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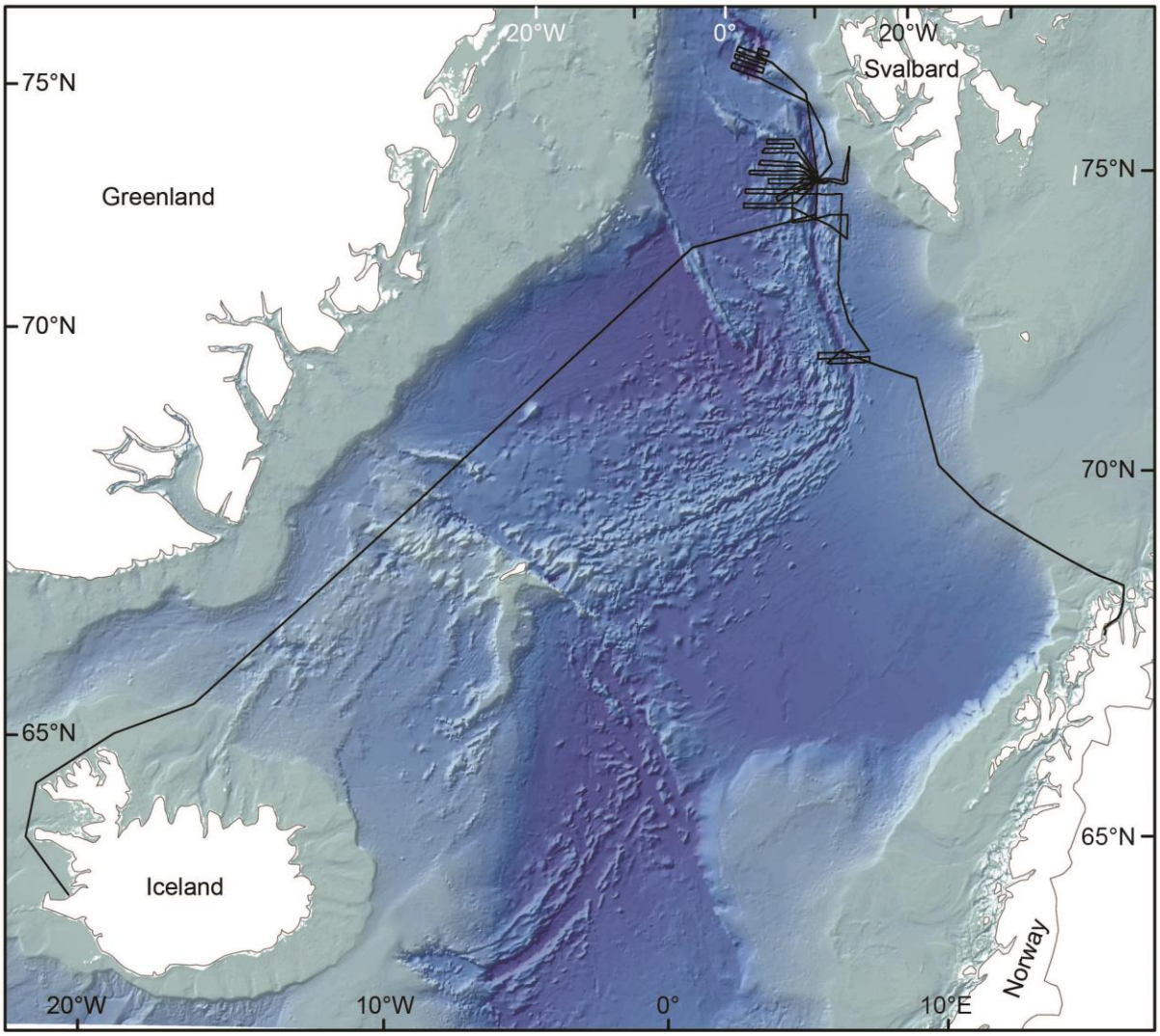
Short Cruise Report
R/V MARIA S. MERIAN Cruise MSM109

Tromsö – Reykjavik
6 July – 3 August 2022
Chief Scientist: Gerhard Bohrmann
Captain: Björn Maass



Ship track of R/V MARIA S. MERIAN cruise MSM109 from Tromsö to Reykjavik.

Objectives

As part of the research unit "The Ocean Floor as Reactor" of the Bremen Cluster of Excellence "The Ocean Floor – Earth's Uncharted Interface" we used RV MARIA S. MERIAN cruise MSM109 to investigate hydrothermal fields of the Knipovich Ridge and Molloy Ridge in the Norwegian Greenland Sea west of Svalbard. In contrast to other spreading ridges in the European Northern Sea and the Arctic, these more than 500 km long segments of ultraslow oceanic spreading have hardly been investigated and active hydrothermal fields on the seabed are not yet known. Previous geological investigations and more recent multi-beam echosounder measurements during MSM57 and MSM68 along the Knipovich Ridge show a clear segmentation in the occurrence of igneous rocks that alternate with sediment-covered sections on the seabed. Based on indications of hydrothermal plumes in the water column, on registered earthquakes, and on detailed multi-beam data, we worked in 4 different areas: The Molloy Ridge, the Brögger AVR, die AVR at Logachev Seamount and at the southern Knipovich Rdige. After having identified plumes during dives with the AUV MARUM-SEAL and in the course of CTD stations, detailed investigations and samplings wascarried out with ROV MARUM-QUEST 4000.

Cruise Narrative

On Wednesday, 6 July 2022, RV MARIA S. MERIAN left Tromsø bunker pier at 11:00 a.m. local time to set sail for the Norwegian Sea. Marine geological investigations of hydrothermal vents and its distribution at the sea floor of the Knipovich ridge are the focus of mission MSM109. The two main devices, the ROV (Remotely Operated Vehicle) QUEST and the AUV (Autonomous Underwater Vehicle) of the MARUM had to be installed on the research vessel during the port time. For this purpose, 8 containers were delivered from Germany to Tromsø, which were partly set up on the ship's deck with a special crane on land. This happened on Sunday 3 July and had to be completed in the evening as the ship had to move from pier 24 to pier 25.

We reached our actual target, the Knipovich ridge, on Friday 8 July, starting to the south with a CTD station in an area where signals from a hydrothermal plume could be identified in the water column in previous years. A planned AUV dive to measure the seabed had to be aborted for technical reasons and so we decided to alternatively carry out measurements of the seabed further north after a second CTD station. The Knipovich ridge is about 500 km long and is part of the spreading zone between the North American plate and the Eurasian plate. On the way there, we passed previously uncharted areas of the seabed and mapped the seabed with the multi-beam echosounder and the sediment echosounder Parasound. We reached the area of potential hydrothermal activity on Saturday evening and started surveying the water column at midnight with a CTD station and our Eh sensors. At a slow speed of only half a knot, we scanned the water column between the sea floor and a water depth of 2,700 m by yoyo-like movements of the probe with the ship's wire over a profile length of about 4 nautical miles and took water samples. The analysis of the water samples will be carried out in the ship's laboratory today, Sunday morning, 10 July. At the same time, MARUM ROV QUEST dives to the seabed for its first dive during the cruise, where we want to carry out investigations in 3,200 m water depth during the course of the day.

In the second week of our expedition we carried out surveys in the northern part of the Knipovich Ridge west of Spitsbergen to find hydrothermal activity. During the first ROV QUEST dive on 10 July, we explored a seafloor region at the southern end of the Axial Volcanic Ridge (AVR) at 77°24'N latitude. There, an Eh anomaly in the water column about 70 m above the sea floor was measured with an AUV during the expedition of the Norwegian

Petroleum Directorate last year. The goals of this dive were to find an explanation for this anomaly on the sea floor, but at the same time to understand the bottom composition of the AVR. Unfortunately, the dive had to be canceled earlier than planned for technical reasons.

During a second longer dive with MARUM ROV QUEST on Tuesday 12 July in this area we were able to investigate a larger area. The pillow basalts form numerous mounds of about 20-40 m in height and 200-300 m in diameter, the areas between the mounds are completely covered with sediment. These hill structures, which are widespread on the AVR, had already been noticed in the high-resolution bathymetric maps of the Norwegian AUV survey, whereby the formation of the hill structures from the dives is now better understood. A second very prominent axial volcanic ridge (AVR), lies close to the Logachev Seamount, about 50 nautical miles south of the previously studied AVR in whose extension an apparently young volcanic area appears morphologically. It is mainly characterized by very high backscatter values in the side-scan sonar and backscatter recordings of the AUV multi-beam survey. Due to technical problems with the ROV, we were no longer able to investigate whether there was still low thermal activity. Unfortunately, the technical problems of the ROV continued until the end of the week and it was not until this Sunday, 17 July, that we are back on the seabed with the ROV.

With the AUV, we carried out micro-bathymetric measurements in the area of slide complex on Tuesday and Thursday night. Here, we were guided by an earlier measurement of the redox potential in the water column too, which we were able to confirm during a CTD measurement with an Eh sensor. In the meantime, this region has proven particularly attractive to continue searching for hydrothermal activity as we have detected Eh anomalies and small temperature anomalies in several Yoyo CTD profiles. In addition, the water samples with levels of 100-1,000 nmol/L have high methane concentrations with otherwise background levels of 2-4 nmol/L. Unfortunately, there were technical issues with both the AUV and ROV in the second half of the week, so we used the ship time for other work. The focus was on surveying with the ship's own multi-beam, especially of the western shoulder of the Knipovich graben together with the CTD measurements.

Our 3rd week was the most successful week so far, because for the first time we were not only able to document but also measure hydrothermal vents at the Knipovich ridge. Also, the technical problems of AUV and ROV have been overcome. The following Monday we steamed north into the Fram Strait between Greenland and Svalbard to conduct investigations at the Molloy spreading center. The ice situation allowed us to do all our surveys, station work and dives from Monday to Wednesday. The sea was extremely calm, there was partly bright sunshine, with otherwise very foggy conditions. Wednesday was special, when we were able to observe a fog bow in several variations from the ship during the day. Similar to a rainbow, a fogbow is formed by reflecting sunlight with a fog front, with the reflecting water droplets being extremely small at 5 microns.

Midweek we steamed out of the Fram Strait back to the Axial Volcanic Ridge (AVR) at 77° 20'N. To distinguish this AVR from the AVR further south near the Logachev Seamount we use the name of Waldemar Christofer Brøgger, a Norwegian geologist who has become internationally famous not only for his work on the igneous rocks of the Oslo Graben. At the geographical latitude of the now named Brøgger AVR, we have the best chance of finding and documenting hydrothermal activities of the Knipovich ridge at the eastern edge of the graben thanks to our Eh and methane anomalies and our first observations from a dive.

Therefore, during two AUV dives, we added further micro-bathymetry to an earlier AUV map of the Norwegian Petroleum Directorate in order to get as much preliminary information as possible on the morphological phenomena for the diving work with the ROV. We are measuring a last missing bathymetry area on the seabed of this region this Sunday night. We focus on a north-south band at a water depth of 3,000 m in the foot area of the eastern rim of the graben, which is characterized by a further subsidence of the seabed to the west up to the Brøgger AVR to about 3,500 m.

The AUV map shows that igneous rock bodies are also present in the deepest part, extending to the foot of the eastern graben depression. During the ROV dives on Friday and Saturday, we repeatedly observed outflows from pillow lavas that formerly flowed onto a sedimentary bedrock. Some rift-parallel fissures at a water depth of about 3,000 m also show on the fissure walls that pillow basalt layers stacked on top of each other contribute to the structure of the lower slope area of the rift wall. During the dives we repeatedly found indicators of hydrothermal venting in an approximately 50-70 m wide strip parallel to the slope. These can usually be recognized by white staining, which can be traced from the lower edges of the rock in a vertical direction on the surface of rocks. On closer inspection, tubeworms cloaked in filaments of bacteria can always be found in the area. Very small gastropods and crabs, a few millimeters in size, can usually be seen. Fluid samples showed that methane concentrations of several 100 nmol/L are present there. During yesterday's dive we sampled an exit site with shimmering fluid that was 8°C and mixed with bottom water at -0.6°C. The methane level rose to almost 2 µmol/L and had a distinct H_2S odor after recovery. The corresponding chemosynthetic organisms and precipitates from the location were recovered and are being investigated within the Bremen Cluster of Excellence. During the dive we were also able to recover sulphide precipitates and parts of a chimney which was mainly gypsum. The sampled region appears to be characterized by widespread diffuse venting, which explains the high methane concentrations we measured in the CTD water samples.

After the 3rd week of our expedition was quite successful, the 4th week was associated with even more scientific highlights. We were able to dive during all days, further examining the region of seafloor hydrothermal activity that we had mapped from the methane and Eh anomalies in the CTD profiles of the water column. On Monday we discovered a black smoker whose fluid at a temperature of over 300°C shot out of an almost 20 cm opening. Since the opening was not directed upwards but to the side and the chimney area sat relatively short on a mound of older hydrothermal deposits, it was a great challenge for the ROV pilots to carry out the necessary sampling on the smoker. In addition to the fluid samples at three different points of the outflow, a piece of the sulphide precipitates could also be obtained from the edge of the smoker. The methane levels, which are in the range of mmol/L, surprised us, but explain why we measured quite high levels of methane in the water of our CTD- casts and profiles. During Tuesday's dive we revisited the smoker for temperature and further fluid sampling and mapped the northward distribution of bottom hydrothermal features. During the night our AUV Seal 5000 surveyed the area with a higher resolution than before by conducting a dive just 60 m above the sea floor. This map gives us more details that we were able to use during the ROV dive the following day.

A complex hydrothermal edifice with numerous chimneys and flanges was found. The hot fluid escaped everywhere, so that the entire structure was completely surrounded by shimmering water and photo documentation was extremely difficult. Here, too, the outlet

temperature was over 250°C and the methane content was several mmol/L. We were so fascinated by this hydrothermal vent that we gave it the name Yggdrasil, the term for the tree of life in Norse mythology. With these results of the expedition we can define a new hydrothermal field, namely the first of the 500-km-long Knipovich Ridge. The field has an extension of about 1 km in north/south direction and with a width of 150-250 m it follows the eastern marginal fault at a water depth of 3,000 m. We call it the Jøtul hydrothermal field, a name for a being that in Norse mythology corresponds to a giant that dwells in a mountain or range. The last two ROV dives, on Thursday and Friday, we dived 50 km to the south in what is probably the youngest volcanic area in 3,200 m water depth. On Friday, 29 July at 5:00 p.m., we had to stop station work and set off for Reykjavik. On the transit route to the port, the ship only travels 10 knots through the water for reasons of energy saving and cost. We use the southbound path in the East Greenland Current, which brings us further advantages in these austerity measures, and will thus arrive in the port of Reykjavik punctually on Wednesday, 3 August, where the cruise officially ends.

Acknowledgements

We scientists are very happy about the goals achieved and return on land with great results. We also owe the success of the scientific work to the excellent and friendly support from the ship's crew in all areas (nautical, WTD, deck crew, engine and service area, etc.) of the shipping company and the employees of the control center in Hamburg and at MARUM as well as the colleagues from the Norwegian Petroleum Directorate. We would especially like to thank Captain Björn Maass and his entire team, who supported us in all matters. At the same time we thank both teams of ROV and AUV, without their achievements we would not have reached our scientific goals. The ship time of MARIA S. MERIAN was provided by the Deutsche Forschungsgemeinschaft and additional funding came from the Bremen Cluster of Excellence “The Ocean Floor – Earth’s Uncharted Interface”.

Cruise participants

1.	Gerhard Bohrmann	Chief scientist	FB5
2.	Hauke Buettner	ROV	MARUM
3.	Ousmane Coulibaly	ROV	MARUM
4.	Christian dos Santos Ferreira	MBES, Parasound	FB5
5.	Daniel H□ttich	ROV	MARUM
6.	Jan Kleint	ISMS, KIPS	MARUM
7.	Janice Malnati	Methane, ICOS	FB5
8.	Lara Marschall	MBES, Parasound	FB5
9.	Pooja More	AUV	MARUM
10.	Ralf Rehage	ROV	MARUM
11.	Jens Renken	AUV	MARUM
12.	Henri Renzelmann	CTD	FB5
13.	Christian Reuter	ROV	MARUM
14.	Tobias Schade	ROV	MARUM
15.	Marcel Schroeder	ROV	MARUM
16.	Daniel Smrzka	ORP, rock samples	FB5
17.	Ulli Spiesecke	AUV	MARUM

18.	Katharina Streuff	Maps, ROV dives	FB5
19.	Abraham Tibebu	ROV	MARUM
20.	Angelly Fiorella Serje Gutierrez	MBES, Parasound	FB5
21.	Stig Morten Knutsen	ROV dives	NPD

Participating Institutions

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FB5, Fachbereich Geowissenschaften der Universität Bremen, Klagenfurtertsr. 4, D-28359 Bremen /Germany

NPD, Norwegian Petroleum Directorate**,** Professor Olav Hanssens vei 10**,** N-4003 Stavanger, Norway https://www.npd.no/en/

Station list

Date 2022	St. MSM109/	Instrument	on seafloor	Latitude N	Longitude E	Water depth (m)
07.07.2022	**001-1**	**CTD-01**	23:34	74° 43.093	8° 24.419	3121
08.07.2022	**002-1**	**CTD-02**	20:53	74° 43.112	8° 24.470	3310
09.07.2022	**003-1**	**CTD-03**	22:59	77° 25.295	7° 16.632	3244
10.07.2022	**004-1**	**ROV-455**	10:24	77° 24.824	7° 20.742	3076
11.07.2022	**005-1**	**CTD-04**	12:05	77° 24.809	7° 20.664	3078
11.07.2022	**006-1**	**CTD-05**	14:46	77° 26.7256	7° 44.155	2981
12.07.2022	**007-1**	**ROV-456**	08:55	77° 24.816	7° 20.592	3136
12.07.2022	**008-1**	**AUV-102**	18:33	77° 25.284	7° 46.728	2170
13.07.2022	**009-1**	**ROV-457**	10:00	76° 49.243	7° 17.991	3126
14.07.2022	**010-1**	**CTD-06**	10:55	77° 24.994	7° 40.964	3044
14.07.2022	**011-1**	**AUV-103**	19:09	77° 27.399	7° 45.356	2920
15.07.2022	**012-1**	**CTD-07**	07:05	77° 26.614	7° 43.865	2954
15.07.2022	**013-1**	**CTD-08**	11:09	77° 26.404	7° 41.159	3142
16.07.2022	**014-1**	**CTD-09**	12:14	77° 26.988	7° 38.914	3230
17.07.2022	**015-1**	**CTD-10**	06:54	77° 26.549	7° 43.052	2969
17.07.2022	**016-1**	**ROV-458**	10:59	77° 26.449	7° 42.434	3053
17.07.2022	**017-1**	**AUV-104**	20:25	77° 23.550	7° 16.752	3250
18.07.2022	**018-1**	**CTD-11**	07:22	77° 26.745	7° 45.536	2872
20.07.2022	**019-1**	**CTD-12**	13:02	79° 29.877	3° 32.578	2972
20.07.2022	**020-1**	**AUV-105**	21:38	79° 26.907	3° 38.010	2900
21.07.2022	**021-1**	**CTD-13**	06:06	79° 24.461	3° 25.372	3022
21.07.2022	**022-1**	**ROV-459**	10:25	79° 24.630	3° 22.205	2891
22.07.2022	**023-1**	**ROV-460**	08:48	77° 26.498	7° 42.600	3024
23.07.2022	**024-1**	**ROV-461**	09:21	77° 26.453	7° 42.504	3022
23.07.2022	**025-1**	**AUV-106**	20:20	77° 32.496	7° 40.699	2920
24.07.2022	**026-1**	**ROV-462**	10:51	77° 26.368	7° 42.326	3043
24.07.2022	**027-1**	**AUV-107**	20:03	77° 25.409	7° 51.921	1957

25.07.2022	**028-1**	**ROV-463**	10:14	77° 26.162	7° 40.196	3044
25.07.2022	**029-1**	**CTD-14**	19:15	77° 26.375	7° 42.516	2984
25.07.2022	**030-1**	**CTD-15**	22:22	77° 26.261	7° 42.110	3034
26.07.2022	**031-1**	**ROV-464**	08:45	77° 26.379	7° 42.549	3023
26.07.2022	**032-1**	**AUV-108**	17:47	77° 27.291	7° 45.440	2870
27.07.2022	**033-1**	**CTD-16**	04:56	77° 26.548	7° 43.342	2942
27.07.2022	**034-1**	**ROV-465**	08:37	77° 26.337	7° 42.715	3010
28.07.2022	**035-1**	**ROV-466**	08:51	76° 49.650	7° 19.987	3255
28.07.2022	**036-1**	**AUV-109**	18:46	76° 49.584	7° 20.893	3150
29.07.2022	**037-1**	**ROV-467**	08:39	76° 49.616	7° 24.450	3263

Scientific work/station work during MSM 109:

AUV SEAL 5000	8 dives
ROV QUEST 4000	13 dives
CTD	16 stations
MBES/Parasound	2829 nm