Cruise Report GS11B

The Sleipner area, North Sea

R/V G.O. Sars, **Expedition No.** 2011108/CGB2011

June 24th– July 1st 2011

Bergen, Norway – Bergen, Norway

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Cruise report prepared by Laila Johanne Reigstad (CGB, UoB).

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1 Introduction

1.1 Participants

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1.2 Objectives

The 2011 cruise to the area overlying the subsurface CO2 storage site of the Utsira Formation around the Sleipner platforms in the North Sea, was part of the activities at the Centre for Geobiology and the research project ECO2 funded by the European Union/European Atomic Energy Community Seventh Framework Programme ([*FP7/2007-2-13*] [*FP7/2007-2011*]) under grant agreement n° [*265847*]. The main objectives of this expedition were 1) to test and improve procedures and techniques for mapping and imaging of the seafloor overlying the CO_2 plume of the Utsira Formation, 2) to test and improve methane bubble detection and imaging techniques at three abandoned wells (Statoil, 1980ies) located close to the rim of the subseafloor CO_2 plume, 3) to test techniques for high resolution digital photoing of seafloor bacterial mats for creating photo mosaic, 4) to sample intact sediment cores from the Sleipner area for on-shore laboratory experiments looking at impacts of a simulated CO_2 leakage.

1.3 Background

1.3.1 Storage of CO2 gas in the Utsira Formation of the North Sea.

Since 1996, Statoil has injected CO2 gas from the Sleipner West field and into the Utsira Formation (Fig 1, left panel). At the Sleipner West platforms in the northern part of the North Sea, Statoil pumps up natural gas from approximately 3000 m depth below the seafloor (Fig. 1, middle panel). The natural gas has a too high content of CO2 gas, and the CO2 is extracted on the platforms by the amide technology. The extracted CO2 gas is contionously reinjected into the saline aquifer of the Utsira Formation at approximately 1200 m depth below the seafloor. By 2011 about 12 million tons of CO2 had been injected. The subseafloor CO2 plume covers today an area of approximately 4 km in length and about 1 km wide (Fig. 1, right panel).

The storage of CO2 in the Utsira Formation is the largest industrial scale storage site worldwide, and is used as study site for several national and European projects on Carbon Capture and Storage (CCS). The CCS is regarded as a key technology for 6the reduction of CO2 emissions from power plants and other industrial sources at

the European and international level.

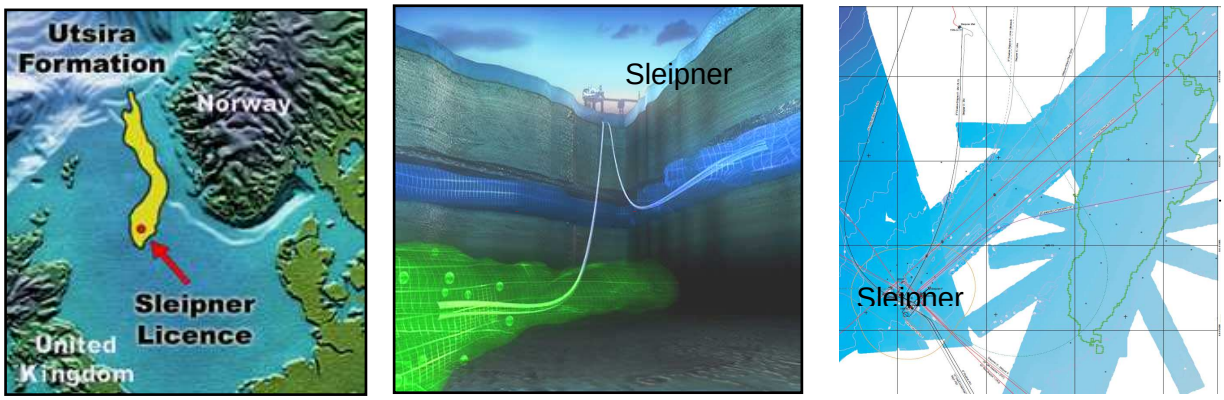

Figure 1. Storage of CO2 gas in the Utsira Formation, North Sea. Left panel: The Utsira Formation (yellow) is a huge saline aquifer. The injection well for the CO2 gas (red dot) is located in the southern part of the formation. Middle panel: Natural gas (green) is pumped to the Sleipner platform from 3000 m depth below the seafloor (mbsf). The CO2 gas extracted on the platform is reinjected into the Utsira Formation (blue) at about 1200 mbsf. Right panel: The green line shows the rim og the injected CO2 gas as it was in 2008, revealing a size of approximately 4 x 1 km of injected CO2. Scale: each square is 1 x 1 km. All drawings modified from Statoil.

1.3.2 Scientific studies of sub-seabed CO2 storage sites.

Center for Geobiology is a partner of two large CCS project; the national SUCCESS project, and the European ECO2 project. Both project have, among other sites, focus on the Sleipner area of subseafloor CO2 injection and storage.

The ECO2 (Sub-seabed Carbon Dioxide Storage: Impact on Marine Ecosystems) project sets out to assess the risks associated with storage of CO2 below the seabed. Little is known about the short-term and long-term impacts of CO2 storage on marine ecosystems even though CO2 has been stored sub-seabed at Sleipner for over 15 years and for more than three years in the Barents Sea (Snøhvit).

Against this background, the ECO2 project will assess the likelihood of leakage and impact of leakage on marine ecosystems. Novel monitoring techniques will be applied to detect and quantify the fluxes of formation fluids, natural gas, and CO2 from storage sites. A best practice guide will be developed for the management of sub-seabed CO2 storage sites considering the precautionary principal and costs of monitoring and remediation. The ECO2 project has 27 partners, including Statoil and Det Norske Veritas, and the scientific core of ECO2 is formed by work packages WP1 – WP4. Centre for Geobiology is directly involved in WP 1, 2 and 3, dealing with application of natural science approaches to constrain the potential pathways and the likelihood of leakage from storage sites through the sedimentary overburden (WP1), to quantify emission rates at the seabed (WP2), and to investigate the fate of the emitted CO2 (WP3).

The Norwegian SUCCESS project (Subsurface CO2 storage, critical elements and superior strategy) addresses several important areas for CO2 storage in the subsurface: storage performance, sealing properties, injection, monitoring and consequences for the marine environment. Centre for Geobiology is here a member of Activity 5: The marine component. The main goal of Activity 5 is to improve the understanding of shallow marine processes and the ecological impact of CO2 exposure, and develop marine monitoring methods. The activity addresses CO2 seeps through the seabed in terms of (i) knowledge gaps on processes in the upper sediment/benthic boundary layer; (ii) ecological impact from CO2 exposure; (iii) monitoring technologies.

This cruise to the Sleipner area in June 2011 was the start-up of Centre for Geobiology´s scientific inputs to both ECO2 and SUCCESS.

1.3.3 Abandoned gas bubbling wells close to the subseafloor CO2 storage site of the Utsira Formation

Over the last decades there have been steadily increasing drilling activity in the North Sea, some successful and some not. This has resulted in a high number of cemented, abandoned wells. Three such abandoned wells, drilled during the early 1980ies by Statoil, are located close to the rim of the subsurface CO2 storage site

in the Utsira formation (Fig. 2). All three wells are known to leak gas bubbles of unknown gas composition, and are featured research sites for the ECO2 project partners. The well 15/9-13 is the well closest to the subseafloor CO2 plume, located only 250-300 m from the rim of the plume.

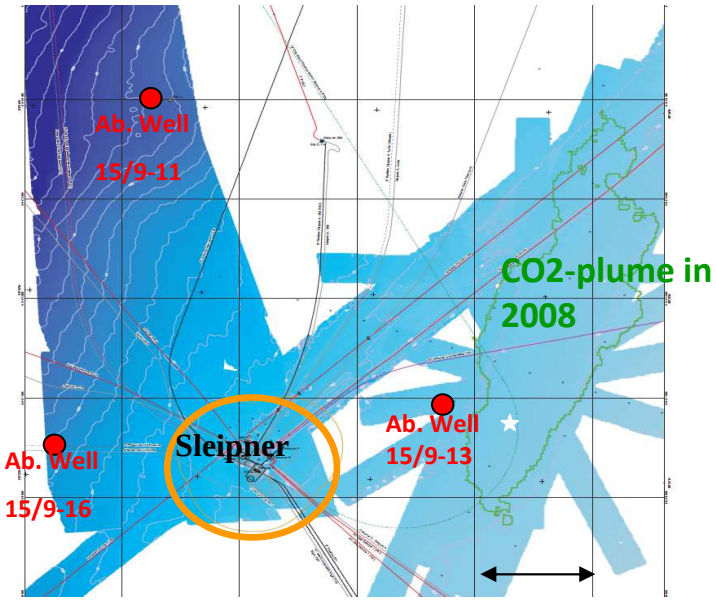

Figure 2: Location of the three abandoned wells (red circles) closest to the rim of the Utsira Formation subseafloor CO_2 plume and the Sleipner West platforms (yellow circle). The approximate location of the CO2 injection point in denoted with a white star. Modified from Statoil. The arrow indicates a distance of 1 km. Ab. Well; abandoned well.

2 METHODS: Cruise Logistics and Operations

2.1 Operational equipment

2.1.1 Multibeam Echosounder EM302

Bathymetric mapping was performed with a EM 302 multibeam echo sounder. The EM 302 use a nominal sonar frequency of 30 kHz, with an angular coverage sector of up to 150 degrees and 135 beams, and is designed to do mapping from 10 m depths up to 7000 m. A transmit fan is split into individual sectors, each with active steering according to the vessel roll, pitch and heave, and each sounding is placed on a best fit on a line perpendicular to the survey line.

2.1.2 Singlebeam echo sounder EK60

The Simrad EK60 installed onboard the G.O. Sars is an echo sounder that can operate sever echo sounder frequencies simultaneously ranging from 18 to 710 kHz.

2.1.3 Parametric Sub Bottom Profiler Topas PS 018

The G.O. Sars is equipped with a parametric sub bottom profiler Topas PS 018 operating at a primary frequency of 15 kHz (secondary 0.5 - 5 kHz) and a primary beam with of 3.5 degrees (secondary 5 degrees). It has a depth range of 30 to 10000 meters, a range resolution of less than 0.3 meters and a penetration capacity of over 150 meters.

2.1.4 ROV

During the cruise the ship was equipped with the ROV Bathysaurus II, which has a depth range of 4000 meters. The Bathysaurus II was equipped with the best manipulator arms available, state-of the-art positioning systems, and high-resolution digital camera for stills, and advanced digital video cameras.

2.1.4.1 ROV equipment

Temperature-probe: A temperature probe for the range of 0-150 °C was used for measurements of seabed sediment (down to 25 cm).

Water samplers: The water sampling system with two 1 l titanium fluid samplers. Depending on the type of fluid sampled, these bottles were attached to a stick (sediment pore fluids), or a funnel (low temperature diffuse flow or gas bubbles sampling).

Gas samplers: 250 ml gas tight samplers (GT) were used.

Biosyringe: A hydraulic sampling cylinder (1 litre) with a ~1 cm wide tube was used for sampling of seafloor bacterial mats.

Sampling box (L:60cm, W:60cm, H:30cm)***:*** An aluminum scuffle box was fixed to the frame of the ROV for bulk collection of seafloor sediment.

Push cores: Two special holders for push cores were placed on the ROV for seabed sampling of sediment with fragile bacterial mats on top. On this cruise only 10 cm pushcores were possible to obtain due to massive extinct shell-harsh areas.

Digital Camera: This year a digital camera was mounted under the ROV (in addition to an extra light source) in order to take hundreds of high resolution (HD) pictures while slow movment over areas of bacterial mats. The pictures were later put together as photo mosaic.

2.1.5 AUV

During the cruise the ship was equipped with the autonomous underwater vehicle (AUV) Hugin 1000 (operated by FFI). The AUV hosted a high resolution interferometric synthetic aperture sonar (HISAS 1030) capable of providing high resolution images and detailed bathymety of the seafloor. In addition, the AUV was equipped with an EM 3002 multibeam echo sounder and with a black/white camera that allowed geo-referenced photo mosaicing.

2.1.6 CTD

For measurements of conductivity, temperature and density of the water column a Seabird 911 CTD rosette with 12 Niskins bottles for water sampling, 5 L each. Standard setup is with SBE 4C conductivity sensor and SBE3plus temperature sensor.

2.2 METHODS: Shipboard geochemical analysis and sample preparation

Dissolved gases and several redox sensitive parameters and nutrients in fluids, water column and sediment porewater (e.g. H_2, CH_4, O_2, sulphide, alkalinity, pH, ammonium, NO_{tot}, PO_4, DIC) were measured onboard. In addition, samples for onshore analyses of other essential parameters (major and trace elements, stable isotopes, organic acids, nutrients) in fluids and solids (TIC, TOC, stable isotopes) were collected and preserved onboard.

2.2.1 Shipboard: Collection of porewater from sediment push cores

Porewater sampling was carried out immediately after obtaining the push cores by using Rhizon samplers at intervals in the range of 3 cm. Rhizon samplers use the vacuum produced by syringes to extract the porewater.

2.2.2 Shipboard: Collection of gas bubbles

Gas bubbles (methane) leaking from the seafloor of three abandoned wells (Statoil) were collected by using a funnel connected to the titanium-major sampling bottles. Gas bubbles were collected as long as a headspace in the funnel became clearly visible and the amount was high enough to fill the two Ti-bottles of 1 liter each. These gas samples were then collected for shipboard CH_4 and H_2 gas chromatography (TOGA SRI 8610C; description of the detectors below), into gas bags for later onshore gas chromatography and and into vacutainors for $\delta^{13}C_{CH4}$ analysis at the ETH Zürich, Switzerland.

2.2.3 Shipboard: Collection of dissolved gases

The dissolved gases collected on the cruise included: O_2, H_2, CH_4, higher hydrocarbons, He and H_2S. The dissolved gases were collected from 4 different sample types: 1) from water column taken by CTD, 2) from porewater extracted from push cores, 3) from fluid samples in Titanium-major samplers, and 4) from gas bubbles rising from the seafloor using a funnel sampler to collect the bubbles (1 hour of bubble sampling on seafloor before the pure gas in the top of the funnel was sampled.

2.2.3.1 He, H_2 and CH_4 analyses.

For H_2 and CH_4 analyses 100 ml of each fluid sample were collected in a 140 ml syringe and added 40 ml helium gas. The fluid and gas were mixed well by shaking and left for at least 30 min at room temperature before the headspace gas in the syringe was analysed onboard by using a TOGA SRI 8610C gas chromatograph (GC) equipped with a highly sensitive He-pulsed discharge detector (PDD) for hydrogen analyses and with a flame ionization detector (FID) for methane analyses provided by the University of Washington, USA. Gas cylinders with 5.0 He (carrier gas, 2 x 50 L), 5.0 H_2 (1 x 50 L) and syntetic air (2 x 50 L) were connected to the gas pipeline system in the gas central room on the ship (regulators onboard). Helium was additionally purified before entering the GC.

Immediately upon recovery of the CTD sampling package, air-free water samples were flushed through 24-inch-long sections of refrigeration grade Cu tubing with duplicate half-sections cold-weld sealed for later laboratory determinations of He concentrations at NOAA/PMEL Helium Isotope Laboratory in Newport, OR, USA.

2.2.3.2. Dissolved H2S gas analyses.

Dissolved H_2S gas was analysed by using the Quaatro Continuous Flow Analyzer (Seal Analytical) as described below (2.2.4).

2.2.3.3. Dissolved O_2 analyses.

Dissolved O_2 concentrations were measured *in-situ* using a needle-type fiber-optic microsensor (PreSens, Germany) directly put into the different sediment horisons. For all sediment horison the O_2 measurements were done over 1 minute, in triplicate.

2.2.3.4 Dissolved gases in sediment of push cores.

For H_2 and CH_4 analyses 5 ml of sediment was collected with a 10 ml tip cut plastic syringe at the middle to bottom part of the 10 cm long push core to a 140 ml syringe with 100 ml of 1.2 M NaCl solution with sodium azide (0.1%) and 40 ml helium gas. The content was mixed by shaking and left for at least half an hour at room temperature before the headspace gas was analysed by using a GC.

Dissolved H_2S was analysed in extraced pore water by using the Quaatro Continuous Flow Analyzer (Seal Analytical) (see 2.2.4).

Dissolved O_2 concentrations were measured in extracted pore water and directly into the sediment using needle-type fiber-optic microsensors (PreSens). For each sample all O_2 measurements were done over 1 minute, in triplicate.

2.2.4 Shipboard: pH, alkalinity and nutrients analyses

Aliquots of pore water (2 ml) and CTD water samples (60-100 ml) was analysed onboard. pH was measured using a mobile pH meter (Metrohm), alkalinity was measured by the use of a Titrino autotitrator (Metrohm).

Concentrations of dissolved sulphide, ammonium, nitrate/nitrite and phosphate in seawater and pore water were analysed onboard by photometric methods using a 4-channels Quaatro Continuous Flow Analyzer (Seal Analytical). For sulphide and

ammonium the methylene blue and indophenol methods were used, respectively. Nitrate was reduced to nitrite by a Cu-Cd reduction coil, and nitrite was then detected as a red complex. For phosphate the blue phosphor-molybdenium method was applied.

2.2.5 Shipboard: Preparation of samples for onshore analyses

For onshore gas chromatography, gas samples collected from gas bubbles were storred in gas-tight bags at room temperature. Aliquots of were collected in gas-tight vials or vacutainer tubes for onshore analyses of stable carbon isotope ratios of methane ($\delta^{13}C_{CH4}$) at the ETH Zürich, Switzerland.

For onshore ion chromatography (IC) analyses at UiB of Cl, SO_4^{2-}, and Br^- aliquots of vent fluid, CTD and pore water samples were filtered (0.2 μm) and collected on 10 or 30 ml sized plastic bottles and stored in the fridge at ~ 4°C.

For onshore inductively coupled plasma optical emission spectrometry (ICP-OES) analyses at UiB of alkali elements (Li, Na, K), alkali earth elements (Mg, Ca, Sr, Ba), and other elements (e.g. Mn, Fe, Si, Al, B, Ti, heavy metals) aliquots of vent fluid, CTD and pore-water samples were filtered (0.2 μm) and collected on 10-100 ml sized acid clean plastic bottles, acidified by adding ultra pure nitric acid to a final concentration of 3%, and stored in the fridge at ~ 4°C.

For onshore analyses of nitrate, nitrite and phosphor by using Quaatro Continuous Flow Analyzer (Seal Analytical) at UoB, aliquots of water from CTDs and pore water samples were filtered (0.2 μm) and collected on 10 or 30 ml sized amber plastic bottles and stored in the freezer at -20°C.

Porewater aliquots and CTD samples for background seawater concentrations were furthermore collected for analyses of stable sulphur isotope composition of sulphide (approx. 4 samples) and sulphate (approx 30 samples), for water isotope composition (H and O) and for carbon isotope composition of DIC in Zürich, Switzerland. Samples for H and O isotope analyses were untreated and stored in amber plastic bottles. For S stable isotope measurements, Cd-acetate was added to

precipitate CdS and preserve the sample in amber plastic bottles. For DIC stable isotopes analyses, 0.2 to 1 ml filtered (0.2 µm) sample was injected into prepared (5 drops of melted phosphoric acid, flushed with He) vacutainors without having air contact. All samples, except for DIC which was stored at room temperature, were stored in the fridge at ~ 4°C.

In addition, sediment samples for analyses of total inorganic carbon (TIC), total carbon (TC), and the stable carbon isotopic composition ($\delta^{13}C_{TIC}$ and $\delta^{13}C_{TOC}$) were collected in sterile sampling bags and stored at -80°C for later analyses at ETH in Zürich, Switzerland. All used instruments were cleaned beforehand with DCM.

2.3 Shipboard Microbial analysis and sample preparations for onshore analysis

The samples for microbial analyses taken on this cruise will not be a part of the ECO2 WP5 as CGB is not playing a role in Sleipner issues in WP5. The data will be analysed in the frame of the Norwegian Research Council project FME-SUCCESS as the microbiologist performing these analysis is working in this project. A short description of sampling for microbial analysis is never the less included below.

The majority of the microbial samples were push cores (PC) of 5 cm inner diameter, retrieved by the ROV. All these cores were sliced cm by cm. Generally, for each cm thick horizon in all of the cores, the sampling strategy was the same; the sediment slice was divided into six pieces, each for a different purposes: RNA analyses, DNA analyses, virus extraction, FISH and DAPI microscopy and macrofauna counts and classification (Fig. 3). The slicing of sediments was performed quickly in a continuous flow of N_2 gas. For selected horizons in selected cores, sediment was also sampled for *in-situ* sulfate reduction rates. This sediment was mostly taken from the part usually going for DNA and macrofauna analyses.

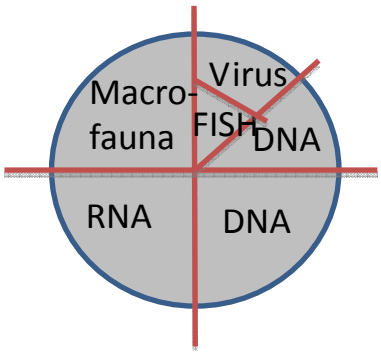

Figure 3: Schematic drawing of a 5 cm in diameter sediment slice highlighting the different sections sampled for different microbial analyses (see text).

Abandoned well 15-9/13 and baseline/background 20 m outside the well

There are three abandoned wells drilled during the 1980ies (Statoil) located close to the rim of the subsurface CO2 storage site in the Utsira formation (Fig. 2). The well closest to the storage site is well 15/9-13. Of the three wells, both geochemical and microbial sampling was focused on this well, but geochemical analyses were also performed on wells 15/9-11 and 15/9-16 (Fig. 2).

For data comparison, a location 20 m from the well was also sampled in order to be used for background/baseline studies. All three wells leaked gas bubbles of unknown composition.

3 CRUISE ACTIVITIES

All cruise activities are listed below. Initial results will be given in Chapter 4.

3.1 Fluid and gas analyses

Table 1: Obtained fluid samples from Titanium-Syringes, Biosyringes and CTDs.

Fluids from Ti-Syringes				
Date	**Station**	**DIC**	**S**	**O,H,B**
01.07.11	GS11B-ROV21-Major1	1 ml	30 ml	30 ml
	GS11B-ROV21-Major2	1 ml	30 ml	30 ml
Fluids from Biosyringe/Slurper				
Date	**Station**	**DIC**	**S**	**O,H,B**
26.06.11	GS11B-ROV4-BS	1 ml	30 ml (filt)	30 l
Water column (CTD)				
Date	**Station**	**DIC**	**Sulphate**	**O,H,B**
29.06.11	GS11B-CTD5 Bt 1 (90 m)	1 ml	30 ml	30 ml

Table 2: Collected gas samples.

Gas Bubbles			
Date	**Station**	**Gas bubbles in evacuated Vacutainer**	**Description/Comment**
28.06.11	GS11B-ROV3-Major	2 x from bag	Well 15/9-13 (Eastern Well, new)
28.06.11	GS11B-ROV8-Major	5 x from GC syringe	Well 15/9-11 (Northern Well)
28.06.11	GS11B-ROV9-Major	5 x from GC syringe and 2 x from bag	Well 15/9-16 (Southern Well)

Table 3: Samples for shore-based analyses from pore water extractions.

Date	Station	DIC	Sulphate
27.06.11	GS11B-ROV7-PC1		
	1		2 ml + HCl
	2		2 ml + HCl
	3		2 ml + HCl
	4		2 ml + HCl
	0-5 cm		2 ml + HCl
29.06.11	GS11B-MC-"Leila 2" Core 10	1 ml	2 ml + HCl
	1.5 cm	1 ml	2 ml + HCl
	4.5 cm	1 ml	2 ml + HCl
	7.5 cm	1 ml	2 ml + HCl
	10.5 cm	1 ml	2 ml + HCl
	13.5 cm	1 ml	2 ml + HCl
	16.5 cm	1 ml	2 ml + HCl
	20 cm	1 ml	2 ml + HCl
28.06.11	GS11B-ROV10-PC		
	1		2 ml + HCl
	2		2 ml + HCl
	3		2 ml + HCl
	4		2 ml + HCl
28.06.11	GS11B-ROV11-PC		
	1		2 ml + HCl
	2		2 ml + HCl
	3		2 ml + HCl
	4		2 ml + HCl
30.06.11	GS11B-ROV18-PC		
	0 to 3 cm	1 ml	
	3 to 6 cm	1 ml	
	6 to 9 cm	1 ml	
	9 to 12 cm	1 ml	
30.06.11	GS11B-ROV19-PC		
	0 to 3 cm	1 ml	2 ml + HCl
	3 to 6 cm	1 ml	2 ml + HCl
	6 to 9 cm	1 ml	2 ml + HCl
	9 to 10.5 cm	1 ml	2 ml + HCl
01.07.11	GS11B-ROV21-PC1		
	0 to 4 cm	1 ml	2 ml + HCl
	4 to 7 cm	1 ml	2 ml + HCl
	7 to 10 cm	1 ml	2 ml + HCl

Table 4: Seawater sampled above push cores and multicores.

Seawater above push cores / multi cores				
Date	Station	DIC	Sulphur	O,H,B
28.06.11	GS11B-ROV12-PC	1 ml	30 ml	30 ml (filt)
29.06.11	GS11B-MC- "Laila 2" Core 14	1 ml	30 ml	30 ml

Table 5: Sampled sediments.

Date	Station	C,N iso	Sulphur	XRD
26.06.11	GS11B-ROV4-PC			
	bacterial mat (top)	x	x	x
	3 cm	x	x	x
	5 cm	x	x	x
	GS11B-ROV7-PC			
	0 to 2.5 cm	x		x
	2.5 to 5 cm	x		x
	5 to 7.5 cm	x		x
	7.5 to 10 cm	x		x
27.06.11	GS11B-ROV9-Skuff			x
	GS11B-ROV10-PC			
	0 to 3 cm	x	(x)	x
	3 to 6 cm	x	(x)	x
	6 to 9 cm	x	(x)	x
	9 to 12 cm	x	(x)	x
28.06.11	GS11B-ROV11-PC 1			
	0 to 3 cm	x	(x)	x
	3 to 6 cm	x	(x)	x
	6 to 9 cm	x	(x)	x
	9 to 12 cm	x	(x)	x
28.06.11	GS11B-ROV12-PC			
	0 to 2 cm	x	x	x
	¨2 to 3 cm	x	x	x
	3 to 4 cm	x	x	x
	4 to 5 cm	x	x	x
	5 to 6 cm	x	x	x
	6 to 7 cm	x	x	x
	7 to 8 cm	x	x	x
	8 to 9 cm	x	x	x
	9 to 10 cm	x	x	x
29.06.11	GS11B-MC- "Laila 2" Core 14			
	1 to 2 cm	x	x	x
	2 to 3 cm	x	x	x
	3 to 4 cm	x	x	x
	4 to 5 cm	x	x	x
	5 to 6 cm	x	x	x
	6 to 7 cm	x	x	x
	7 to 8 cm	x	x	x
	8 to 9 cm	x	x	x
	9 to 10 cm	x	x	x
	10 to 11 cm	x	x	x
	11 to 12 cm	x	x	x
	12 to 13 cm	x	x	x
	13 to 14 cm	x	x	x
	14 to 15 cm	x	x	x
	15 to 16 cm	x	x	x
	16 to 17 cm	x	x	x
	17 to 18 cm	x	x	x
	18 to 19 cm	x	x	x
	19 to 19.5 cm	x	**x**	x

Table 6: Overview of CTD casts.

Activity	Date	Time (Norw)	Coordinates		Depth (m)	Subject	Comments	Sensors	Analysis
11B-01-CTD-01	24.06.2011	11:58	60°25.44`N	05°16.92`E		file = 236	Calibration	calibr	no water samples
11B-03-CTD-02	25.06.2011	05:17	58°24.52`N	01°59.51`E	80	file = 237	Calibration	calibr	no water samples
11B-35-CTD-03	28.06.2011	17:13	58°24.019`N	01°53.62`E	87	file = 238	Plume of Well 15/9-11. Currents towards 45°. We moved to 25 m NE of the well to catch the plume. Depths: 1) 80, 2) 69, 3) 59, 4) 49, 5) 39, 6) 29, 7) 19, 8) 9 - did not close, 9) 4.	x	dis gas, anions, cations, pH, alk, nut
11B-39-CTD-04	29.06.2011	09:07	58°33.24`N	02°05.69`E	91	file= 239	Calibration	calibr	no water samples
11B-40-CTD-05	29.06.2011	10:20	58°41.437`N	02°09.799`E	100	file = 240	Background water column gas and water analyses, at site "Laila". 36 km NE of Well 15/9-11. Depths: 1) 90, 2) 79, 3) 69, 4) 59, 5) 49, 6) 39, 7) 29, 8) 20, 9) 10, 10) 4.	x	dis gas, anions, cations, pH, alk, nut
11B-54-CTD-06	29.06.2011	16:40	58°33.153`N	01°40.758`E	120	file = 241	Bottom seawater for the large laboratory CO2-exposure experiment. Plus water analysis (Ingunn).	x	anions, cations, pH, alk
11B-60-CTD-07	30.06.2011	18:30	58°22.561`N	01°56.754`E	85	file = 243	Bottles 1, 3, 4 and 6 not closed. We will redo this CTD.	x	no water samples
11B-61-CTD-08	30.06.2011	18:45	58°22.561`N	01°56.754`E	85	file = 244	Above CO2 plume.4 km SE of Well 15/9-11. Depths: 1) 80, 2) 69, 3) 59, 4) 48, 5) 39, 6) 29, 7) 18, 8) 9 9) 5	x	dis gas, anions, cations, pH, alk
11B-63-CTD-09	30.06.2011	20:43	58°25.165`N	01°54.897`E	88	file = 245	2.5 km NE of Well 15/9-11. Depths: 1) 80, 2) 69, 3) 59, 4) 49, 5) 39, 6) 29, 7) 20, 8) 9 9) 5 m.	x	dis gas, anions, cations, pH, alk

3.2 Microbial and macrofauna sampling/preservations

3.2.1 Sampling at the abandoned gas-bubbling well 15/9-13 (ROV4, ROV11 and ROV12):

ROV4_Biosyringe (BS): for DNA, RNA, FISH, DAPI, virus analyses.

ROV4_Push core (PC): for DNA, RNA, FISH, DAPI, virus analyses.

ROV11_PC: for DNA, RNA, FISH, DAPI, virus analyses.

ROV12_PC: for DNA, RNA, FISH, DAPI, virus and microbial sulfate reduction rate

analyses.

3.2.2 Sampling at Baseline/background site located 20 m outside well 15/9-13 (ROV7, ROV10):

ROV7_PC: for DNA, RNA, FISH, DAPI analyses.

ROV10_PC: DNA, RNA, FISH, DAPI, virus and microbial sulfate reduction rate analyses.

3.2.3 Harvest of intact sediment cores for CO2 leakage lab experiment

As a part of the SUCCESS project intact sediment cores overlying the Utsira Formation north of the Sleipner West platforms, were sampled using a multicorer (capable of four cores pr dive, each 10 cm in diameter and approximately 20 cm long). After harvest some of the cores were immediately sliced for microbial analysis (DNA, RNA, SRR, FISH/DAPI, macrofauna) and geochemical apore water analysis onboard the ship. The remaining intact sediment cores were stored at 7^{o}C (*in-situ* temperature) in the fridges onboard the vessel until back in Bergen. The seawater above the cores was frequently exchanged with original bottom seawater from the area during the 2 days before being back in Bergen. When in Bergen, the cores were immediately transferred to the coldroom in the CGB geomicrobiology lab, where half of the cores were incubated with CO2 acidified seawater (experimental cores) and the remaining incubated with normal seawater. The CO2 acidification experiment will last for 1,5 months.

3.2.4 Fracture site

The very last hours of the cruise was used for two ROV dives to a long fracture structure discovered on the seafloor by the use of the AUV during the cruise. The dives are ROV 20 and 21.

ROV20_SHUFFLE BOX: The material collected in the shuffle box appeared to be a compact layer of H2S rich sediment about 10-15 cm high. No white bacterial mats.

Samples were teken for DNA, RNA, FISH, DAPI, virus analyses.

ROV21_BS: For microbial analysis, only the Biosyringe (BS) sample was available. Samples were teken for DNA, RNA, FISH, DAPI, virus analyses.

3.2.5 Shipboard Macrofaunal analysis and sample preparations

3.2.5.1 Shell hash area

ROV1_Shuffle box: As push cores were unsuccessful in collecting the large, compact shell fragments (all dead), the shuffle box was used for harvest. Single shells were washed and packed in plastic for later dating (UoB). Sediments including shells were sampled and fixed in 4% formalin (1 litre) for later meio- and macrofauna analyses.

3.2.6 Abandoned well 15-9/13 and Baseline/background site located 20 m outside the well

3.2.6.1 Abandoned well (ROV4, ROV11 and ROV12):

ROV4_PC: The top 10 cm of the core was transferred to 4% Formalin/borat. In addition, 1 cm3 of the top sediment cm was transferred to a 15 ml falcon tube and frozen directly at -20^{o}C.

ROV11_PC: From each cm of the 12 cm long core, 2 cm3 was cut out and transferred to separate 15 ml falcon tubes containing 4% Formalin/borat. In addition, 1 cm3 of the top cm was transferred to a 15 ml falcon tube and frozen immediately at -20^{o}C.

ROV12_PC: From each cm of the 9 cm long core, 2 cm3 was cut out and transferred to separate 15 ml falcon tubes containing 4% Formalin/borat. In addition, 1 cm3 of the top cm was transferred to a 15 ml falcon tube and frozen immediately at -20^{o}C.

3.2.6.2 Baseline/Background samples taken 20 m outside well 15/9-13:

ROV7_PC: From each cm layer of the 10 cm long core, 2 cm3 sediments was sampled in 15 ml Falcon tubes and fixed in 4% formalin/borat, separately. In addition, 1 cm3 of the top cm was transferred to a 15 ml falcon tube and frozen immediately at -20^{o}C.

ROV10_PC: From each cm layer of the 9 cm long core, 2 cm3 with sediments was sampled in 15 ml Falcon tubes and fixed in 4% formalin/borat, separately. In addition, 1 cm3 of the top cm was transferred to a 15 ml falcon tube and frozen immediately at -20^{o}C.

4 INITIAL RESULTS

The log reveals 68 activities carried out during the cruise, including 21 ROV dives, 11 multicorer dives and 6 AUV dives.

Table 7: Ship log on GS11B to Sleipner area.

gear	label	name	resp person	description	date/time	latitude	longitude	water	notes
CTD	CTD-01	108-B-01	Tamara Baumberger	Deployd	2011/06/24 11:58	60°25.44`N	05°16.92`E	320	Calibration
				Recovered	2011/06/24 12:25	60°25.44`N	05°16.92`E	320	
Subbottom profi	TOPAS-01	108-B-02	Rolf Pedersen	Start of line	2011/06/24 16:45	60°06.03`N	04°58.20`E	120	
				End of Line	2011/06/25 04:59	58°24.52`N	01°59.51`E	80	
CTD	CTD-02	108-B-03	Tamara Baumberger	Deployd	2011/06/25 05:17	58°24.52`N	01°59.51`E	80	Calibration
				Recovered	2011/06/25 05:17	58°24.52`N	01°59.51`E	80	
Multibeam	EM302-01	108-B-04	Rolf Pedersen	Start of line	2011/06/25 05:30	58°24.413`N	01°59.319`E	82	
				End of Line	2011/06/25 13:30	58°23.148`N	01°57.266`E	82	
ROV	ROV-01	108-B-05	Several	Deployd	2011/06/25 14:44	58°23.164`N	01°57.260`E	82	
				Recovered	2011/06/25 16:11	58°23.164`N	01°57.260`E	82	
ROV	ROV-02	108-B-06	Several	Deployd	2011/06/25 16:34	58°23.004`N	01°57.140`E	82	
				Recovered	2011/06/25 17:41	58°23.004`N	01°57.140`E	82	
BC	BC-01	108-B-07	Laila Reigstad	Deployd	2011/06/25 18:15	58°23.095`N	01°62.75`E	82	Empty BC
				Recovered	2011/06/25 18:25	58°23.095`N	01°62.75`E	82	
GC	GC-01	108-B-08	Laila Reigstad	Deployd	2011/06/25 18:30	58°23.095`N	01°57.265`E	82	Empty GC
				Recovered	2011/06/25 18:40	58°23.095`N	01°57.265`E	82	
GC	GC-02	108-B-09	Laila Reigstad	Deployd	2011/06/25 18:45	58°23.095`N	01°57.265`E	82	Empty GC
				Recovered	2011/06/25 18:55	58°23.095`N	01°57.265`E	82	
GC	GC-03	108-B-10	Laila Reigstad	Deployd	2011/06/25 18:52	58°23.095`N	01°57.265`E	82	Empty GC
				Recovered	2011/06/25 19:02	58°23.095`N	01°57.265`E	82	
GC	GC-04	108-B-11	Laila Reigstad	Deployd	2011/06/25 19:10	58°23.095`N	01°57.265`E	82	Empty GC
				Recovered	2011/06/25 19:30	58°23.095`N	01°57.265`E	82	
MUC	MC-01	108-B-12	Laila Reigstad	Deployd	2011/06/25 19:48	58°23.095`N	01°57.265`E	82	Empty MC
				Recovered	2011/06/25 20:10	58°23.095`N	01°57.265`E	82	
Multibeam	EM302-2	11M-13	Rolf Pedersen	Start of lines	2011/06/25 20:17	58°24.043`N	01°57.283`E	82	
				End of lines	2011/06/25 21:26	58°21.840`N	01°52.632`E	86	
Subbottom profi	TOPAS-02	108-B-14	Rolf Pedersen	Start of lines	2011/06/25 21:41	58°21.840`N	01°52.632`E	86	
				End of lines	2011/06/25 22:50	58°24.043`N	01°57.283`E	82	
AUV	AUV-01	108-B-15	Rolf Pedersen	Deployd	2011/06/25 23:39	58°21.108`N	01°55.370`E	82	
				Recovered	2011/06/26 11:17	58°22.395`N	01°55.951`E	82	
Multibeam	EM302-03	108-B-16	Rolf Pedersen	Start of lines	2011/06/26 12:20	58°20.566`N	01°55.166`E	83	Well 15/9-13
				End of lines	2011/06/26 13:20	58°22.402`N	01°55.953`E	83	
ROV	ROV-03	108-B-17	Several	Deployd	2011/06/26 13:28	58°22.395`N	01°55.951`E	83	
				Recovered	2011/06/26 14:31	58°22.395`N	01°55.951`E	83	
ROV	ROV-04	108-B-18	Several	Deployd	2011/06/26 14:49	58°22.395`N	01°55.951`E	83	
				Recovered	2011/06/26 16:17	58°22.395`N	01°55.951`E	83	

ROV	ROV-05	108-B-19	Several	Deployd	2011/06/26 17:46	58°22.395`N	01°55.951`E	83	
				Recovered	2011/06/26 19:10	58°22.395`N	01°55.951`E	83	
ROV	ROV-06	108-B-20	Several	Deployd	2011/06/26 19:52	58°22.395`N	01°55.951`E	83	
				Recovered	2011/06/26 21:43	58°22.395`N	01°55.951`E	83	
Hydroacoustic	EK60	108-B-21	Rolf Pedersen	Start of Line	2011/06/26 22:20	58°20.566`N	01°55.166`E	83	Well 15/9-13
				End of Line	2011/06/26 22:35	58°22.30`N	01°55.916`E	83	
AUV	AUV-02	108-B-22	Rolf Pedersen	Deployd	2011/06/26 23:25	58°22.215`N	01°55.111`E	82	
				Recovered	2011/06/27 08:56	58°22.215`N	01°55.111`E	82	
Multibeam	EM302-04	108-B-23	Rolf Pedersen	Start of line	2011/06/27 09:30	58°22.093`N	01°56.968`E	82	
				End of line	2011/06/27 10:16	58°18.971`N	01°52.744`E	85	
Subbottom profi	TOPAS-03	108-B-24	Rolf Pedersen	Start of line	2011/06/27 10:20	58°18.971`N	01°52.744`E	85	
				End of line	2011/06/27 10:44	58°22.093`N	01°56.968`E	82	
ROV	ROV-07	108-B-25	Several	Deployd	2011/06/27 12:36	58°22.394`N	01°55.9304`E	82	
				Recovered	2011/06/27 13:01	58°22.394`N	01°55.9304`E	82	
ROV	ROV-08	108-B-26	Several	Deployd	2011/06/27 13:48	58°24.012`N	01°53.607`E	86	Well 15/9-11
				Recovered	2011/06/27 15:03	58°24.012`N	01°53.607`E	86	
ROV	ROV-09	108-B-27	Several	Deployd	2011/06/27 16:34	58°22.129`N	01°55.623`E	83	
				Recovered	2011/06/27 17:38	58°22.129`N	01°55.623`E	83	
ROV	ROV-10	108-B-28	Several	Deployd	2011/06/27 18:52	58°22.3950`N	01°55.9268`E	81	Well 15/9-13.
				Recovered	2011/06/27 19:32	58°22.3950`N	01°55.9268`E	81	
ROV	ROV-11	108-B-29	Several	Deployd	2011/06/27 19:49	58°22.3965`N	01°55.9585`E	81	Well 15/9-13
				Recovered	2011/06/27 20:15	58°22.3965`N	01°55.9585`E	81	
ROV	ROV-12	108-B-30	Several	Deployd	2011/06/27 20:27	58°22.3967`N	01°55.9535`E	81	Well 15/9-13
				Rcovered	2011/06/27 21:16	58°22.3967`N	01°55.9535`E	81	
AUV	AUV-03	108-B-31	Rolf Pedersen	Deployd	2011/06/27 22:14	58°24.012`N	01°53.607`E	86	
				Recovered	2011/06/28 08:59	58°24.012`N	01°53.607`E	86	
Multibeam	EM302-05	108-B-32	Rolf Pedersen	Start of line	2011/06/28 09:35	58°24.764`N	01°58.342`E	83	
				End of line	2011/06/28 12:34	58°43.568`N	02°11.343`E	104	
Subbottom profi	Topas-04	108-B-33	Rolf Pedersen	Start of line	2011/06/28 12:40	58°43.568`N	02°11.343`E	104	
				End of line	2011/06/28 14:46	58°24.00`N	01°53.600`E	104	
ROV	ROV-13	108-B-34	Several	Deployd	2011/06/28 15:56	58°24.00`N	01°53.600`E	87	Well 15/9-11
				Recovered	2011/06/28 16:40	58°24.00`N	01°53.600`E	87	
CTD	CTD-03	108-B-35	Tamara Baumberger	Deployd	2011/06/28 17:13	58°24.019`N	01°53.62`E	87	Well 15/9-11
				Recovered	2011/06/28 17:23	58°24.019`N	01°53.62`E	87	
ROV	ROV-14	108-B-36	Several	Deployd	2011/06/28 17:56	58°24.00`N	01°53.600`E	87	Well 15/9-11
				Recovered	2011/06/28 19:17	58°24.00`N	01°53.600`E	87	
AUV	AUV-04	108-B-37	Rolf Pedersen	Deployd	2011/06/28 19:30	58°23.894`N	01°54.334`E	87	
				Recovered	2011/06/28 20:09	58°23.894`N	01°54.334`E	87	
AUV	AUV-05	108-B-38	Rolf Pedersen	Deployd	2011/06/28 22:13	58°33.098`N	02°03.263`E	89	
				Recovered	2011/06/28 08:46	58°33.098`N	02°03.263`E	89	
CTD	CTD-04	108-B-39	Tamara Baumberger	Deployd	2011/06/29 09:07	58°33.24`N	02°05.69`E	91	Calibration
				Recovered	2011/06/29 09:17	58°33.24`N	02°05.69`E	91	
CTD	CTD-05	108-B-40	Tamara Baumberger	Deployd	2011/06/29 10:20	58°41.437`N	02°09.799`E	100	
				Recovered	2011/06/29 10:30	58°41.437`N	02°09.799`E	100	
BC	BC-02	108-B-41	Laila Reigstad	Deployd	2011/06/29 10:40	58°41.437`N	02°09.799`E	100	
				Recovered	2011/06/29 10:49	58°41.437`N	02°09.799`E	100	
BC	BC-03	108-B-42	Laila Reigstad	Deployd	2011/06/29 10:50	58°41.437`N	02°09.799`E	100	
				Recovered	2011/06/29 10:59	58°41.437`N	02°09.799`E	100	
MUC	MC-02	108-B-43	Laila Reigstad	Deployd	2011/06/29 11:00	58°41.437`N	02°09.799`E	100	
				Recovered	2011/06/29 11:15	58°41.437`N	02°09.799`E	100	
Multibeam	EM302-06	108-B-44	Rolf Pedersen	Start of line	2011/06/29 11:31	58°41.437`N	02°09.799`E	100	
				End of line	2011/06/29 13:13	58°33.153`N	01°40.758`E	120	
MUC	MC-03	108-B-45	Laila Reigstad	Deployd	2011/06/29 13:20	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 13:35	58°33.153`N	01°40.758`E	120	
MUC	MC-04	108-B-46	Laila Reigstad	Deployd	2011/06/29 14:05	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 14:20	58°33.153`N	01°40.758`E	120	
MUC	MC-05	108-B-47	Laila Reigstad	Deployd	2011/06/29 14:35	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 14:50	58°33.153`N	01°40.758`E	120	
MUC	MC-06	108-B-48	Laila Reigstad	Deployd	2011/06/29 15:05	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 15:20	58°33.153`N	01°40.758`E	120	
MUC	MC-07	108-B-49	Laila Reigstad	Deployd	2011/06/29 15:25	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 15:40	58°33.153`N	01°40.758`E	120	

MUC	MC-08	108-B-50	Laila Reigstad	Deployd	2011/06/29 15:45	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 15:55	58°33.153`N	01°40.758`E	120	
MUC	MC-09	108-B-51	Laila Reigstad	Deployd	2011/06/29 16:00	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 16:10	58°33.153`N	01°40.758`E	120	
MUC	MC-10	108-B-52	Laila Reigstad	Deployd	2011/06/29 16:15	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 16:25	58°33.153`N	01°40.758`E	120	
MUC	MC-11	108-B-53	Laila Reigstad	Deployd	2011/06/29 16:30	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 16:40	58°33.153`N	01°40.758`E	120	
CTD	CTD-06	108-B-54	Tamara Baumberger	Deployd	2011/06/29 16:45	58°33.153`N	01°40.758`E	120	
				Recovered	2011/06/29 16:55	58°33.153`N	01°40.758`E	120	
ROV	ROV-15	108-B-55	Several	Deployd	2011/06/29 20:20	58°22.395`N	01°55.951`E	83	
				Recovered	2011/06/29 20:40	58°22.395`N	01°55.951`E	83	
ROV	ROV-16	108-B-56	Several	Deployd	2011/06/29 20:50	58°22.395`N	01°55.951`E	83	
				Recovered	2011/06/29 21:34	58°22.395`N	01°55.951`E	83	
AUV	AUV-06	108-B-57	Rolf Pedersen	Deployd	2011/06/29 23:13	58°18.162`N	02°11.093`E	77	
				Recovered	2011/06/30 08:53	58°18.162`N	02°11.093`E	77	
ROV	ROV-17	108-B-58	Several	Deployd	2011/06/30 12:10	58°23.158`N	01°57.225`E	85	
				Recovered	2011/06/30 14:03	58°23.158`N	01°57.225`E	85	
ROV	ROV-18	108-B-59	Several	Deployd	2011/06/30 15:14	58°22.396`N	01°55.949`E	78	
				Recovered	2011/06/30 17:07	58°22.396`N	01°55.949`E	78	
CTD	CTD-07	108-B-60	Tamara Baumberger	Deployd	2011/06/30 18:30	58°22.561`N	01°56.754`E	85	
				Recovered	2011/06/30 18:40	58°22.561`N	01°56.754`E	85	
CTD	CTD-08	108-B-61	Tamara Baumberger	Deployd	2011/06/30 18:45	58°22.561`N	01°56.754`E	85	
				Recovered	2011/06/30 18:55	58°22.561`N	01°56.754`E	85	
ROV	ROV-19	108-B-62	Several	Deployd	2011/06/30 19:02	58°22.561`N	01°56.754`E	85	
				Recovered	2011/06/30 20:11	58°22.561`N	01°56.754`E	85	
CTD	CTD-09	108-B-63	Tamara Baumberger	Deployd	2011/06/30 20:43	58°25.165`N	01°54.897`E	88	
				Recovered	2011/06/30 20:55	58°25.165`N	01°54.897`E	88	

4.1 Initial results: Seafloor mapping

Seabed areas north and east of the CO_2-plume were searched for fluid escape features. This was based on knowledge about previously identified fault systems reaching shallow levels, being potential fluid escape structures. The scanned areas are shown in Fig. 4. For the scanning, both Ship-based and AUV-mounted equipment were used.

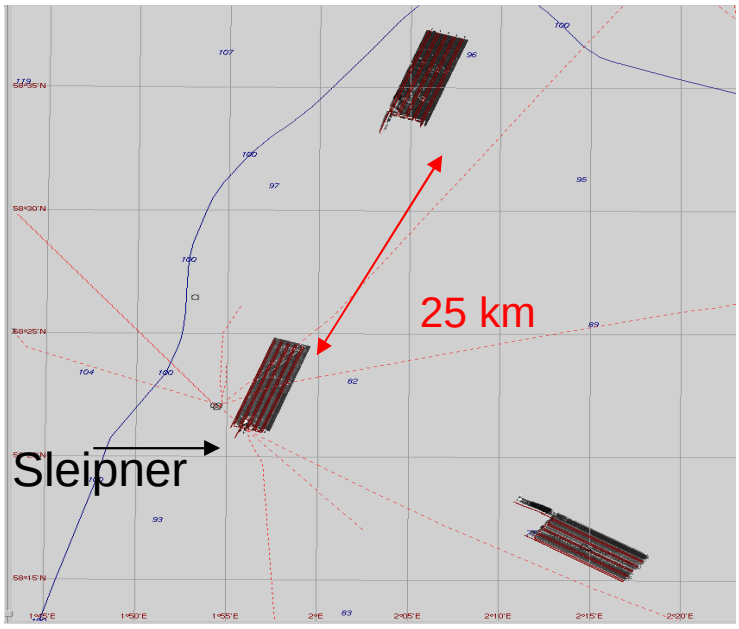

Figure 4: Map highlighting the seafloor areas scanned north and east of the Sleipner platforms.

The AUV were mostly launced in the evenings and rescued in the mornings. A total of six AUV dives were carried out. After data analysis a fracture structure on the seafloor was discovered about 25 km north of the Injected CO_2 plume (Fig. 5).

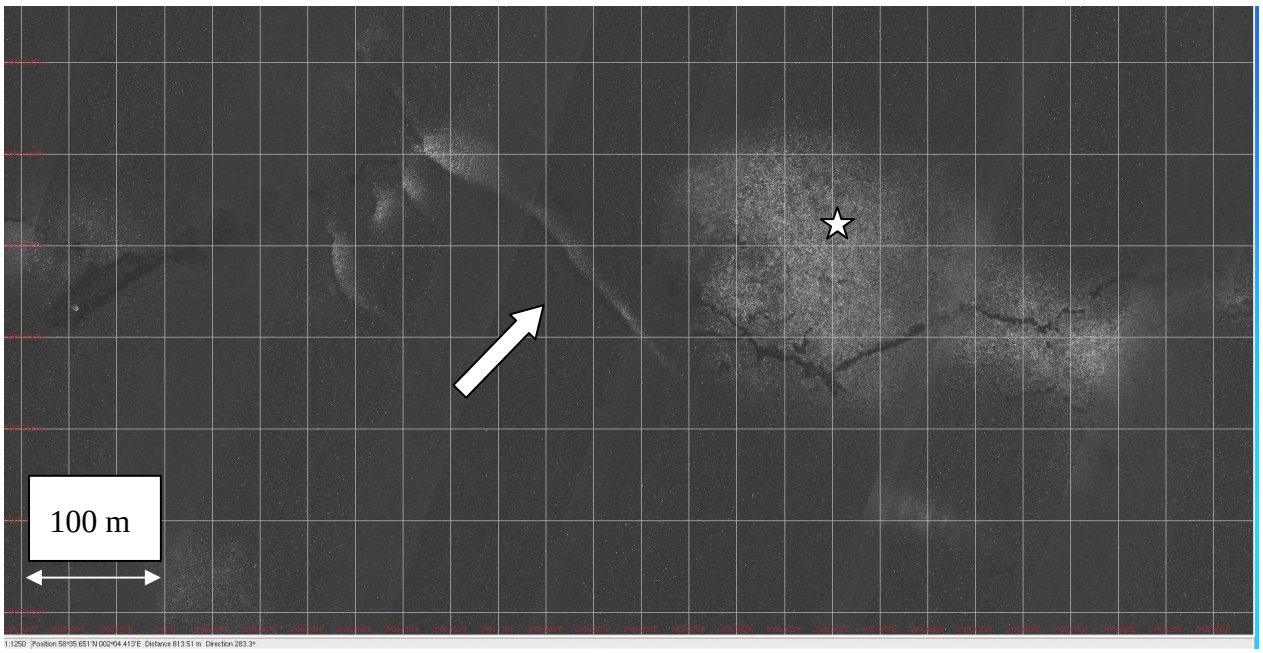

Figure 5: AUV obtained SAS image revealing a (at least) 2,5 km long fracture structure on the seafloor. Branching fracture structures were observed (white

arrow). Large areas of shell hash were clearly visible on the SAS images (star).

Sub-bottom profiling using the TOPAS on the ship showed subsurface fluid escapes along the structure (Fig.6).

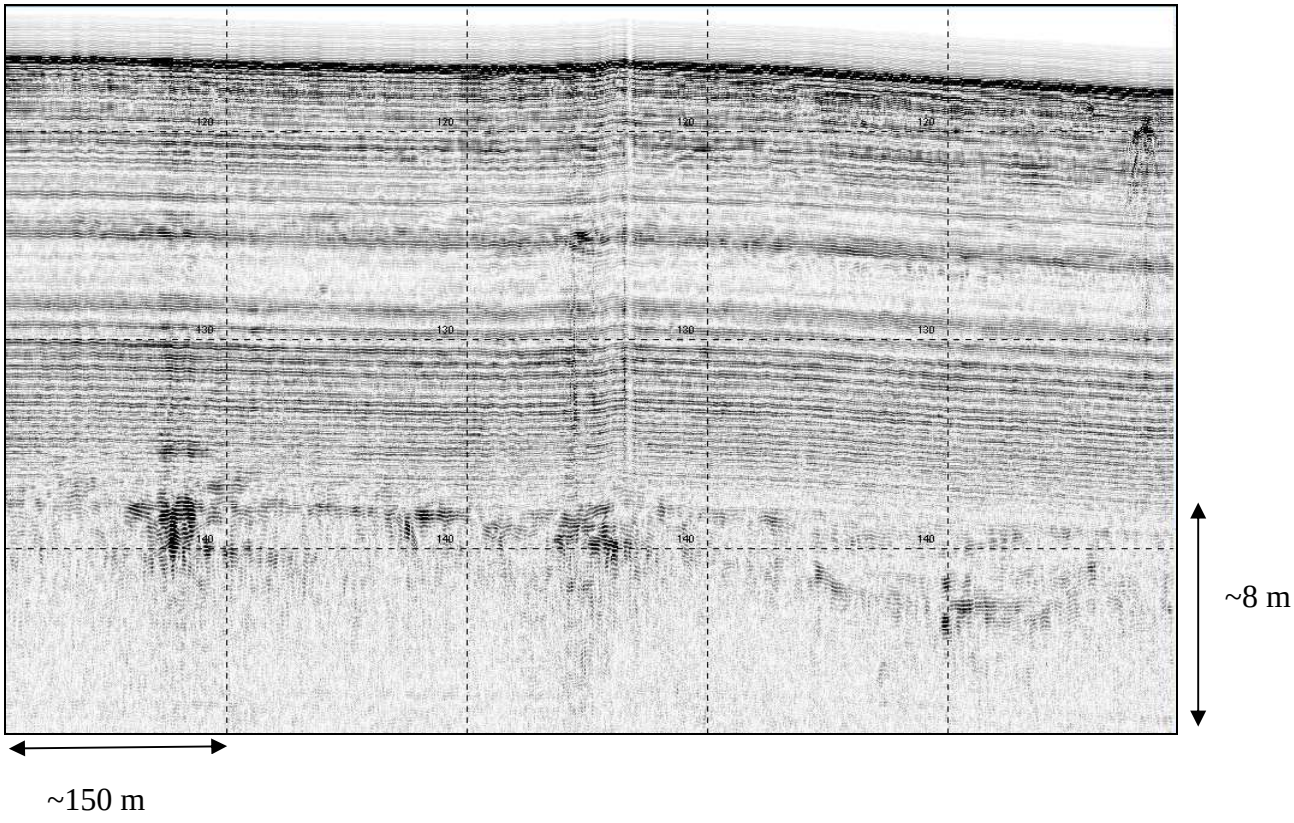

Figure 6: Sub-bottom profiling of the deformation area.

A closer look at the TOPAS data reveals 0,5 m dip-slip displacements of layers across one of the zones
(Fig.7).

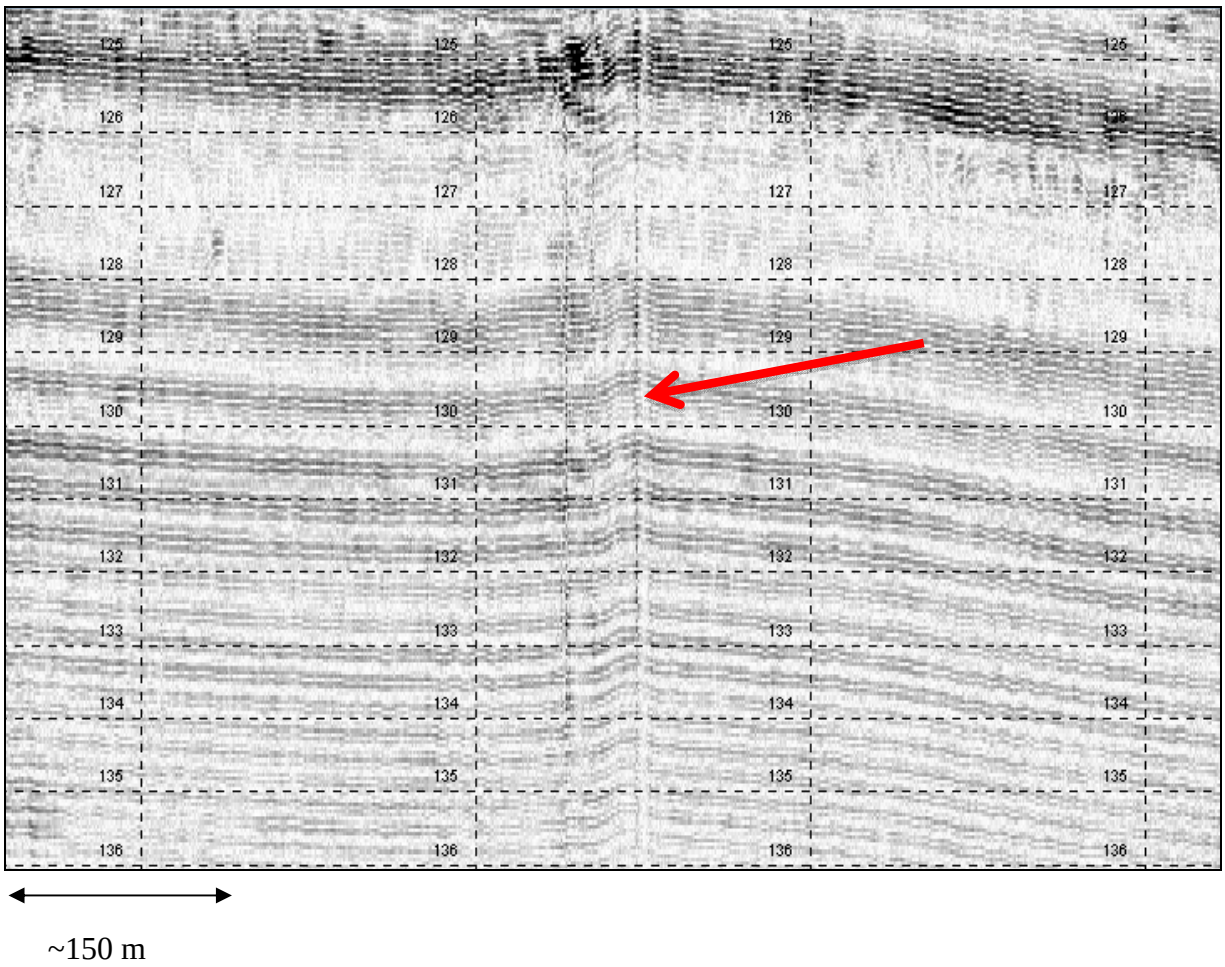

Figure 7: Dip-slip displacements (0,5 m) detected by sub-bottom profiling.

The fracture site was investigated closer during ROV dives 20 and 21. No bubbles were detected along the deformation line, but extensive white microbial mats were observed. The microbial mats showed a special growth pattern being indicative of fluid flow from below the seafloor (Fig. 8). Just outside the deformation structure there were no microbial mats. Microbial mats and high sulfide concentration in the top of the sediment hints to seepage of reduced fluids.

Figure 8: Microbial mats cover the fracture structure. At this spot the mats grew in circular patterns. Picture taken from ROV film.

Water composition: For the collected fluid samples collected just above the sediment surface with microbial mats, there were no differences between the obtained values and the bottom seawater. Nevertheless, the dissolved gas concentrations of CH4 and H2 were enhanced over background seawater concentrations.

4.2 Three abandoned wells leaking methane.

Three abandoned wells drilled by Statoil during early 1980ies were visited; wells 15/9-11, 15/9-13 and 15/9-16. All three wells leaked methane in the form of bubbles rising from several locations within each well. White, fragile microbial mats were present in all wells, but absent outside the wells. Well 15/9-13 is the well closest to the subseafloor CO2 plume, and was therefore selected for in-depth microbial analyses, in addition to the geochemical analyses. Results from each well are presented below.

4.2.1 Well 15/9-11

At several locations within the well, bubble streamers rised from the seafloor (Fig. 9).

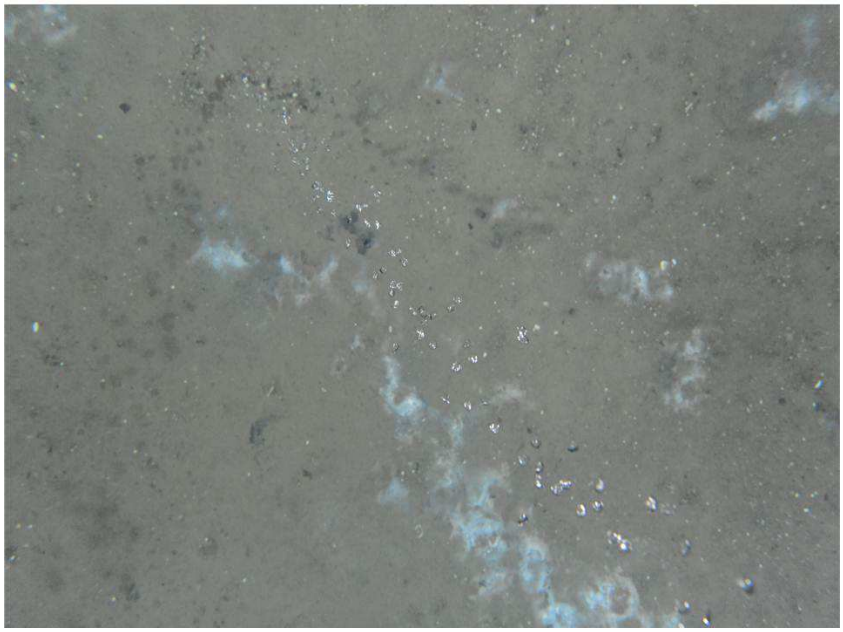

Figure 9: Bubble streamers arising from the sefloor at well 15/9-11. Picture taken from ROV film.

The gas leaking from the well contained over 99% methane. The methane signal could be traced all the way to the surface (approximately 80 m water mass). Using CTD dives, the depth profile of dissolved methane was measured (Fig. 10).

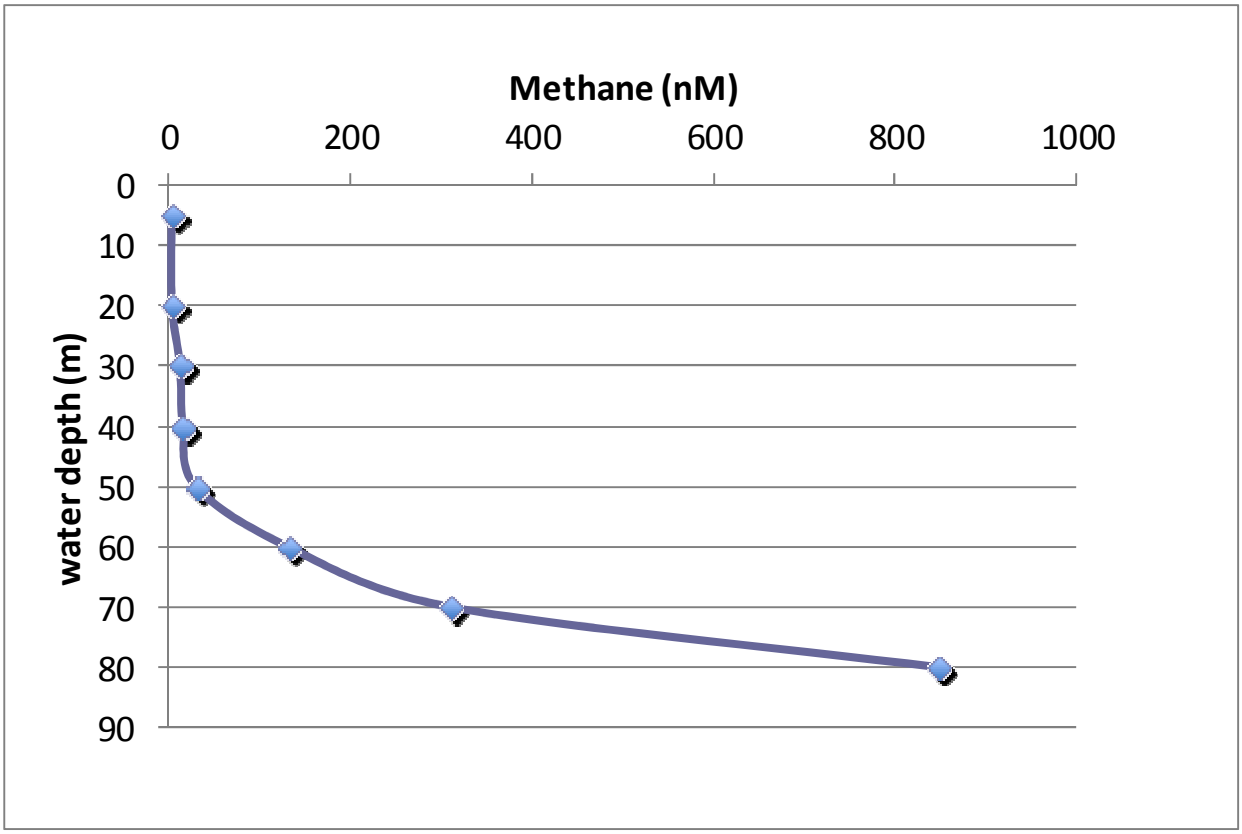

Figure 10: Dissolved CH4 in water column above well 15/9-11.

Using a HD digital camera mounted under the ROV, it was possible to take hundreds of photoes of the white microbial mats at the methane leaking well 15/9-11 by flying a few meters over the seafloor. All photoes were afterwards put together in a photomosaic, resulting in a high resolution color photo were the whole mat structure is captured (Fig. 11).

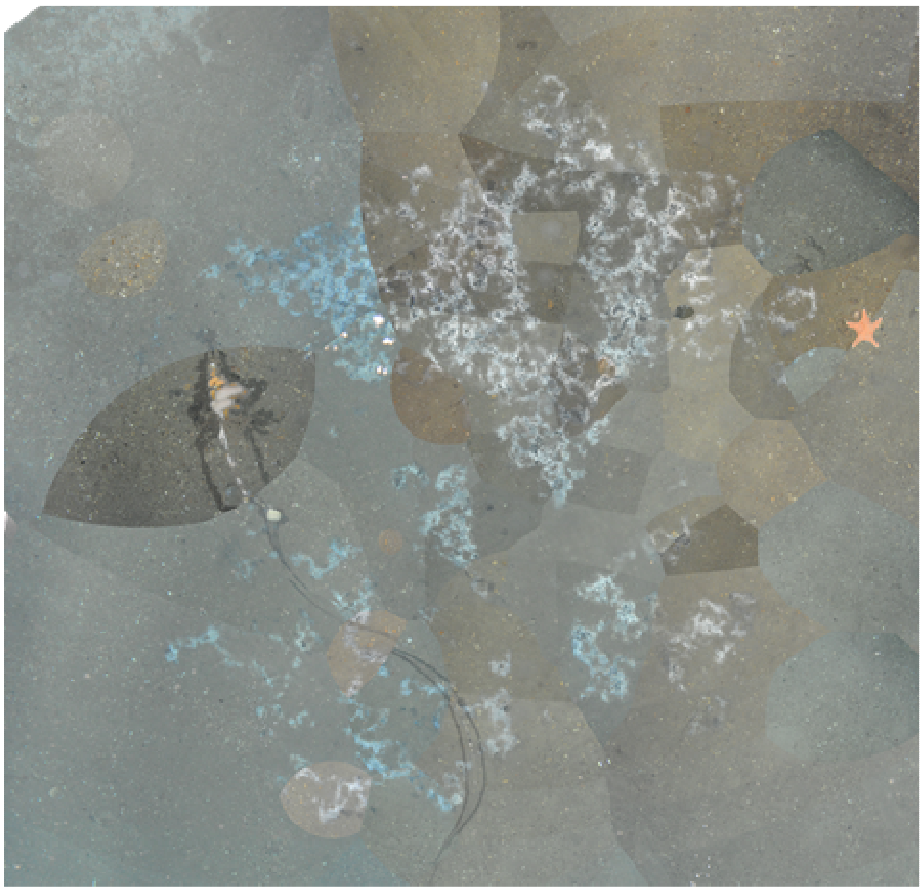

Figure 11: High resolution color photomosaic showing the structure of microbial mats at abandoned well 15/9-11.

The water column over the subseafloor CO_2 plume was imaged using Hull-mounted eco sounder system (EM302) and AUV-mounted sonar system. Bubbles of methane, leaking from abandoned wells (clearly showed up on side scan sonar images from both methods (Fig. 12).

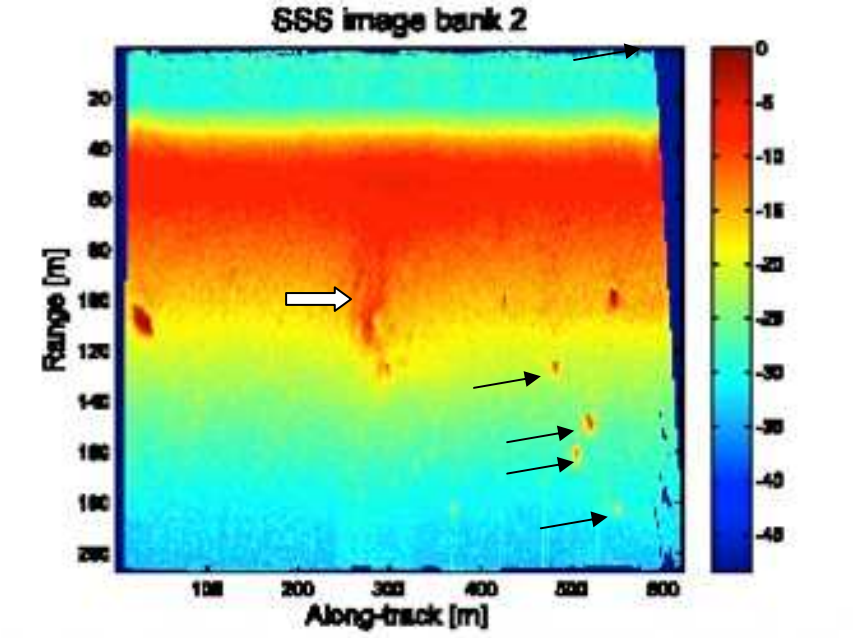

Figure 12: Side scan sonar image of methane leaking well 15/9-11, taken by the AUV. The gas plume is indicated by the white arrow, and seabed rocks by black arrows.

4.2.2 Well 15/9-13 and baseline site located 20 m from the well.

At the well site, thin, fragile white microbial mats were observed. Outside the well site there were no mats visible (Fig. 13).

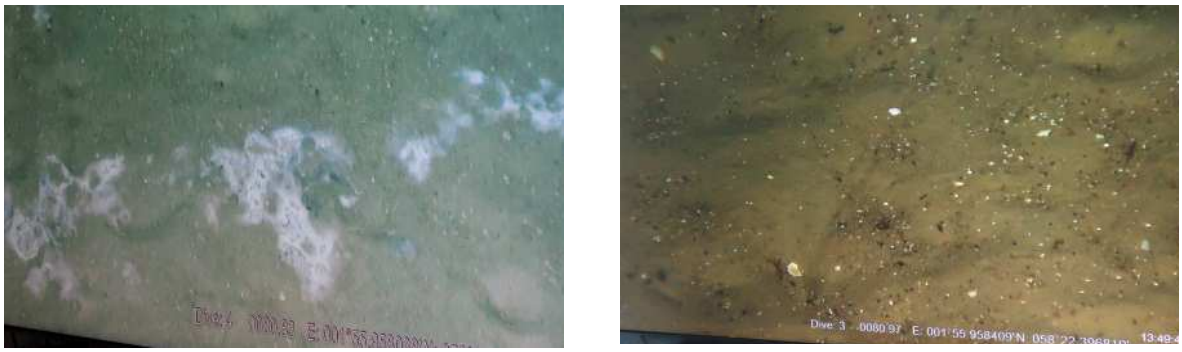

Figure 13: Seafloor images (from ROV) of well 15/9-13 (left panel) and of baseline site 20 m outside well (right panel). Pictures taken from the ROV film.

Seven bubble streamers were detected in a radius of 6 meter. The methane signal from well 15/9-13 could be followed all the way from the seabed to the surface, meaning through a water column of approximately 82 m (Fig. 14).

The methane concentration in the gas was measured to ~900 nM at the seafloor. The gas consisted of 99% methane. CTD casts were not performed over this well.

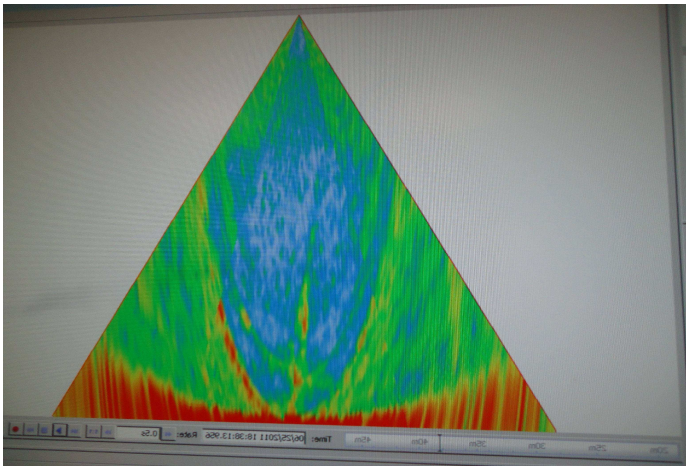

Figure 14: Single beam eco sounder (EC60) image showing the methane signal of well 15/9-13 rising from the seafloor towards the surface.

The geochemical analysis of extracted pore water from sediment push cores taken in the leaking well and 20 m outside the well (baseline).

4.3 CO2 Injection well.

One CTD cast and two push cores for pore water extraction were performed over the injection well. From the CTD dive the depth profile of dissolved methane was measured (Fig. 15).

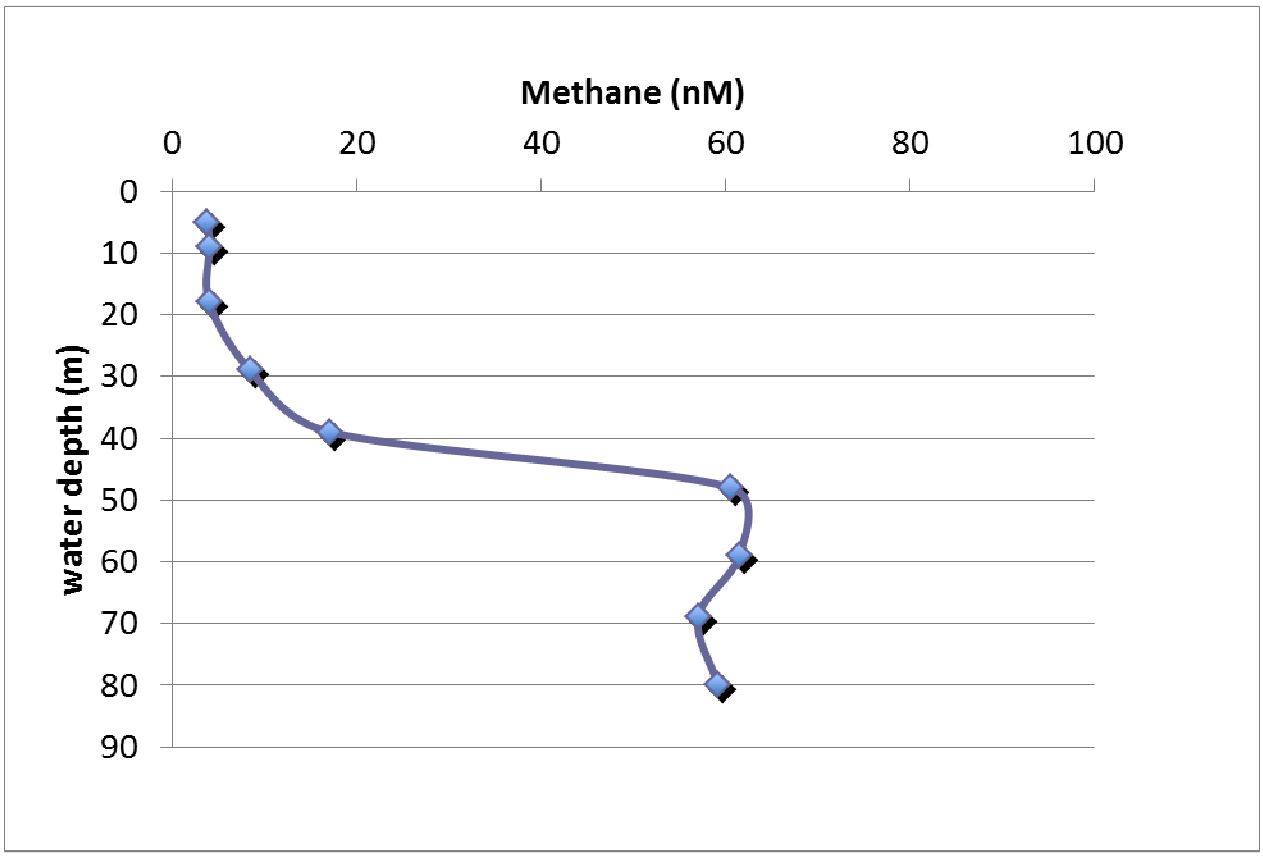

Figure 15: Methane composition of water column above CO2 injection well (GS11B-CTD8).

Two push cores were taken at the site of the injection well. Both were used for geochemical analysis on extracted pore water.

4.4 Multicore Baseline site for harvest of intact cores for CO_2 acidification set-up at CGB.

At this site 9 Multi core dives were carried out, retrieving 27 cores altogether. Both geochemical and microbial analysis were carried out on some cores upon retrieval on deck. These will represent baseline. Site name “Laila-2”. Pore water was extracted from Multi core nr 10 (GS11B-MC6-10) and pH and alkalinity measured.

Sediment sample was taken from Multi core nr 14 (GS11B-MC7-14) for determination of methane and hydrogen gas.

4.5 Shell hash areas

The observed shall hash areas consists of dead shells only. Two sampling rounds with the ROV were carried out to investigate the shell hash areas (Figs. 5 and 16, ROV1 og ROV17). In ROV1 dive a shufflebox was taken and shell cleaned, dried and kept for dating analysis, while in ROV17 a small trench was made to find out how deep the shell layer goes. Shells were here observed down to 25 cm depth. Temperature measured in the sediment here: 8.4^{o}C.

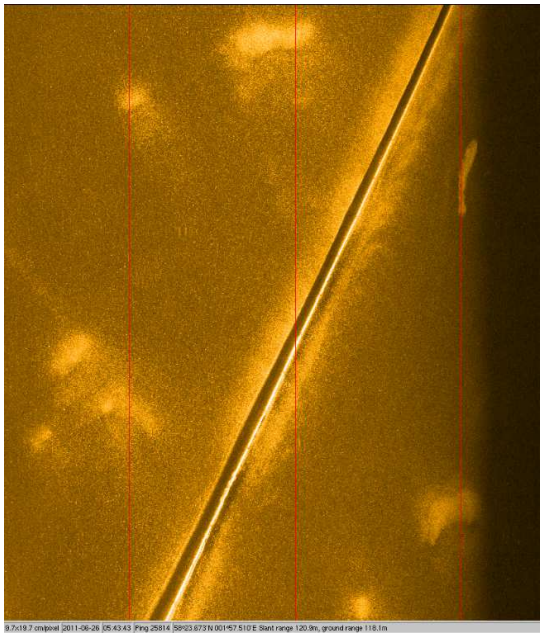

Figure 16: SAS image from the AUV showing shell hash areas and a pipeline. The pictured area is located over the subsurface CO_2 plume.

5. ACKNOWLEDGEMENT

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