Cruise Report

Jan Mayen vent fields (JMVF)

R/V G.O. Sars, **Expedition No. 2012109**/CGB2012B

23. July – 04. August 2012

Bergen, Norway – Akureyri, Iceland

Chief Scientist: Rolf B. Pedersen, Centre for Geobiology, UiB

Cruise report prepared by Tamara Baumberger

Contents

1 Introduction

1.1 Cruise participants

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1.2 Cruise Objectives

The 2012 cruise to the Jan Mayen vent fields (JMVF) was part of the research activities at the Centre for Geobiology and the European research project ECO2. The main objectives of this expedition were 1) quantify the CO_2-outgassing from the hydrothermal vents 2) to study dispersion of dissolved gases in the water column with emphasis on the carbon chemistry and 3) to constrain the effect of CO_2-outgassing on the environment. The investigations focus on sampling and analyzing the hydrothermal components based on ROV and CTD operations followed by diverse shipboard analytical methods, as well as mapping of the seafloor by echosounder operations. Daytime operations focus on ROV dives and night activities are mainly CTD and echosounder operations.

1.3 Background

1.3.1 Arctic Mid-Ocean Ridges

For the first two decades of hydrothermal exploration, hydrothermal activity at ultraslow ridges was thought to be little or even absent. However, the last 10 years have shown that hydrothermal systems are more abundant than expected at the AMOR (Figure 1), a representative of the ultra-slow spreading ridge class (below 20 mm/yr). Several workers reported the discovery of venting hydrothermal systems at the seafloor or hydrothermal anomalies in the water column [*Edmonds et al.*, 2003; *Pedersen et al.*, 2005; *Connelly et al.*, 2007; *Pedersen et al.*, 2010a; *Pedersen et al.*, 2010b]. The crust can become very thin or even missing in ultraslow environments what can result in a local exposure of the upper mantle to the seafloor [*Dick et al.*, 2003; *Michael et al.*, 2003]. Because there are also magmatic ridge segments present, is it likely that basalt-hosted and peridotite-hosted hydrothermal systems could be found in close vicinity. It was previously thought that low spreading rates and the thin crust at ultraslow-spreading ridges lead to a reduced magmatic heat budget and thus a lower number of vent fields than at faster spreading ridges. Nevertheless, relative to the available heat, there is increasing evidence for a larger degree of hydrothermal activity at the AMOR than previously thought.

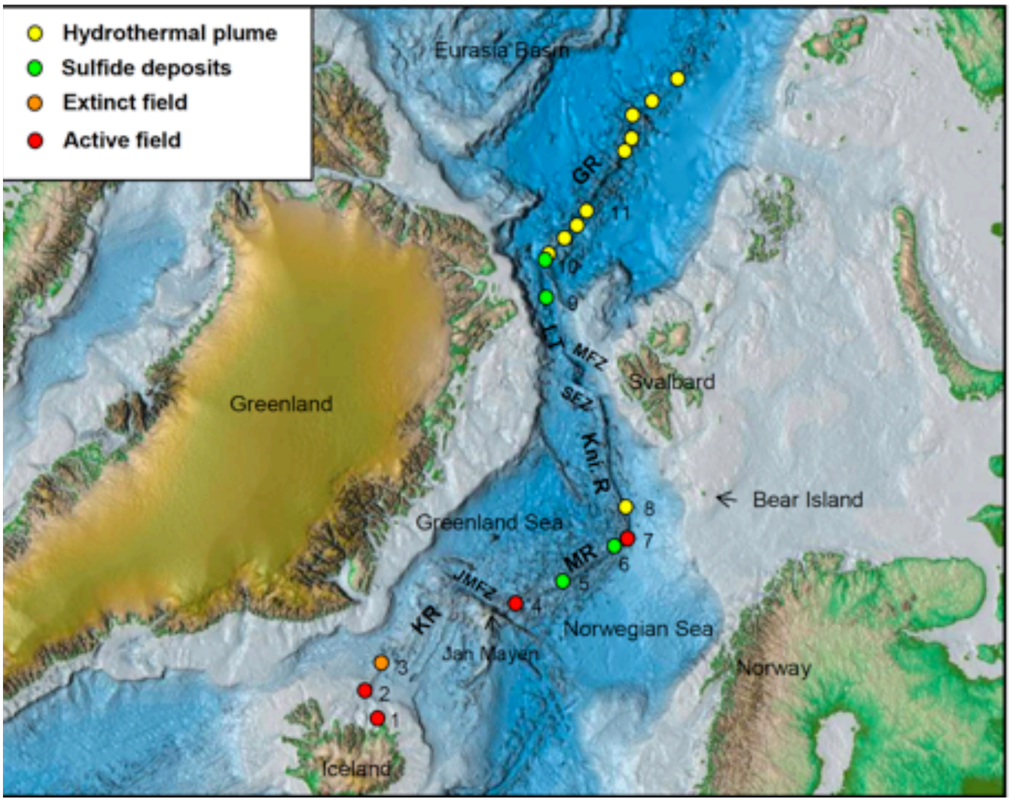

Figure 1: Map after Pedersen et al. [2010b] showing the Arctic Mid-Ocean Ridges with the locations of active and extinct vent field, sulfide deposits and hydrothermal plumes: **4 Jan Mayen Vent Fields** [Pedersen et al., 2005],.

The AMOR has been defined as the ridge systems north of the Arctic Circle at 66°N [*Pedersen et al.*, 2010c]. The AMOR is 4000 km long and may be divided into six ridge segments: (1) the Kolbeinsey Ridge (540 km), (2) the Mohns Ridge (550 km), (3) the Knipovich Ridge (500 km), (4) the Molley Ridge (60 km), (5) the Lena Through (330 km), and (6) the Gakkel Ridge (1600 km). Between the Mohns Ridge and the Knipovich Ridge, a major change in the orientation takes place at about 74°N. The same was found at 83°C between the Lena Through and the Gakkel Ridge. In addition, the AMOR contains three major fracture zones. One of these is the Jan Mayen fracture zone (JMFZ) at 71°N [*Pedersen et al.*, 2010b].

1.3.2 Hydrothermal activity at the Mohns Ridge – Jan Mayen Vent Fields

Hydrothermal activity was detected at the Mohns Ridge in 2005. *Pedersen et al.* [2005] found two vent fields, named Trollveggen ("Troll Wall") and Soria Moria (Figure 2), near the southwestern end of the ridge. The two hydrothermal fields are located in the central part of the southernmost Mohns Ridge segment, not far from the JMFZ.

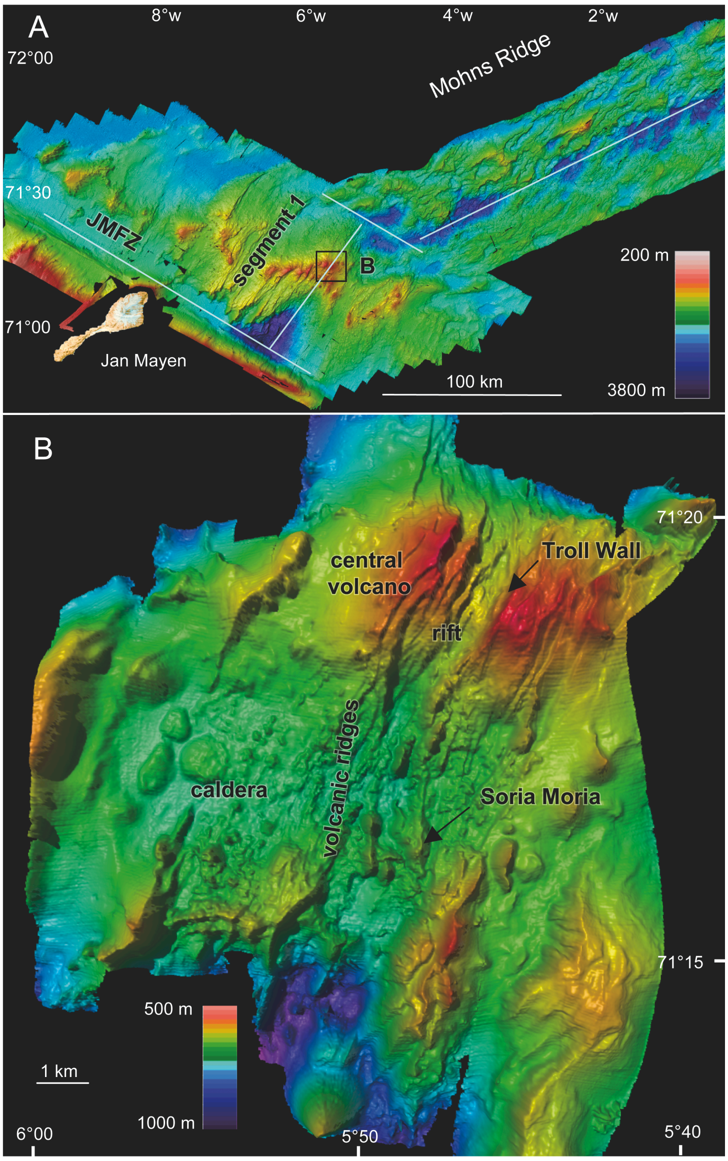

Figure 2: Bathymetric map from *Pedersen et al.* [2010b], showing location of the Jan Mayen Vent Fields (Troll Wall = Trollveggen and Soria Moria).

Trollveggen is located about 5 km north of Soria Moria. Both are in relatively shallow waters of maximum 700 m water depth. Trollveggen is located along the eastern margin of a rift valley and consists of multiple high-temperature and diffuse flow venting sites. High-temperature venting up to 270°C (white smoker) occurs through talus deposits along the base of a normal fault at about 550 m water depth. Venting is observed at a length of about 1 km, and expresses local differences in intensity. Ten different major vent sites are present and each of them consists several chimney structures, reaching up to 10 m in height. These chimneys structures are composed of anhydrite, barite, sphalerite and pyrite [*Pedersen et al.*, 2010b]. The second vent field, Soria Moria, is located at the top of a volcanic ridge and high-temperature venting takes place at 700 m water depth. This volcanic ridge has grown on an older lava field made of massive lava flows and tubes among other, similar, volcanic ridges. Two different types of chimney compositions that are separated by a few hundred meters, are venting at Soria Moria. Several, up to 9 m tall sulfide chimneys vent high-temperature white smoker fluids and a more non-uniform type of chimneys constructions are venting fluids of lower temperature. These structures are composed of barite, silica, and secondarily pyrite, sphalerite and galena [*Pedersen et al.*, 2010b].

2 Cruise Logistics and Operations

2.1 Operational equipment

2.1.1 Multibeam echosounder EM302

Bathymetric mapping was performed with an EM 302 multibeam echosounder. The EM 302 uses a nominal sonar frequency of 30 kHz and is designed to do mapping from 10 m up to 7000 m depths. 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 echosounder EK60

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

2.1.3 CTD

For measurements of conductivity, temperature and depth (CTD) of the water column a Seabird 911plus including a SBE32 carousel with 12 Niskin bottles for water sampling, 2.5 l each, was used until it broke down after three casts. It was not possible to repair it because of missing spare parts. Thus, the large CTD-rosette with 21 bottles (10 l) was used for the remaining time of the expedition. Standard setup of the CTD is with SBE 4C conductivity sensor, SBE3plus temperature sensor and SBE43 dissolved oxygen sensor. A Ko-ichi Eh-sensor (difference in voltage between Pt-electrode in seawater and a silver/silver chloride reference electrode) was additionally attached to one of the available auxiliary ports.

2.1.4 ROV

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

2.1.4.1 Equipment of ROV

The dives were performed with two different equipment configurations. The geo-configuration included 3 gas samplers, 3 water samplers, the real-time temperature probe and the hydraulic chain saw. The bio-configuration included 3 water samplers, the biosyringe, a maximum of 3 push cores, a low-temperature probe and the suction sampler.

Chain saw: The ROV was equipped with a hydraulic concrete chain saw (ICS) to cut chimneys and rock outcrops for rock sampling as well as easier access to the chimney orifices to sample for vent fluids.

Temperature-probes: A temperature probe for the range of 0-400 °C measured temperature of fluids in real-time. An additional temperature probe for the range of 0-150 °C was used for diffusive flow in sediment or for measurements in microbial mats.

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

Gas samplers: Marv Lilley's six (~250 ml) gas tight samplers (GT) were used for gas sampling. Three bottles were attached on every geo-configured dive.

Biosyringe: A hydraulic sampling cylinder with a ~1 cm wide tube was used for sampling of biological mats.

Suction sampler: A suction sampler was used for collection of macrofauna samples.

Sampling box**:** An aluminum scuffle box was fixed to the frame of the ROV for collection of rock, sediment, and biology samples.

Push cores: Two pushcores were attached to the front of the ROV sampling box.

Sensors: A CO2 – and a pH –sensor from SAMI (A. Omar and T. de Lange) were available to be mounted on to the ROV.

2.2 Shipboard geochemical analysis and sample preparation

Selected dissolved gases, redox sensitive parameters and nutrients in vent fluids and water column (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 geochemical parameters (major and trace elements, stable isotopes, organic acids, nutrients) in fluids were collected and preserved onboard.

2.2.1 Collection and analyses of dissolved gases (H_2, CH_4, higher hydrocarbons, He and H_2S)

Volatiles in vent fluids: Dissolved gases in high-temperature vent fluids were collected with gas-tight fluid samplers. The total gas content in gas tight fluid samplers was extracted with a gas extraction line and collected for onshore analyses at the University of Washington in the U.S.

Concentrations of dissolved sulphide, in vent fluids were analysed onboard by photometric methods using a 4-channels Quaatro Continuous Flow Analyzer (Seal Analytical). For sulphide the methylene blue was used.

CTD samples: Water column samples were collected with a CTD rosette package. For H_2 and CH_4 analyses 100 ml of bubble-free fluid sample was drawn into 140 ml syringes followed by the addition of 40 ml of headspace gas of ultra-pure helium. The sample was vigorously shaken and left for at least 30 min at room temperature to reach equilibrium between the water and the gas phase. The headspace gas was then analysed onboard by using a TOGA SRI 8610C gas chromatograph (GC) equipped with a highly sensitive He-pulsed discharge detector (PDD) for H_2 analyses and with a flame ionization detector (FID) for CH_4 analyses. Gas cylinders with 5.0 He (carrier gas, 2 x 50 l), 5.0 H_2 (1 x 50 l) and synthetic air (2 x 50 l) were connected to the gas pipeline system in the gas central room on the ship (regulators on board). The sampling and analytical precision, determined through replicate draws, was about 3% of the measured concentrations.

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 (Young and Lupton, 1983).

2.2.2 Collection and analyses of other fluid constituents

Aliquots of vent fluid and water column samples were collected and partly also analysed onboard for pH, alkalinity, ammonium, nutrients, anions and cations.

Aliquots were first analysed for pH and then for alkalinity. The pH measurements were done by using a Methrom 826 pH mobile pH meter. The samples were collected in 60 ml Nalgene bottles with coned caps. During sampling the bottles were overflowed with approximately three times the sample volume and filled completely to avoid air in the bottle. All samples were put in a water bath for half an hour prior to measure to ensure equal temperature conditions. The measurement of the pH was done in a closed system to avoid outgassing of CO_2. Calibration of the system was done daily, using Methrom disposable buffers (pH 4, 7 and 9). Two parallels were always analysed for the CTD samples while the ROV samples were analyzed without parallels.

Alkalinity was measured through a dynamic titration by a Methrom 888 Titrando titrator and the Tiamo^{TM} software. The following settings were used during the titration: measuring point density 2, endpoint recognition 30 mV, minimum waiting time 5 seconds, maximum waiting time 36 seconds, minimum increment 2µm, maximum dosing rate 3 ml/min. Endpoint evaluation were performed with a minimum ERC of 20, the last endpoint was used for alkalinity calculation. The acid used for the titration was 0.1 N HCl and the sample volume was 100 ml for CTD samples and between 25 and 80 ml for ROV samples. The following formula was used for the calculation of the alkalinity

Alkalinity = volume acid * acid concentration * 1000 / sample volume

Concentrations of ammonium, nitrate/nitrite and phosphate in vent fluids, water column and pore water were analyzed on-board by photometric methods using a 4-channels Quaatro Continuous Flow Analyzer (Seal Analytical). For ammonium the 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-molybdenum method was applied.

For onshore ion chromatography (IC) analyses at UiB of Cl, SO_4^{2-}, and Br^- aliquots of vent fluid, water column and pore water samples were filtered (0.2 µm) and collected on 15 and 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, water column and pore water samples were filtered (0.2 µm) and collected on 15-100 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 a continuous flow analyzer at UiB, aliquots of vent fluid, water column and pore water samples were filtered (0.2 µm) and collected on 15 and 30 ml sized amber plastic bottles and stored in the freezer at ~ 20°C.

2.2.3 Collection of samples for stable isotope analysis

Vent fluid aliquots as well as water column samples for background seawater concentrations were furthermore collected for analyses of water isotopic composition (H and O), for B isotope composition and for C isotope composition of DIC. Samples for H, O and B isotope analyses were untreated and stored in amber plastic bottles of 30 ml. For DIC stable isotopes analyses, 0.2 to 1 ml filtered (0.2 µm) sample was injected into prepared (8 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.

3 Cruise Activities and Initial Results

3.1 Survey log GS 12

label	description	date/time	latitude	longitude	water depth (m)	location
12B-01-CTD-01	Deployed	2012/07/24 04:10	61°01.497`N	-04°16.679`E	408	
	Recovered	2012/07/24 04:27	61°01.498`N	-04°16.677`E	408	
12B-02-CTD-02	Deployed	2012/07/24 05:06	61°05.753`N	-04°21.646`E	85	
	Recovered	2012/07/24 05:14	61°05.826`N	-04°21.659`E	98	
12B-03-CTD-03	Deployed	2012/07/27 04:30	71°14.108`N	-07°13.147`E	1413	JMFZ
	Recovered	2012/07/27 05:25	71°14.129`N	-07°13.055`E	1411	
12B-04-ROV-01	Deployed	2012/07/27 10:55	71°17.851`N	-05°45.932`E	461	Trollveggen
	Recovered	2012/07/27 15:13	71°17.881`N	-05°46.374`E	461	
12B-05-ROV-02	Deployed	2012/07/27 16:42	71°17.881`N	-05°46.374`E	461	Trollveggen
	Recovered	2012/07/27 18:20	71°17.881`N	-05°46.374`E	461	
12B-06-ROV-03	Deployed	2012/07/27 21:10	71°15.559`N	-05°48.903`E	725	Soria Moria
	Recovered	2012/07/27 22:40	71°15.561`N	-05°49.015`E	744	
12B-07-CTD-04	Deployed	2012/07/28 01:24	71°17.875`N	-05°46.316`E	548	Trollveggen
	Recovered	2012/07/28 02:43	71°17.866`N	-05°46.360`E	554	
12B-08-CTD-05	Deployed	2012/07/28 04:30	71°17.875`N	-05°46.316`E	550	Trollveggen
	Recovered	2012/07/28 07:30	71°17.866`N	-05°46.360`E	550	
12B-09-ROV-04	Deployed	2012/07/28 11:00	71°17.799`N	-05°46.436`E	535	Trollveggen
	Recovered	2012/07/28 14:40	71°17.791`N	-05°46.465`E	501	
12B-10-ROV-05	Deployed	2012/07/28 16:00	71°17.887`N	-05°46.318`E	530	Trollveggen
	Recovered	2012/07/28 18:14	71°17.897`N	-05°46.357`E	551	
12B-11-ROV-06	Deployed	2012/07/28 20:35	71°17.898`N	-05°46.358`E	550	Trollveggen
	Recovered	2012/07/28 23:00	71°17.898`N	-05°46.358`E	548	
12B-12-CTD-06	Deployed	2012/07/28 23:30	71°17.875`N	-05°46.191`E	463	Trollveggen
	Recovered	2012/07/28 23:45	71°17.873`N	-05°46.191`E	463	
12B-13-CTD-07	Deployed	2012/07/29 01:00	71°17.840`N	-05°46.246`E	466	Trollveggen
	Recovered	2012/07/29 01:20	71°17.840`N	-05°46.245`E	465	
12B-14-EM302-01	Start of line	2012/07/29 08:28	71°17.400`N	-05°47.700`E	575	Trollveggen
	End of line	2012/07/29 10:37	71°18.651`N	-05°45.450`E	630	
12B-15-ROV-07	Deployed	2012/07/29 12:28	71°17.887`N	-05°46.312`E	500	Trollveggen
	Recovered	2012/07/29 15:50	71°17.886`N	-05°46.348`E	550	
12B-16-ROV-08	Deployed	2012/07/29 19:15	71°17.886`N	-05°46.348`E	550	Trollveggen
	Recovered	2012/07/29 23:15	71°17.903`N	-05°46.392`E	550	
12B-17-CTD-08	Deployed	2012/07/30 00:24	71°17.919`N	-05°46.177`E	460	Trollveggen
	Recovered	2012/07/30 00:45	71°17.920`N	-05°46.172`E	460	
12B-18-CTD-09	Deployed	2012/07/30 01:10	71°17.920`N	-05°46.322`E	565	Trollveggen
	Recovered	2012/07/30 01:32	71°17.921`N	-05°46.323`E	565	

12B-19-CTD-10	Deployed	2012/07/30 01:40	71°17.919`N	-05°46.493`E	602	Trollveggen
	Recovered	2012/07/30 02:06	71°17.919`N	-05°46.493`E	602	
12B-20-CTD-11	Deployed	2012/07/30 02:15	71°17.892`N	-05°46.322`E	569	Trollveggen
	Recovered	2012/07/30 02:37	71°17.919`N	-05°46.493`E	569	
12B-21-CTD-12	Deployed	2012/07/30 03:40	71°17.862`N	-05°46.100`E	569	Trollveggen
	Recovered	2012/07/30 04:00	71°17.862`N	-05°46.100`E	569	
12B-22-CTD-13	Deployed	2012/07/30 04:10	71°17.801`N	-05°46.436`E	476	Trollveggen
	Recovered	2012/07/30 04:35	71°17.801`N	-05°46.436`E	476	
12B-23-CTD-14	Deployed	2012/07/30 05:20	71°17.850`N	-05°46.335`E	505	Trollveggen
	Recovered	2012/07/30 05:48	71°17.849`N	-05°46.340`E	505	
12B-24-CTD-15	Deployed	2012/07/30 05:55	71°17.889`N	-05°46.238`E	465	Trollveggen
	Recovered	2012/07/30 06:10	71°17.889`N	-05°46.238`E	465	
12B-25-CTD-16	Deployed	2012/07/30 06:20	71°17.966`N	-05°46.060`E	510	Trollveggen
	Recovered	2012/07/30 06:35	71°17.966`N	-05°46.060`E	510	
12B-26-CTD-17	Deployed	2012/07/30 06:52	71°17.966`N	-05°46.153`E	530	Trollveggen
	Recovered	2012/07/30 07:15	71°17.966`N	-05°46.060`E	530	
12B-27-CTD-18	Deployed	2012/07/30 07:25	71°17.966`N	-05°46.978`E	470	Trollveggen
	Recovered	2012/07/30 07:40	71°17.965`N	-05°46.981`E	470	
12B-28-ROV-09	Deployed	2012/07/30 10:20	71°17.998`N	-05°46.887`E	598	Gallionella Garden
	Recovered	2012/07/30 14:17	71°18.001`N	-05°46.859`E	601	
12B-29-ROV-10	Deployed	2012/07/30 18:02	71°15.687`N	-05°48.856`E	665	Soria Moria
	Recovered	2012/07/30 21:37	71°15.687`N	-05°48.802`E	664	
12B-30-ER60-01	Start of line	2012/07/31 00:25	71°17.881`N	-05°46.311`E	520	Trollveggen
	End of line	2012/07/31 00:40	71°17.880`N	-05°46.311`E	520	
12B-31-CTD-19	Deployed	2012/07/31 00:55	71°17.881`N	-05°46.311`E	520	Trollveggen
	Recovered	2012/07/31 01:17	71°17.880`N	-05°46.311`E	520	
12B-32-CTD-20	Deployed	2012/07/31 01:45	71°17.880`N	-05°46.311`E	520	Trollveggen
	Recovered	2012/07/31 02:07	71°17.880`N	-05°46.311`E	520	
12B-33-CTD-21	Deployed	2012/07/31 03:00	71°17.963`N	-05°46.070`E	510	Trollveggen
	Recovered	2012/07/31 03:25	71°17.963`N	-05°46.070`E	510	
12B-34-ROV-11	Deployed	2012/07/31 11:58	71°15.558`N	-05°48.902`E	717	Soria Moria
	Recovered	2012/07/31 17:35	71°15.548`N	-05°48.941`E	717	
12B-35-ROV-12	Deployed	2012/07/31 20:35	71°17.799`N	-05°46.388`E	470	Trollveggen
	Recovered	2012/07/31 23:45	71°17.909`N	-05°46.406`E	555	
12B-36-CTD-22	Deployed	2012/08/01 00:11	71°17.826`N	-05°46.683`E	614	Trollveggen
	Recovered	2012/08/01 00:34	71°17.825`N	-05°46.681`E	612	
12B-37-CTD-23	Deployed	2012/08/01 01:15	71°15.558`N	-05°48.902`E	717	Soria Moria
	Recovered	2012/08/01 01:45	71°15.560`N	-05°48.907`E	717	
12B-38-CTD-24	Deployed	2012/08/01 02:55	71°15.560`N	-05°48.908`E	717	Soria Moria
	Recovered	2012/08/01 09:00	71°15.560`N	-05°48.907`E	717	
12B-39-ROV-13	Deployed	2012/08/01 09:35	71°15.123`N	-05°50.269`E	800	Lava flow plane
	Recovered	2012/08/01 12:25	71°15.123`N	-05°50.269`E	800	
12B-41-ROV-14	Deployed	2012/08/01 14:10	71°17.907`N	-05°46.364`E	465	Trollveggen
	Recovered	2012/08/01 17:05	71°17.873`N	-05°46.315`E		
12B-42-CTD-25	Deployed	2012/08/01 20:59	71°04.766`N	-07°25.272`E	2200	JMFZ
	Recovered	2012/08/01 22:00	71°04.800`N	-07°25.200`E	2200	

3.2 Monitoring with multibeam and singlebeam echosounder systems

During this cruise, several longterm multibeam surveys were performed over the venting areas to obtain data on bubbles rising through the water column as well as more detailed information about the bathymetry. The data was not analysed during the cruise. Additionally, a 15 minutes long record of the Trollveggen bubble plume was obtained at 31 July 12 by using the ER60 echosounder system. It was possible to detect single bubbles rising up in the water column. Differences in the slope of the rising bubbles were seen that might point to different rising speeds and thus composition or size. Further onshore investigations of this data set will show if the changes in the slopes are real or probably and artifact due to minimal movements of the ship.

3.3 CTD operations

CTD operations were performed to constrain the distribution of dissolved gases in the water column above the Jan Mayen vent fields with emphasis on Trollveggen. A total of 25 vertical casts were performed during this expedition, whereas 21 casts were conducted over the vent fields, 2 casts over the Jan Mayen fracture zone and 2 casts at the Norwegian shelf. CTD-01 to CTD-03 were performed with a 12 bottles rosette. Sampling with this CTD/rosette system was hampered by a defect of the pumping system. A repair was not possible and the whole CTD/rosette system had to be replaced by the spare CTD/rosette. Thus, CTD-04 to CTD-25 were performed by using a CTD/rosette system with 21 bottles. During cast CTD-05 and CTD-24 no water samples were obtained but instead the Sami-CO2-sensor of the Bjerknes Center attached to the CTD frame. Based on the equilibration time of the sensor, these casts were performed over several hours. When water samples were obtained during vertical casts, the Niskin bottles were subsampled as listed in Table 1. Mechanical problems of the copper crimping device, severely hampered the sampling for He isotopes. It was only possible to get in total 9 samples from two hydro casts (CTD-04 and CTD-22).

Table 1: Principle investigators of CTD water samples

Sample Type	Abbreviation	Principle Investigator
Helium isotopes	^3He	Tamara Baumberger, *CGB*
Methane and hydrogen	CH_4, H_2	Tamara Baumberger, *CGB*
Carbon chemistry	C	Abdir Omar & Tor de Lange, *UniBjerknes, UniResearch*
pH, alkalinity	pH, alk	Ingeborg Økland, *CGB*
Sulphide, Ammonium	H_2S, NH_4^+	Ingunn Thorseth, *CGB*
Nutrients	nut	Ingunn Thorseth, *CGB*
Anions, cations	an,cat	Ingunn Thorseth, *CGB*

Table 2: Distribution of CTD rosette water samples

Cast	^3He	CH_4, H_2	TC	TA	pH	Alk	Nut	IC	ICP	Comment
GS12B-CTD-01 - Station 233			12	12						12 bottles CTD
GS12B-CTD-02 - Station 234			6	6						12 bottles CTD
GS12B-CTD-03 - Station 235			3	3						12 bottles CTD
GS12B-CTD-04 - Station 236	5	17	17	17	17	17	17	17	17	21 bottles CTD; Bt 3 not released
GS12B-CTD-05 - Station 237										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-06 - Station 238		8	8	8	8	8	8	8	8	21 bottles CTD; Bt 3 not released
GS12B-CTD-07 - Station 239		9	9	9						21 bottles CTD; Bt 3 not released
GS12B-CTD-08 - Station 240		1								21 bottles CTD; Bt 3 not released
GS12B-CTD-09 - Station 241		1								21 bottles CTD; Bt 3 not released
GS12B-CTD-10 - Station 242		2								21 bottles CTD; Bt 3 not released
GS12B-CTD-11 - Station 243		2								21 bottles CTD; Bt 3 not released
GS12B-CTD-12 - Station 244		3								21 bottles CTD; Bt 3 not released
GS12B-CTD-13 - Station 245		3								21 bottles CTD; Bt 3 not released
GS12B-CTD-14 - Station 246										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-15 - Station 247										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-16 - Station 248										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-17 - Station 249										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-18 - Station 250										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-19 - Station 251										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-20 - Station 252		12	12	12	12	12	12	12	12	21 bottles CTD; Bt 3 not released
GS12B-CTD-21 - Station 253										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-22 - Station 254	4	13								21 bottles CTD; Bt 3 not released
GS12B-CTD-23 - Station 255		11	11	11	11	11	11	11	11	21 bottles CTD; Bt 3 not released
GS12B-CTD-24 - Station 256										21 bottles CTD; Bt 3 not released; no samples
GS12B-CTD-25 - Station 257		12	12	12	12	12	12	12	12	21 bottles CTD; Bt 3 not released
Total	**9**	**82**	**78**	**78**	**48**	**48**	**48**	**48**	**48**	

3.3.1 Preliminary results from water column CTD samples

Dissolved gases

The Trollveggen area was carefully investigated to trace the chemical plume arising from the vent fields. In the areas were the bubble plume was identified by acoustic water column surveys the chemical sensors on the CTD did not show a strong anomaly to clearly identify the chemical plume. However, water column samples analysed for dissolved CH_4 and H_2 concentrations exhibited high CH_4 concentrations up to 180 nM (CTD-20) in samples that were collected about 15 to 30 m above seafloor in the Trollveggen area. Additionally, a strong signal for the hydrothermal plume above Trollveggen was found in CTD-04 with CH_4 concentrations of up to 163 nM in the water column at about 150 m above seafloor. At the same depth, dissolved H_2 was not elevated above background seawater concentrations.

Carbon chemistry (by Abdirahman M. Omar and Tor de Lange)

The Geophysical Institute and UniBjerknes Centre were responsible for the measurement of concentrations of inorganic carbon in the seawater. For the JMVF cruise the objective was to study the effect of the CO_2 venting on seawater carbon concentrations. Additionally, new sensors for autonomous, in situ determination of CO_2-system parameters have been tested during both cruises.

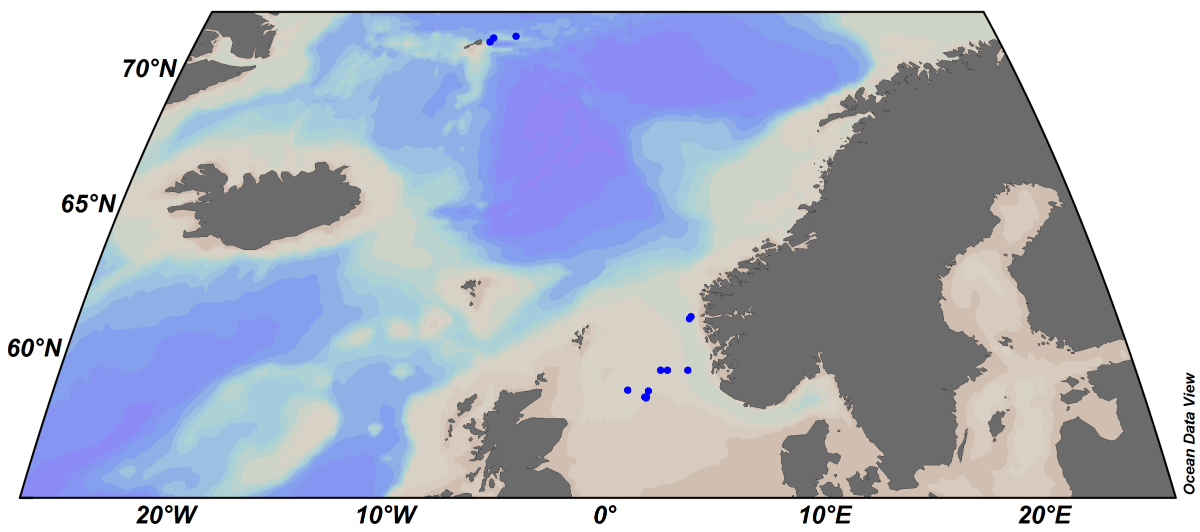

Figure 3: Map of the northern North Atlantic showing the stations visited during the ECO2 cruises in June 26-30 (Sleipner) and July 23 – August 5 (JMVF), 2012 (this expedition).

All main variables of the seawater CO_2-system were measured. Seawater samples taken from CTD bottles have been analyzed for:

1) The concentration of **Dissolved Inorganic Carbon (DIC).** This variable has been determined in the lab onboard the ship by using the coulometric method (e.g. Johnson et al., 1993) with the accuracy set by running Certified Reference Material (CRM).

   During the JMVF cruise DIC was determined for about 10 CTD stations (Figure 3, Table 2). Preliminary analyses of these data indicate that concentrations around the vents might be slightly higher than reference station, but the quantification of this awaits for the ancillary data needed to correct for other processes. Samples obtained with the ROV from the "chimney" and immediately surrounding bottom water showed extremely high DIC values.

2) **Total alkalinity (TA)**, which has been determined by titrating samples with 0.1 M HCl as described by Haraldson et al. (1997). The accuracy set in the same way as for CT.

   During the JMVF cruise TA was determined for about 10 CTD stations (Figure 3, Table 2). Highly anomalous TA values were observed around the "chimney" and immediately surrounding bottom water. These samples were taken by the ROV.

3) **pH** which has been determined by an instrument developed at GFI/BCCR based on a spectrophotometric principle. No preliminary conclusions can be drawn from these data since they need to be corrected to in situ salinity and temperature.

   Additionally, **partial pressure of CO_2 (pCO2)** has been measured semi-continuously (every 3 minute) for surface water (pumped from 4 m below the sea surface) using a continuous flow system similar to that described by Feely et al. (1998) and Wanninkhof and Thoning (1993).

Table 3: CTD stations with seawater samples at the Jan Mayen vent field (JMVF) cruise**.**

Stat. no	Date time UTC	Lat	Lon	Depth [m]	Samples depth [m]
233 12B-CTD-01	240712 0211	61 01.50 N	004 16.68 E	408	401, 298, 249, 199, 149, 100, 74, 49, 29, 18, 7, 4
234 12B-CTD-02	240712 0309	61 05.79 N	004 21.65 E	80	90, 50, 29, 18, 10, 4
235 12B-CTD-03	270712 0232	71 14.11 N	007 13.15 W	1390	1384, 1249, 1099,
236 12B-CTD-04	280712 0024	71 17.88 N	005 46.29 W	514	520, 490, 429, 399, 369, 339, 309, 280, 249, 219, 189, 160, 129, 99, 70, 39, 9
238 12B-CTD-06	280712 2131	71 17.87 N	005 46.19 W	463	451, 400, 300, 250, 200, 149, 99, 49
239 12B-CTD-07	280712 2305	71 17.84 N	005 46.25 W	465	454, 399, 347, 299, 249, 199, 149, 99, 49
252 12B-CTD-20	300712 2341	71 17.88 N	005 46.31 W	525	511, 500, 449, 399, 349, 299, 249, 199, 149, 98, 49, 9
255 12B-CTD-23	310712 2316	71 15.56 N	005 48.91 W	717	709, 629, 559, 489, 419, 349, 279, 208, 140, 69, 10
257 12B-CTD-25	010812 1900	71 04.74 N	007 25.33 W	2218	1677, 1332, 1035, 991, 890, 790, 691, 592, 444, 197, 99, 9

3.4 ROV dives

3.4.1 Summary ROV dives

A total of 14 ROV dives were performed during this expedition to the JMVF. Trollveggen was investigated during 9 dives and at Soria Moria totally 3 ROV dives were performed. Both, Gallionella Garden and the lava flow plain were visited once.

During the dives at the *Trollveggen* area, the following main observations regarding the structural setting were made. Several small ridge segments with different characteristics were observed. Active hot fluid venting chimneys as well as solid, but not active chimney structures were observed. A highlight was in-situ hydrate formation at some of the actively venting chimneys. In addition, some active fluid venting pointed to ongoing phase separation processes.

Soria Moria comprised until now two vent fields, Soria Moria I and Soria Moria II, respectively. At Soria Moria I a flange that was already sampled last year was the main object to be investigated. By using the chain saw, it was possible to get a solid sample from the flange in addition to bio and fluid samples. At Soria Moria II, the high-temperature chimney Lilleputt was resampled. Additionally, more high-temperature venting chimneys were discovered in the Soria Moria II area. During the dives at Soria Moria, a new area containing many ironoxide and ironhydroxide structures was discovered. The Fe-rich structures made a solid impression. They were sampled for further investigations and for comparison with the Gallionella Garden Fe-rich materials. Outside of the hydrothermal active areas lava flow plains were present. These were investigated and sampled during a separate ROV dive dedicated to lava sampling.

Gallionella Garden was visited to for enrichment and ecological studies of Fe-oxidizers.

Table 4: ROV fluid and gas sampling list

Sample	Type	Latitude	Longitude	Depth (m)	Site
12B-05-ROV-02-Major1	vent fluid	71°17.9`N	05°46.3`W	559	Trollveggen - The Flame
12B-05-ROV-02-Major2	vent fluid	71°17.9`N	05°46.3`W	559	Trollveggen - The Flame
12B-09-ROV-04-Major3	bottom SW	71°17.8`N	05°46.3`W	518	Trollveggen
12B-11-ROV-06-GT1	gas	71°17.9`N	05°46.3`W	560	Trollveggen - The Flame
12B-11-ROV-06-Major1	vent fluid	71°17.9`N	05°46.3`W	560	Trollveggen - The Flame
12B-11-ROV-06-GT2	gas	71°17.9`N	05°46.3`W	563	Trollveggen - Chain Saw
12B-11-ROV-06-Major2	vent fluid	71°17.9`N	05°46.3`W	563	Trollveggen - Chain Saw
12B-15-ROV-07-Major1	vent fluid	71°17.9`N	05°46.3`W	557	Trollveggen - A Flame
12B-15-ROV-07-GT1	gas	71°17.9`N	05°46.3`W	557	Trollveggen - A Flame
12B-16-ROV-08-Major 1	vent fluid	71°17.9`N	05°46.3`W	562	Trollveggen - The Bubbler
12B-16-ROV-08-Major 3	vent fluid	71°17.9`N	05°46.3`W	562	Trollveggen - The Bubbler
12B-28-ROV-09-Major 1	seawater	71°18.0`N	05°46.8`W	614	Gallionella Garden
12B-29-ROV-10-GT1	gas	71°15.7`N	05°48.8`W	666	Soria Moria 1 - Sphinx
12B-29-ROV-10-Major1	low temp fluid	71°15.7`N	05°48.8`W	666	Soria Moria 1 - Sphinx
12B-29-ROV-10-Major2	vent fluid	71°15.7`N	05°48.8`W	662	Soria Moria 1
12B-29-ROV-10-GT2	gas	71°15.7`N	05°48.8`W	662	Soria Moria 1
12B-29-ROV-10-Major3	SW 70 m asf	71°15.7`N	05°48.8`W	590	Soria Moria - bubble plume
12B-34-ROV-11-GT1	gas	71°15.5`N	05°48.9`W	723	Soria Moria 2 - tall new chimney
12B-34-ROV-11-Major1	vent fluid	71°15.5`N	05°48.9`W	723	Soria Moria 2 - tall new chimney
12B-34-ROV-11-GT2	gas	71°15.5`N	05°48.9`W	723	Soria Moria 2 - tall new chimney
12B-34-ROV-11-Major2	vent fluid	71°15.5`N	05°48.9`W	712	Soria Moria 2 - Lilleputt
12B-34-ROV-11-Major3	vent fluid	71°15.5`N	05°48.9`W	712	Soria Moria 2 - Lilleputt
12B-39-ROV-13-Major1	seawater	71°15.1`N	05°50.3`W	808	above basalts 1 km from vent fields
12B-39-ROV-13-Major2	seawater	71°15.1`N	05°50.3`W	800	above basalts 1 km from vent fields
12B-39-ROV-13-Major3	seawater	71°15.1`N	05°50.3`W	750	above basalts 1 km from vent fields
12B-41-ROV-14-Major3	vent fluid	71°17.9`N	05°46.3`W	563	Trollveggen - Chain Saw
12B-41-ROV-14-GT2	gas	71°17.9`N	05°46.3`W	563	Trollveggen - Chain Saw
12B-41-ROV-14-Major2	vent fluid	71°17.9`N	05°46.3`W	562	Trollveggen - The Flame
12B-41-ROV-14-GT3	gas	71°17.9`N	05°46.3`W	562	Trollveggen - The Flame
12B-41-ROV-14-Major1	diffuse fluid	71°17.9`N	05°46.3`W	562	Trollveggen - Flame chimney wall

3.4.2 Collection of gas tight samples

During this expedition, 9 successful gas tight samples were collected in total (see Table 4). Five high temperature water samples were obtained from Trollveggen, one from Soria Moria I and two from Soria Moria II. Multiple subsamples were taken from each sample for shore-based laboratory analyses for gas concentrations and isotopic composition at the University of Washington, U.S.

At Soria Moria I, one low temperature sample was obtained from a fluid venting at a flange. Again, multiple subsamples were taken for shore-based gas concentration and isotopic analyses at the University of Washington, U.S.

3.4.3 Collection and preliminary results from Ti major bottle samples

During this expedition, in total 13 high temperature vent fluid samples were collected for analyses of the fluid compositions. Therefrom, three samples were collected at Soria Moria II, one was collected at Soria Moria I and nine were obtained at Trollveggen (Table 4).

In addition, several low temperature vent fluids and seawater samples were obtained. One low temperature fluid sample was obtained at the Sphinx in the Soria Moria I vent field. One sample was taken 70 m above the Soria Moria I vent fields within the bubble plume. A seawater sample was obtained at Gallionella Garden right above the seafloor. At Trollveggen, a diffuse fluid sample was obtained from the chimney wall of one of the high temperature chimneys. Additionally, a bottom seawater sample was obtained for combining the macro biology sampling with the corresponding background seawater chemistry.

Bottom seawater was also collected right above the lava plain about 1 km from venting fields.

All samples obtained by the Ti major bottles, were analysed for pH and alkalinity as well as for ammonium, sulphide, nutrients, major element and trace element compositions. Additionally, subsamples for stable C,O,H,S,B isotope and for Sr isotope analyses were collected.

3.5 Macrofauna – environmental sampling

Macrofauna at the JMVF was investigated to get information on the influence of CO_2-leakage on the local environment at a natural seeping site. The JMVF macrofauna was therefore sampled by using the ROV suction sampler combined with video footage. In addition to the macrofauna, seawater samples were obtained from the same sampling sites. This allows a direct correlation between the occurrence of macrofauna and its environment.

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