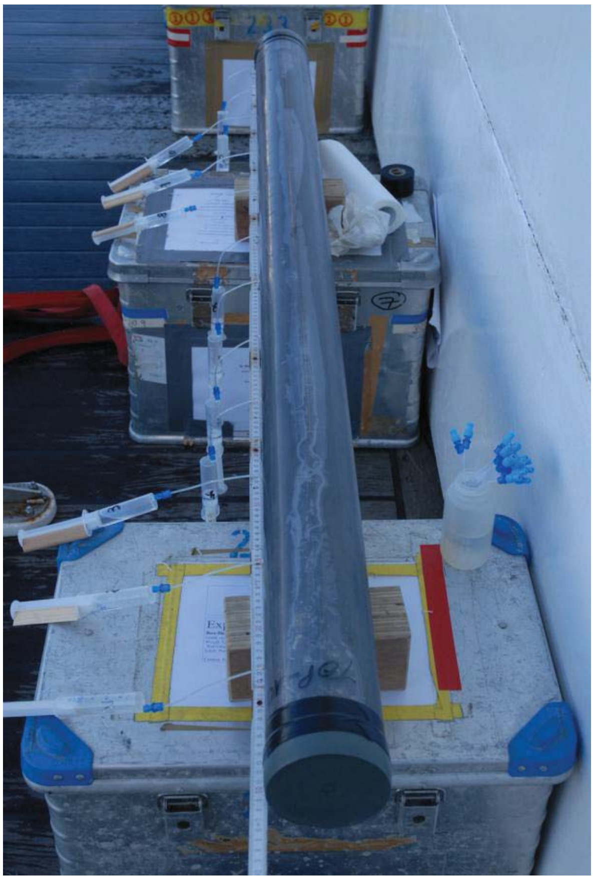

Fig. 4.4.2: Porewater extraction by rhizone sampling.

The PCs for $^{14}C_{DIC}$ and THg sampling were processed completely in a glovebag under argon atmosphere and at ambient room temperature (~19 °C). Porewater samples for $^{14}C_{DIC}$ analyses were treated with 2.0 g of $BaCl_2$ powder and 200 µl of 3.4M NaOH solution to precipitate the DIC quantitatively as $BaCO_3$ and poisoned with 30 µl of saturated $HgCl_2$ solution per a total of 50 ml of porewater. This amount of porewater sample is necessary to guarantee a quantity of 3 mg of DIC-carbon required for the ^{14}C dating. Thus, the porewater volume extracted from successive intervals was combined in 120-ml glass vial until a total volume of 50 ml was reached. Subsequently, the glass vials were tightly cramped and manually shaken for some seconds to homogenize the sample and precipitate the DIC-carbon.

1.9 ml of porewater were subsampled for THg and acidified with 5 µl of 96% suprapure H_2SO_4 in 2-ml headspace (resulting acid concentration: ~0.2 vol%) vials and tightly cramped. The entire procedure of porewater extraction and subsampling was conducted in a glovebag under O_2-free argon atmosphere.

For δD of CH_4 and ^{210}Pb analyses a second PC was processed. The δD_{CH4} analysis requires at least 1 ml of headspace with at least 1 Vol% of CH_4, i.e. 10 µl or 0.4 µmol of CH_4. Thus, defined sediment volumes of 60 ml were taken with cut-off syringes and sampled into 120-ml headspace glass vials. The vials were filled up with 55 ml of saturated NaCl solution and an excess of 3 g of NaCl to produce 5 ml of free headspace volume as exactly as possible. Then the vials were tightly cramped and shaken for 1 h on an overhead-shaker to homogenize the sample. For ^{210}Pb analysis, 3 ml of wet sediment was taken with a cut-off syringe in 0.5-cm intervals.

A third PC was collected for paleoceanographic determination of living and dead foraminifera species and communities in the surface sediments. The cores were stored refrigerated for shore-based analysis.

Aliquots of the extracted porewater from the $^{14}C_{DIC}$-PCs as well as the VCs were sub-sampled for various onboard and shore-based analyses (Tab. 4.4.1). Subsamples for ICP-AES analysis were acidified with 30 µl of concentrated suprapur HNO_3 per 3 ml of porewater sample (i.e., pH<1) and subsamples (~1.8 ml) for $\delta^{13}C$ and DIC were treated with 10 µl of $HgCl_2$ to inhibit further microbial degradation. All of these subsamples and the untreated subsamples for IC and isotope analyses were stored refrigerated until they were further processed in the home laboratories. Porewater subsamples for NO_3^- were stored frozen at -80 ºC. About 5 ml of wet sediment of each 5 cm interval was collected for porosity analyses.

<u>*Porewater analyses*</u>

Analyses for the nutrients NH_4^+, PO_4^{3-}, SiO_4^{4-} as well as H_2S were completed onboard using a Hitachi UV/VIS spectrophotometer. The respective chemical analytics followed standard procedures (GRASSHOFF et al., 1999), i.e. ammonium was measured as indophenol blue, phosphate and silicate as molybdenum blue, and sulfide as methylene blue. The total alkalinity of the porewater was determined by titration with 0.02 N HCl using a mixture of methyl red and methylene blue as indicator. The titration vessel was bubbled with argon to strip any CO_2 and H_2S produced during the titration. The IAPSO seawater standard was used for the calibration of the method. The analytical precision and accuracy of each method are given in Table 4.4.2.

Table 4.4.1: List of retrieved sediment cores and sub-samples collected for geochemical analyses.

Station Device	Area	Latitude (N)	Longitude (E)	Water depth / m	PW	TA	NO_3^-	CH_4	Poros + CNS	IC	ICP-AES	DIC $\delta^{13}C$	δD_{CH4}	$\delta^{18}O$ δD_{H2O}	^{14}C+ THg	^{210}Pb	Length of core / cm	No. of samples
131-ROV3-PC20	Fracture bacterial mat	58°35.743'	02°05.356'	90.7	-	X	-	-	X	X	-	-	-	-	X	-	17.0	2
131-ROV3-PC24	Fracture bacterial mat	58°35.743'	02°05.356'	90.7	-	-	-	-	-	-	-	-	X	-	-	X	22.0	47
133-VC1	Fracture reference	58°35.758'	02°05.187'	93.7	X	X	X	X	X	X	X	X	-	X	-	-	340.0	14
134-ROV4-PC2	Fracture reference	58°35.734'	02°05.089'	92.0	-	-	-	-	-	-	-	-	X	-	-	X	18.0	41
134-ROV4-PC17	Fracture reference	58°35.734'	02°05.089'	92.0	-	X	-	-	X	X	-	-	-	-	X	-	20.5	4
136-VC2	Fracture bacterial mat	58°35.722'	02°05.384'	95.2	X	X	-	X	X	X	-	-	-	-	-	-	385.0	13
139-VC4	Fracture bacterial mat	58°35.736'	02°05.358'	94.2	X	X	-	X	X	X	X	-	-	-	-	-	336.0	13
141-ROV6-PC10	Fracture bacterial mat	58°35.744'	02°05.369'	92.2	-	X	-	-	X	X	X	X	-	X	X	-	19.0	4
141-ROV6-PC20	Fracture bacterial mat	58°35.744'	02°05.369'	92.2	-	-	-	-	-	-	-	-	X	-	-	X	18.0	41
144-VC7	Fracture bacterial mat	58°35.754'	02°05.360'	94.3	X	X	-	X	X	X	X	-	X	-	-	-	191.0	12
145-ROV7-PC17	Fracture bacterial ring	58°35.709'	02°04.437'	91.5	-	X	-	-	X	X	X	X	-	X	X	-	19.5	4
145-ROV7-PC22	Fracture bacterial ring	58°35.709'	02°04.437'	91.5	-	-	-	-	-	-	-	-	X	-	-	X	20.5	47
147-VC8	Fracture bacterial ring	58°35.717'	02°04.415'	94.4	X	X	X	X	X	X	X	X	-	-	-	-	234.0	16
149-VC9	Chimney 'rabbits eye'	58°19.377'	01°54.658'	82.0	X	X	X	X	X	X	X	X	-	X	-	-	216.0	11
150-VC10	Chimney reference	58°19.165'	01°54.513'	83.8	X	X	X	X	X	X	X	X	-	X	-	-	191.0	14
152-VC11	Fracture bacterial ring	58°35.713'	02°04.424'	94.3	X	X	X	X	X	X	X	X	X	X	-	-	361.0	15

PCs have ROV and VCs ship coordinates. PC = push core; VC = vibro core; PW = onboard analyses of H_2S, NH_4, PO_4, SiO_4; CH_4 = dissolved hydrocarbons (CH_4, and higher alkanes) and $\delta^{13}C_{CH4}$, δD_{CH4}; Poros = sediment porosity; CNS = sediment $CaCO_3$, C, N, S element concentration; IC = ion chromatography (SO_4, Br, Cl, I); ICP-AES = inductively-coupled atomic emission spectroscopy (for various dissolved cations); ^{14}C = ^{14}C of DIC.

Table 4.4.2: Analytical methods of onboard geochemical analyses.

Parameter	Method	Detection limit	Analytical precision/accuracy
H_2S	UV/VIS photometry	1 µmol/l	3 %
NH_4^+	UV/VIS photometry	2 µmol/l	5 %
PO_4^{3-}	UV/VIS photometry	1 µmol/l	5 %
SiO_4^{4-}	UV/VIS photometry	5 µmol/l	2 %
TA	HCl Titration	0.01 meq/l	2 %

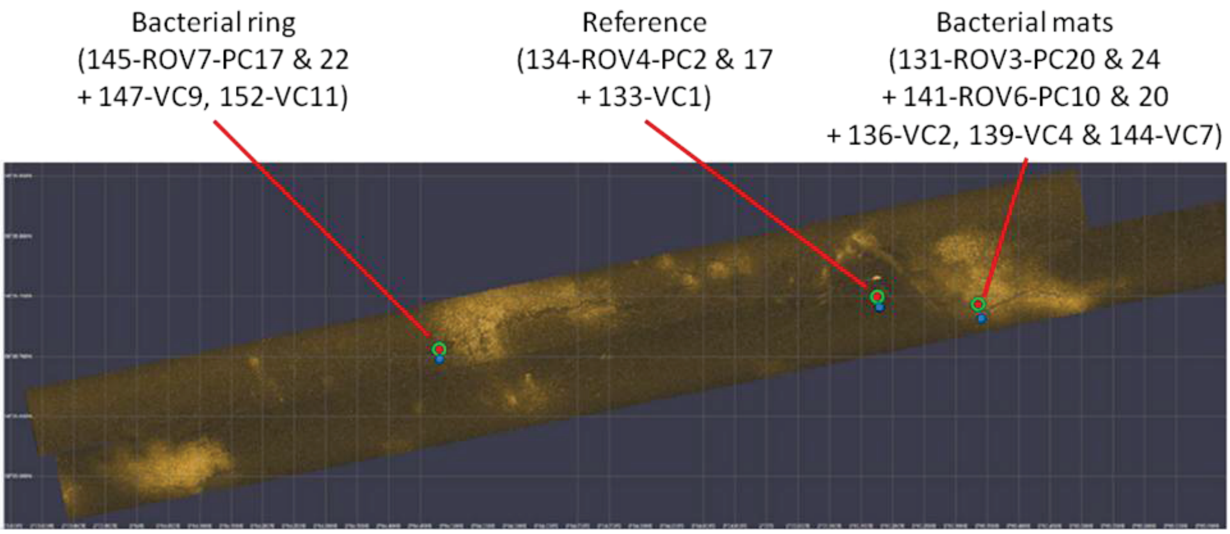

Figure 4.4.3: PC (red) and VC (blue) coring locations at the fracture, ~25 km north of Sleipner.

Preliminary results

Fracture

At the large "Hugin" fracture, ~25 km north of the Sleipner CO_2 injection point, seepage of reduced fluids and dissolved methane occurs and bacterial mats are abundant all along this structure. From the data collected in the course of CE12010, 2 sites with bacterial mats have been identified that have an exceptionally high seepage activity of fluids with approximate fluid advection velocities of 30 cm/a. These 2 sites as well as the reference site were revisited and cored again (Figs. 4.4.3+4.4.4).

Each PC showed a thin white-grayish fluffy bacterial coverage recovered directly at the fracture. The sediments consisted of sand throughout the core. The upper 10-20 cm of the sediment below bacterial mats were typically black and also smelled of H_2S. No living clams or tube worms were observed. The black sediments were covered by a very thin cover of brownish sediment, sometimes the black sediment was exposed directly on the seafloor, likely due to bioturbation from ubiquitous crabs and flat fish. The black sediment layer was usually followed by a 5-10 cm thick layer of shell hash from clams and sea urchins (in about 20-40 cmbsf in the vibrocores). From this shell layer downwards the sandy sediment was of gray color also with shell hash from mussels. In the vibrocores, a second shell layer was found in about 70-80 cmbsf. The grayish sand reaches down to

385 cmbsf (longest retrieved VC). From 170-200 cmbsf small black spots occur in the gray sand. At the reference site 50 m south of the fracture greenish-brownish sand was found instead of the black sediment. The transition to gray sand was typically observed below the upper shell layer.

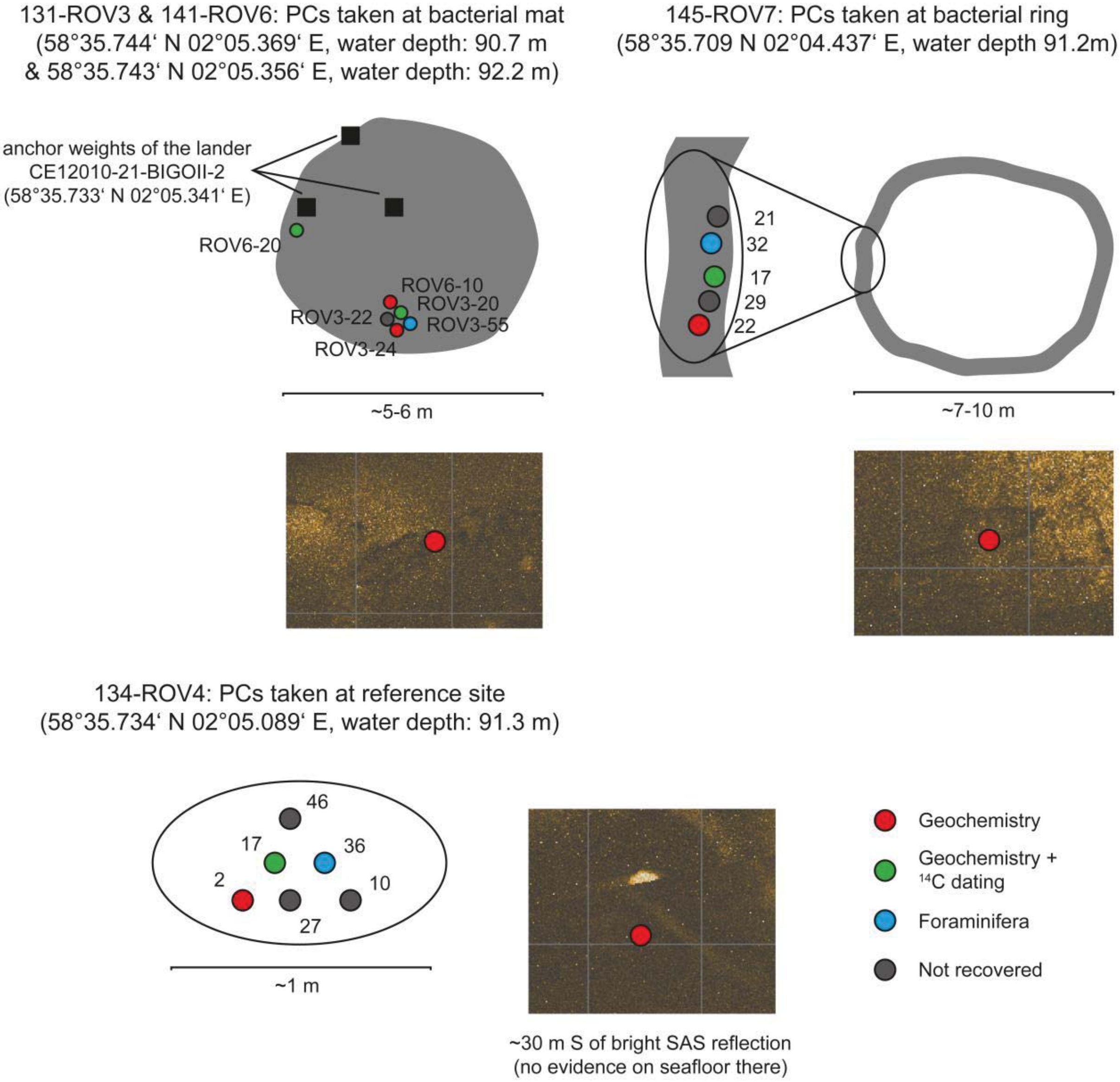

Figure 4.4.4: Details of the push coring at the fracture north of Sleipner. The PCs used for geochemical analyses including δD_{CH4} and $^{14}C_{DIC}$ are indicated by red and green dots, respectively. Location of the BIGOII lander from CE12010 is given in ship coordinates. PC locations are ROV-coordinates.

From the high TA values of the collected fracture PCs it can be deduced that fluid seepage activity at the revisited sites of the fracture is comparable to last year. As last year, the VCs from the fracture show only moderate TA increase from 2.8-3.7 meq/l up to 4.1 meq/l at around 40-60 cmbsf (Fig. 4.4.7). The reference situation is characterized by an even lower TA increase from 2.6 meq/l to ~3.5 meq/l at around 80 cm depth (Fig. 4.4.6). The moderate TA increase at the reference site as well as from the VC cores from the fracture indicate degradation of particulate organic carbon (POC) utilizing manganese(IV) and iron(III) oxy-hydroxides. Ammonium and phosphate concentrations, produced during POC degradation, generally stay moderate around 40-100 µM and <25 µM (Figs. 4.4.6+4.4.7), respectively. Three cores show a slight drop in phosphate concentration downwards, similar to the reference site (Figs. 4.4.6+4.4.7): the bacterial ring and 2 bacterial mats, 136-VC2, 147-VC8 and 144-VC7, Fig. 4.4.3). The elevated H_2S concentrations of >400 µM indicate sulfate reduction around 40-80 cmbsf.

Seismic chimney

At the 'rabbits eye' location in the centre of the seismic chimney site and the corresponding reference site 300 m to the south (Fig. 4.4.5), the visual sediment inspection as well as the downcore porewater solute profiles reveal no apparent differences (Figs. G4.4.6+4.4.7). The geochemical data are also very similar to the reference site of the fracture ~25 km north of Sleipner and thus, indicating degradation of particulate organic carbon (POC) utilizing manganese(IV) and iron(III) oxy-hydroxides and releasing NH_4 and PO_4 into the porewater (Figs. 4.4.6+4.4.7). No geochemical indications for active fluid or gas seepage exist at this seismic chimney.

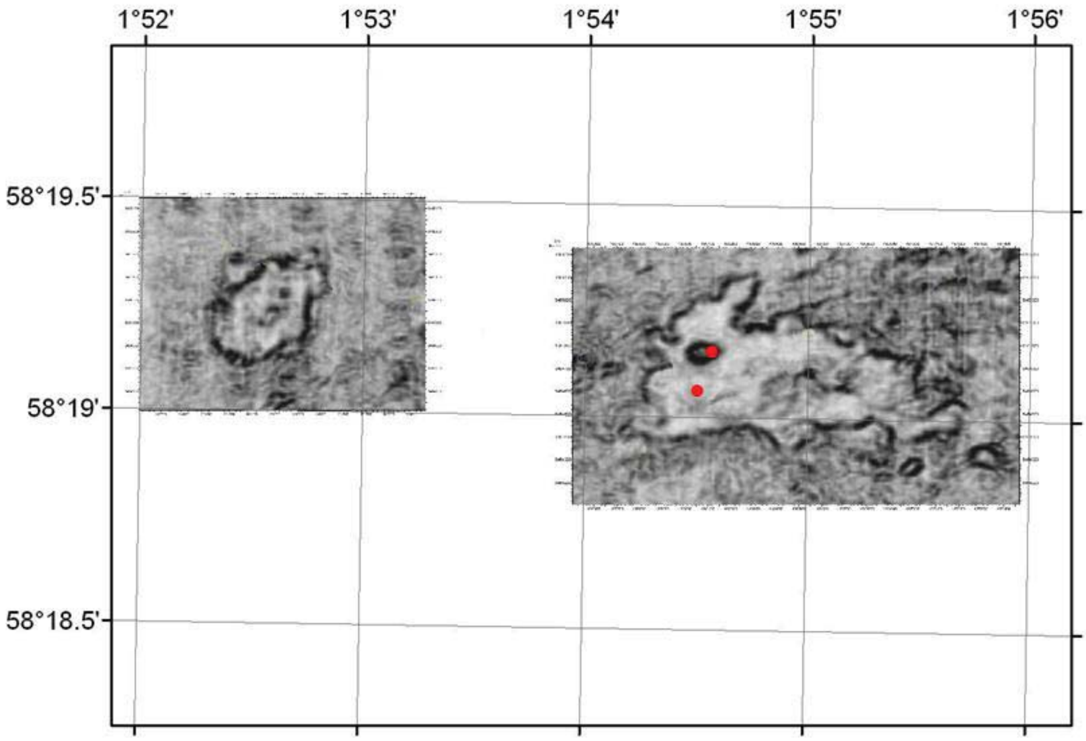

Figure 4.4.5: Vibro-Coring locations ('rabbits eye' and reference) at the seismic chimneys ~10 km south of Sleipner.

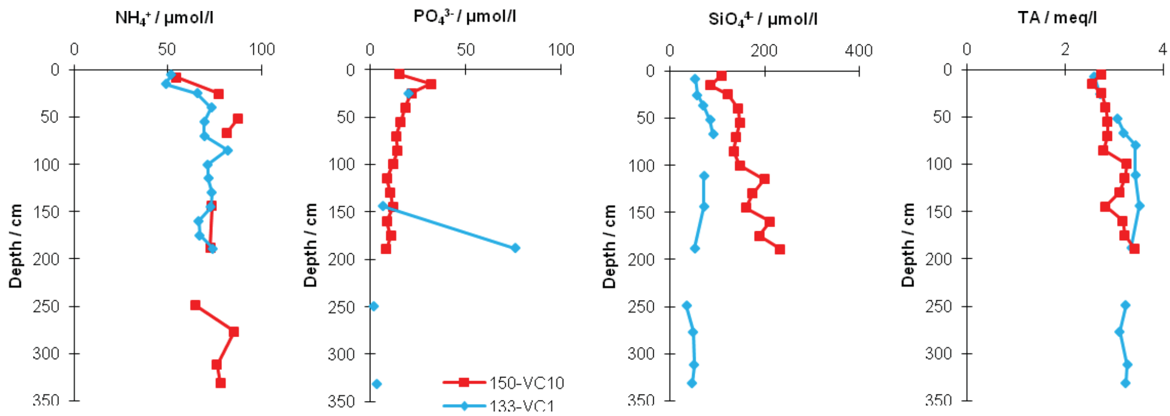

Figure 4.4.6: Reference VCs from the fracture north of Sleipner (blue) and the seismic chimneys south of Sleipner (red). Depths are given with respect to the top of the recovered core and are not corrected for any sediment loss that has occurred.

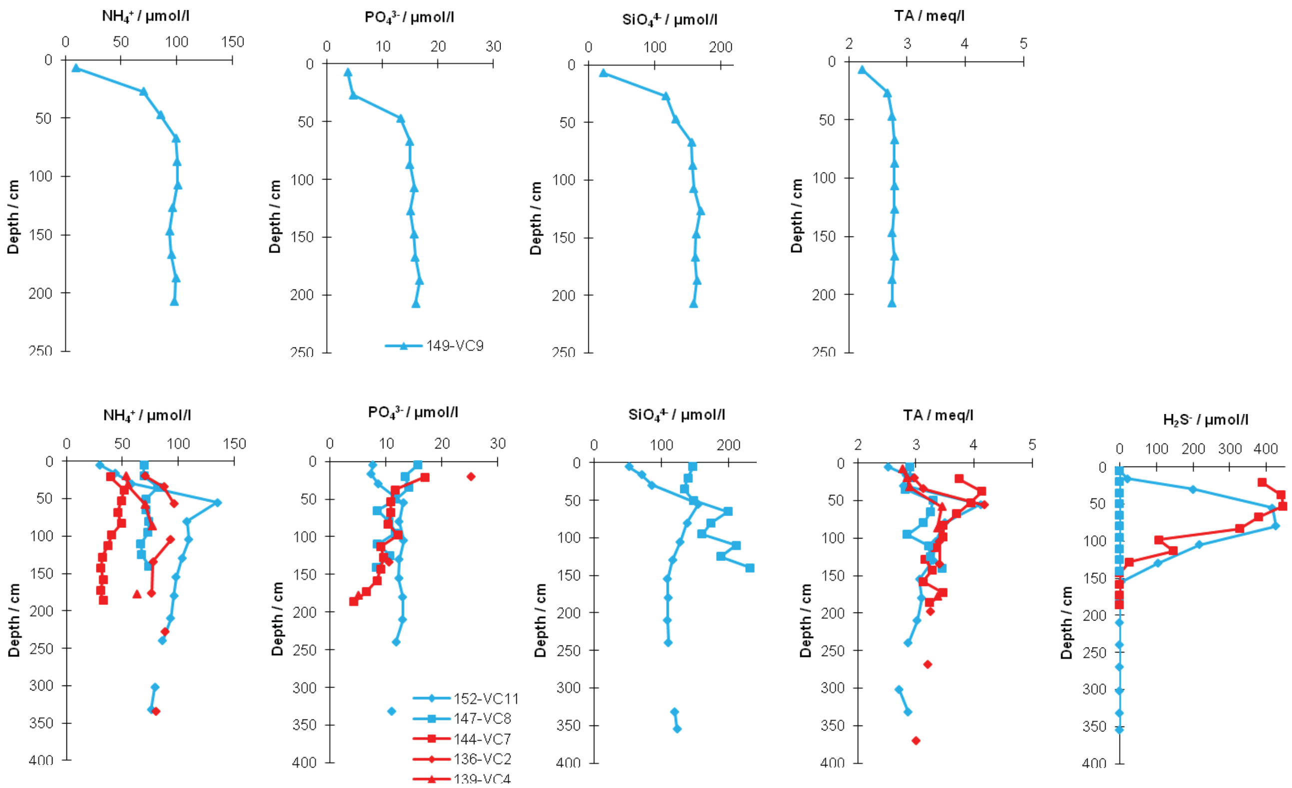

Figure 4.4.7: VCs from the centre of the seismic chimney 'rabbits eye' south of Sleipner (blue, top) as well as from the bacterial ring (blue, bottom) and the bacterial mat (red, bottom) at the fracture north of Sleipner. Depths are given with respect to the top of the recovered core and are not corrected for any sediment loss that has occurred.

5. *References*

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6. *Acknowledgements*

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7. *List of Stations*

Station No.	Gear	No.	Area	Date 2013	Start Time	Lat. °N	Long. °E	Depth (m)	at depth Time	Lat. °N	Long. °E	Depth (m)	End stat. Time	Lat. °N	Long. °E	Depth (m)	Remarks
120	VCTD	1	Blowout	26.03.	20:00	57°55.585'	1°38.301'	95					20:29	57°55.310'	1°38.030'	96	communication problem/no samples
121	VCTD	2	Blowout	26.03.	21:45	57°55.237'	1°37.768'	96					22:30	57°55.223'	1°37.979'	98	with CH4 sensor (001) at 85 m depth
122	PMS	1	Blowout	26.03.	23:00	57°55.466'	1°37.293'	96					01:32	57°54.960'	1°37.466'	96	1 km2 grid, air sampling in the mast
123	PMS	2	Blowout	27.03.	01:39	57°54.990'	1°37.618'	96					04:11	57°55.43'	1°37.22'	96	1 km2 grid, air sampling at working deck
124	Lander	1	Blowout	27.03.	07:45	57°55.312'	1°37.792'	95	07:47	57°55.301'	1°37.834'	94	07:55	57°55.281'	1°37.920'	95	
125	HISEM	1	Blowout	27.03.	08:46	57°55.525'	1°37.947'	95	09:13	57°55.304'	1°37.839'	95	09:18	57°55.269'	1°37.839'	95	sensor package tipped over
126	ROV	1	Blowout	27.03.	11:15	57°55.250'	1°37.880'	96					13:57	57°55.470'	1°37.440'	96	connecting sensor to lander by a line
127	VCTD	3	Blowout	27.03.	14:36	57°55.256'	1°37.995'	96					15:20	57°55.333'	1°37.656'	96	with CH4 sensor (001) at 40 m depth
128	VCTD	4	Blowout	27.03.	15:54	57°55.327'	1°37.991'	95					16:27	57°55.348'	1°37.672'	96	with CH4 sensor (001) at 10 m depth
129	VCTD	5	Blowout Referenz	27.03.	17:10	57°58.218'	1°39.655'	92					17:44	57°58.205'	1°39.740'	92	CTD failure/no samples
130	ROV	2	Sleipner	28.03.	07:35	58°35.910'	2°04.890'	92	07:59	58°35.801'	2°04.738'	92	11:04	58°35.580'	2°04.350'	92	Thruster failure/no push corer
131	ROV	3	Sleipner	28.03.	14:40	58°35.750'	2°05.330'	92	14:51	58°35.760'	2°05.340'	93	17:23	58°35.879'	2°05.120'	92	4 push cores
132	VCTD	6	Sleipner	28.03.	18:35	58°27.395'	1°58.591'	83	18:50	58°27.300'	1°58..640'	83	23:15	58°24.610'	1°57.345'	83	
133	VC	1	Sleipner	31.03.	06:10	58°35.755'	2°05.178'	94	06:12	58°35.758'	2°05.228'	94	06:41	58°35.749'	2°05.187'	94	
134	ROV	4	Sleipner	31.03.	07:25	58°35.861'	2°05.448'	92	07:35	58°35.820'	2°05.382'	92	10:55	58°35.719'	2°05.120'	93	6 push cores/problems with navigation
135	ROV	5	Sleipner	31.03.	12:30	58°35.807'	2°01.839'	93	12:49	58°35.807'	2°01.837'	93	14:45	58°35.700'	2°02.430'	93	no samples
136	VC	2	Sleipner	31.03.	15:13	58°35.726'	2°05.374'	95	15:15	58°35.722	2°05.384'	95	15:29	58°35.705'	2°05.541'	82	
137	VCTD	7	Sleipner	31.03.	16:50	58°24.662'	1°57.393	83	17:03	58°24.620'	1°57.390'	83	22:05	58°22.828'	1°57.016'	82	8 niskins
138	VC	3	Sleipner	01.04.	06:12	58°35.739'	2°05.363'	94	06:15	58°35.737'	2°05.356'	94	06:29	58°35.690'	2°05.255'	92	
139	VC	4	Sleipner	01.04.	07:10	58°35.737'	2°05.354'	94	07:12	58°35.736'	2°05.358'	94	07:21	58°35.740'	2°05.358'	94	

Station No.	Gear	No.	Area	Date 2013	Start Time	Lat. °N	Long. °E	Depth (m)	at depth Time	Lat. °N	Long. °E	Depth (m)	End stat. Time	Lat. °N	Long. °E	Depth (m)	Remarks
140	VCTD	8	Sleipner	01.04.	08:49	58°31.436'	2°01.049'	87	09:00	58°31.530'	2°01.070'	87	12:02	58°35.103'	2°00.590'	94	
141	ROV	6	Sleipner	01.04.	12:34	58°35.378'	2°05.336'	92	12:56	58°35.763'	2°05.336'	92	15:03	58°35.736'	2°05.675'	93	
142	VC	5	Sleipner	02.04.	06:05	58°35.752'	2°05.361'	94	06:07	58°35.748'	2°05.348'	94	06:15	58°35.742'	2°05.350'	94	
143	VC	6	Sleipner	02.04.	06:40	58°35.742'	2°05.358'	94	06:42	58°35.741'	2°05.352'	94	06:51	58°35.737'	2°05.347'	94	
144	VC	7	Sleipner	02.04.	07:07	58°35.754'	2°05.356'	94	07:10	58°35.754'	2°05.360'	94	07:23	58°35.770'	2°05.356'	94	
145	ROV	7	Sleipner	02.04.	08:03	58°35.394'	2°04.094'	92	08:41	58°35.736'	2°04.508'	91	10:45	58°35.726'	2°04.478'	91	
146	ROV	8	Sleipner	02.04.	12:30	58°35.777'	2°01.780'	94	12:38	58°35.773'	2°01.779'	94	14:12	58°35.759'	2°01.853'	93	
147	VC	8	Sleipner	02.04.	16:01	58°35.719'	2°04.427'	94	16:05	58°35.717'	2°04.415'	94	16:18	58°35.706'	2°04.399'	94	
148	ROV	9	Sleipner	03.04.	06:09	58°19.172'	1°54.528'	82	06:18	58°19.175'	1°54.526'	82	09:05	58°19.410'	1°54.550'	83	
149	VC	9	Sleipner	03.04.	10:29	58°19.162'	1°54.504'	84	10:30	58°19.165'	1°54.513'	84	10:54	58°19.193'	1°54.477'	84	
150	VC	10	Sleipner	03.04.	11:18	58°18.839'	1°54.373'	84	11:20	58°18.839'	1°54.371'	84	11:30	58°18.842'	1°54.354'	84	
151	ROV	10	Sleipner	03.04.	12:27	58°19.241'	1°52.665'	83	12:38	58°19.243'	1°52.684'	83	15:40	58°19.405'	1°52.256'	84	
152	VC	11	Sleipner	04.04.	06:02	58°35.713'	2°04.426'	94	06:05	58°35.713'	2°04.424'	94	06:14	58°35.726'	2°04.401'	94	
153	VC	12	Sleipner	04.04.	06:40	58°35.715'	2°04.421'	94	06:42	58°35.707'	2°04.419'	94	06:58	58°35.713'	2°04.411'	93	
154	VC	13	Sleipner	04.04.	07:21	58°35.713'	2°04.425'	94	07:23	58°35.708'	2°04.423'	94	07:37	58°35.711'	2°04.433'	94	
155	VCTD	9	Sleipner	04.04.	10:00	58°22.140'	1°56.113'	81	10:15	58°22.100'	1°57.030'	81	12:06	58°23.126'	1°53.335'	85	
156	VCTD	10	Blowout Referenz	05.04.	06:00	57°58.202'	1°39.701'	95					06:30	57°58.252'	1°39.658'	95	
157	Lander with HISEM	1	Blowout	05.04.	11:04	57°55.200'	1°37.810'	95					13:42	57°55.310'	1°37.610'	95	Acoustic release failed but the mooring was taken up by a hook
158	VCTD	11	Blowout	05.04.	12:38	57°55.267'	1°37.823'	95					13:09	57°55.290'	1°37.750'	95	CTD with a hock to recover lander

ROV PHOCA (ROV), Video - CTD/Rosette (VCTD), Lander (STL), Vibro Corer (VC), Picarro CRDMS (PMS)