Cruise report – DeepInsight2025

KH25-263

University of Bergen

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UNIVERSITY OF BERGEN

Centre for Deep Sea Research

NORWEGIAN OFFSHORE DIRECTORATE

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Contents

Background and summary of overall objectives

A primary objective of the DeepInsight-2025 cruise was targeted sampling of seafloor massive sulfide (SMS) deposits using a remotely operated vehicle (ROV), aiming to collect sufficient Cu-rich material to develop and demonstrate a sustainable beneficiation process - a key responsibility of ReSiTec within the EMINENT project. Another important goal was conducting video surveys of these deposits and surrounding areas to refine methods for generating 3D visualizations of geology and benthic fauna along survey transects.

The DeepInsight-2025 cruise was funded through the Green Platform EMINENT project (Energy Minerals for the Net Zero Transition), in which the University of Bergen (UiB) - responsible for leading and facilitating the cruise using the Ægir 6000 ROV system - is an academic partner. Additionally, the Norwegian Offshore Directorate participated and funded extended video transects across off-axis seamounts to document benthic megafauna.

The primary targets were three extinct polymetallic SMS deposits, two located on the northwestern flank of the central Mohns Ridge. This area was identified as an extinct hydrothermal zone during the CDeepSea-2022 cruise, where a large SMS deposit, provisionally named DeepInsight, was discovered during the DeepInsight-2023 cruise. Another deposit, Grøntua, was found during the CDeepSea-2024 cruise. The region is a key site for research on extinct SMS deposits, mineral exploration methods, and environmental baseline studies, critical for assessing resource potential within Norway's Exclusive Economic Zone.

During transit from Longyearbyen to the Mohns Ridge, we aimed to stop at the Knipovich Ridge (~77° N) to revisit a hydrothermal area first approximately located in 2017, now known as the Jøtul vent field. The specific objective was to target a major low-angle fault zone with documented hydrothermal activity, where a massive sulfide sample was recovered during the November 2024 “Ultima Thule” cruise.

Departing Longyearbyen on March 14, we reached the study area within 12 hours and commenced ROV dives that evening. We confirmed abundant massive sulfide deposits, and through successful dives collected sufficient Cu-enriched sulfide material, achieving the primary cruise objective. Several video transects documented benthic fauna within and surrounding these SMS deposits, named “Gygra” by the participants. A final ROV transect along the fault zone revealed talc-serpentinites, presumably resulting from exhumation of mantle lithologies during oceanic core complex formation.

We arrived at the DeepInsight and Grøntua SMS deposits on the Central Mohns Ridge on March 18, after a 35-hour transit. The study began by deploying two Aanderaa SeaGuard instruments to measure ocean currents, particle density, oxygen, and temperature. This was followed by video transects across the Grøntua deposit and adjacent areas.

ROV inspections of Grøntua revealed a cone-shaped structure (40 m high, 200 m wide) mostly covered by sediment, at least 1.5 m thick on its flat top. Exposed massive sulfide areas were sampled, with onboard XRF analyses confirming significant Cu enrichment. To expose additional parts of the SMS deposit, we deployed a hydraulic dredge operated by Ægir 6000, uncovering yellow-brown oxidized sediments above bluish-gray clay sediments, both enriched in Cu. Push cores collected adjacent to and within dredged trenches showed systematic porewater variations consistent with sulfide oxidation.

Similar dredging at DeepInsight did not reveal Cu-rich, weathering-influenced sedimentary layers, likely because its upper part comprises silica-rich hydrothermal deposits with low Cu concentrations. Systematic video transects were also conducted here.

After recovering the SeaGuard instruments, preliminary data analyses indicated relatively low current speeds with tidal-influenced direction shifts and intermittent significant temperature variations, as well as notable oxygen-level fluctuations requiring further analysis.

Despite gale-force winds during most of the cruise, RV Kronprins Haakon's stability and moonpool operations enabled regular ROV deployments. On March 22, due to an approaching storm, we transited approximately 90 nautical miles west-southwest to a seamount for planned video transects. After a 24-hour halt due to heavy seas, transects commenced, covering flat muddy seafloor (~2500 m depth), sedimented slopes, and steep escarpments to the summit at ~1500 m depth. Onboard biologists collaborated with shore-based IMR biologists monitoring ship-to-shore video feeds, gathering data for quantitative assessments of benthic ecosystems.

Two SeaGuard instruments were deployed at the seamount base and summit to collect one year of oceanographic data. Sampling along summit escarpments revealed altered gabbros and serpentinites, indicating tectonic exhumation of deeper crustal and mantle lithologies along the southwestern Mohns Ridge segment.

On March 26, we returned to DeepInsight for additional geological exploration and sediment sampling for eDNA analysis. Three parallel push cores were collected from the summits of DeepInsight and Grøntua, and three reference sites nearby. With this, all cruise objectives were successfully fulfilled, and we began our return voyage to Tromsø.

I sincerely thank the captain and crew for excellent seamanship and support, the Ægir 6000 ROV team for outstanding operations and maintenance, and the scientific party for their dedicated efforts and good spirit throughout the cruise.

Rolf B. Pedersen, Cruise Leader

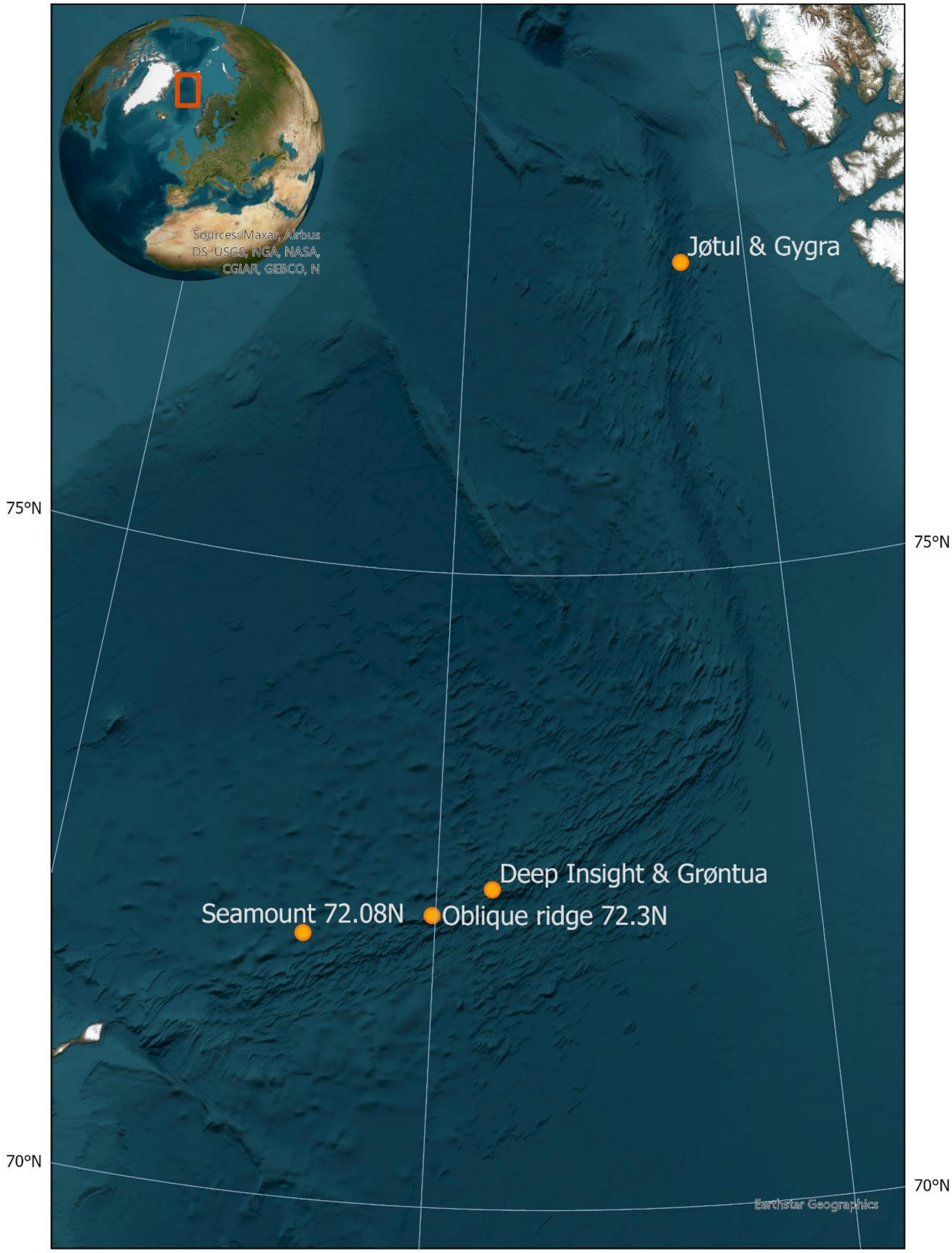

Figure 1. Location overview from the cruise showing the main study areas.

List of participants

Rolf Birger Pedersen	Cruise leader, Professor, UiB
Ingunn Thorseth	Professor, UiB
Håvard Stubseid	Researcher, UiB
Maja Jæger	Data Manager, UiB
Thilde Voje	PhD candidate, UiB
Rosalyn Fredriksen	Biologist, NOD
Jan Stenløkk	Geologist, NOD
Janka Rom	Geologist, NOD
Camilla Marnor	Biologist, Bergwerk
Mahesh Kulkarni	Engineer, ReSiTec
Thore Sørensen	Engineer, ReSiTec
Åse Sannem Inderberg	Student, UiB
Kari Skeie	Student, UiB
Ihne Ousdal	Student, UiB
Guro Thoresen	Student, UiB
Live Sundnes	Student, UiB
Frode Evensen	ROV Supervisor, BSA
Jonas Broberg	ROV pilot, DWS
Kai Roger Loven	ROV pilot, DWS
Johan Skøld	ROV pilot, Saga subsea
Bjørn Løfquist	ROV pilot, Saga subsea
Andreas Storebø	ROV pilot, BSA

Figure 2- The scientific participants of the KH25-263 research cruise.

Public outreach

During the expedition, Maja Jæger has been responsible for managing the Instagram account for Centre for Deep Sea Research, called @centredeepsea, sharing updates on Instagram about various activities we've been involved in—both related to the research and the life on the ship. Everyone has contributed to this in one way or another with photos, videos and being present in photos.

Methods and equipment

R/V Kronprins Haakon

The polar class 3 ice breaker research vessel Kronprins Haakon has a total length of 100 meters and weighs above 10.000 t. It is equipped with the very latest high-tech equipment, enabling us to perform complex studies, such as ROV operations, sediment coring, and water column measurements. The ship has 15 laboratories and the capacity of 55 passengers including 15-17 crew.

The ROV system is launched through a moonpool located on the 3rd deck of the ship, enabling the launch of the ROV in ice as well as in rougher seas compared to the standard launch over the side of the vessel. In addition, the R/V Kronprins Haakon is equipped with an EM302 multibeam echo sounder capable of mapping a swath width up to 3.5 times the water depth with a resolution of up to 25 m. During transit, the multibeam system is continuously recording bathymetry. R/V Kronprins Haakon has a cruising speed of 15 knots and can break through ice up to one meter thick. Kronprins Haakon represents a state-of-the-art research vessel.

More details about the ship can be found here:
https://kronprinshaakon.hi.no/en/projects/kronprins-haakon/about-the-vessel/world-class-vessel

ROV ÆGIR 6000

The ROV Ægir 6000 is a Kystdesign 'Supporter' working class vehicle connected to a Kystdesign tether management system (TMS) capable of submerging down to 6000 m. Standard equipment on the ROV includes two manipulators (Schilling T4 and ATLAS), telemetry sensors, 4 horizontal and 3 vertical thrusters, a high precision positioning system, multiple cameras, and an array of fixed and adjustable LED lights. The TMS system is stacked on top of the ROV during launch and recovery, and the ROV is released from the TMS at a suitable depth above the seafloor. The ROV is connected to the TMS via a 600 m long tether with neutral buoyancy, which provides a large degree of freedom of movement along the seafloor. The TMS also holds a mounted hydraulic basket for larger samples or tools. Further, several additional tools are possible to utilize with the ROV, explained in more detail below.

Positioning

Positioning of the ROV is obtained from a combination of: (1) a High Precision Acoustic Positioning system (HiPAP), (2) a Doppler Velocity Logger (DVL), and (3) Inertial Navigation System (INS). The HiPAP system utilizes the ship's GPS position and a transducer that receives acoustic signals from transponders mounted on the ROV and TMS. The Doppler system gives additional information on the direction and speed of the ROV. A gyroscope and an accelerometer in the INS provide precise data of rotation, velocity, altitude, and horizontal position. This combination of systems provides a 5-20 m accuracy on the ROV positioning.

Cameras

Ægir 6000 is equipped with multiple cameras including a pan-and-tilt HD camera for video recording, positioned at the center top of the ROV. The center camera is a pan-and-tilt 4K camera, used for high quality imaging through still photos and video recording. LED lights provide adequate background lighting.

Sampling

Rock sampling with the ROV is primarily conducted using two manipulators: the strong Schilling Atlas manipulator and the Schilling Titan 4 (T4), which offers greater precision and movability. Sampled rocks are stored in a basket on the underside of the ROV. Additionally, a custom-designed shovel, affectionately named "Frankenstein," is utilized for collecting loose and more fragile materials. For more rigorous rock sampling, the Ægir 6000 can be outfitted with a diamond grinder that features a 50 cm diameter blade, powered by the ROV's High Pressure Unit (HPU). This saw is particularly effective for collecting samples from thick manganese crusts and solid rocks that are beyond the capabilities of the manipulators. Furthermore, the ROV is equipped with a suction sampler designed for macrofauna, which works by vacuuming specimens through a tube into five separate sample containers.

Hot stab

A new hot stab system was installed on the ROV prior to the cruise. The hot stab allows us to change tooling subsea by connecting/disconnecting it. The hot stab is also designed so that it releases the tool if the ROV loses connection. This is especially useful in under-ice operations to avoid getting stuck.

Dredger

At the current cruise, an ROV dredger (6 inch) was rented from NOR Offshore Rental. This is a jet pump that sucks in seawater and drags with it sediments from the seafloor before it is blown out in the rear part of the ROV. This was mounted on the ROV to remove sediments to reach the underlying rocks in specific areas

Push coring

During each dive, up to 10 push cores for sediment coring can be mounted to the TMS (Tether Management System), as indicated in Figure 3. Utilizing up to 1.5-meter-long core barrels, these push cores are deployed by the ROV's manipulators and pressed into the seafloor's sediment to collect samples. To ensure the samples remain securely within the core barrel, a one-way check valve is installed at the top of each barrel to expel water and maintain a vacuum to contain the sediments. The cores are securely placed in plastic holsters, which are fastened to the outside of the TMS using metallic hose clamps, allowing for the collection of up to 10 push cores per dive. Additionally, core catchers may be attached to the bottom of the push cores to further enhance the retention of collected sediments.

Figure 3. New push core valves with bigger openings

SeaGuards

Both SeaGuards have the same sensors and work in the same way. The only difference is the communication opportunities, where SeaGuard II uses a program "Real time collector" and SeaGuard I has its own screen on the SeaGuard I component.
Sensors on the SeaGuards:

1. DCS – measures what direction the current flows [Deg from north] to and shows the speed of current "abs speed" [cm/s]
2. Turbidity - measures the number of undissolved particles in the water in [FTU] (formazin turbidity unit)
3. Oxygen optode – measures air saturation [%] and O_2 concentration [μM]
4. Conductivity – measures the waters ability to conduct electricity, which can indicate the salinity in the water depending on temperature and pressure. (The sensor has its own temperature sensor
5. Pressure - measures the pressure and gives useful data about the tidal wave.

Before the deployment the time on both SeaGuards is checked (They should be in UTC time and the time can drift), amt the oxygen sensor is calibrated after it has been in water for 24 hours.

Settings short period: Ping count: 150, Time interval: 1 min
Settings long period: Ping count: 150, Time interval: 30 min

Portable X-ray Fluorescence (PXRF)

In the current expedition the Portable Handheld X-Ray Fluorescence Spectrometer (PXRF) model no XL3t950, by Thermo Scientific has been used to measure the chemical composition of samples collected from the seabed. The inbuilt standard settings and calibration of soils/minerals/mining are used for measurements. The non-homogeneous irregular shaped rock samples are measured by visually selecting the spots on the surface of the rocks. Some powder and crushed grain samples are prepared by drying and crushing manually with laboratory mortar and pestle. These powder and grain samples are filled in standard cups with mylar films provided along with the instrument. Thus, it is obvious that the accuracy of measurements is subject to exact spot of measurement and may vary depending on the conditions such as surface, inclusion grains and moisture content.

Seafloor mapping

Multibeam, backscatter and water column data were principally acquired using the hull-mounted Kongsberg EM302 30 kHz multibeam echo-sounder. Data were collected with a total swath angle 110º. In the research areas, the survey was done at 5kn enabling a final grided resolution of 25/35 m depending on the water depth. During transit the multibeam is generally always running outside of the 12 nm territorial border, and the data is acquired at variable speed, up to 10 kn.

In addition, ROV Ægir6000 can also be equipped with a multi-beam echo sounder (EM2040) for high-resolution mapping that operates at frequencies of 200-400 kHz. The multibeam surveys are typically performed at an altitude of about 100-200 m above the seafloor, both while drifting with the ice and in open waters.

The *NaviPack* software package was used to process the collected echo sounder data in a three-step process. Firstly, *NaviEdit* was utilized to preprocess the data files so they could be imported into NaviModel. The data files were always imported into NaviEdit and depending on if they were from the ROV or the hull mounted echo sounder they were processed accordingly. If from the ROV, the pitch, roll and heading were changed to fit according to the placement of the multibeam on the ROV, whereas for the hull mounted echosounder this was not needed. Secondly, the data were cleaned in *NaviModel*, and the ROV track and coordinates of the sampling locations, were added to the map. Then it was grided and exported with the bathymetry.

Video transects

Aim: (1) Optimize video collection with the intention of using object detection/machine learning to automate parts of the post-processing of ROV video material and collect image material that can be used to increase the training dataset. (2) Explore Grøntua and other areas close to DeepInsight.

ROV video collection (1)

For collecting training material for object detection models, we need video frames of good quality, variety and, ideally, to recognize the individual biological specimens without context. It is an advantage to avoid video frames with motion blur, dark and distorted areas (water column and slopes), sampling and sediment plumes, and overexposed light (white areas have no information - this is for instance relevant in areas with the white Rossellidae sponges, which we observe in the Grøntua and DeepInsight area). These factors can lead to edge cases (i.e., the AI model is uncertain and might choose the wrong label).

When straight transect lines and constant ROV speed were not of importance, better images were obtained when the ROV followed the terrain and not a straight line as this gave the flexibility of adjusting the ROV heading to ensure that the seafloor always covered the field of view (FOV) → no distorted edges and water column in frame = better quality images.

On flat surfaces it was necessary to use some zoom to get good images and video of biology. Then the ROV speed had to be lowered to 0.2 knots to reduce motion blur. This was especially the case for sediment areas with a high abundance of brittle stars.

Lasers can be confusing for object detection. When there is a lot of marine snow in the water column, the lasers create lines in the upper part of the image. During the dives at this cruise there were few particles in the water column and the lasers appeared only as two points and they were used during the transects for size reference (10 cm). The effect for object detection will have to be tested.

Video options: HD, 4K compressed and 4K. We extracted one frame per second from the 4K compressed video automatically while filming the transects. We will check if these frames are of better quality than frames extracted from the video material after the dives.

Biology (2)

Large areas with sediments and aggregations of Ophiuroids, some places mixed with Polychaeta (tubes protruding from the sediment) and/or Bivalvia. Other organisms observed were Nemertea, Gastropoda and the sponge *Stylocordyla borealis*. Hard substrate areas were dominated by white vase-shaped glass sponges in the family Rosselidae, crinoids (Antedonidae), soft corals (*Gersemia*) and carnivorous sponges (Cladorhizidae). In some areas there were also many arctic skates (*Amblyraja hyperborea*) and skate egg capsules.

Dredge - plume generation - map plume spread in transect areas

Aim: Compare pre- and post-dredging to investigate whether we can see the influence of the plume generated by dredging with the ROV.

- Pre-transects in the area of dredging where it was expected that the plume would settle (ROV09).
- Transects after dredging (ROV15): Observed more sediment cover as we came closer to the dredge area. We could see sediments on sponges and tunicates. We could also see some sediments on sponges and tunicates 80 m from the westernmost dredge area. It is difficult to say if this is from the dredging or not, but we do not usually observe these tunicates with sediments on them.
- ROV20: We went back and looked at some of the same sponges close to the dredging area that were filmed post-dredging on ROV15. The sponges still had sediments on them.

Photogrammetry and Stereo camera setup

Aim: Using the images from the video transect and the precise positioning of the ROV, it is possible to reconstruct 3D georeferenced models of the seafloor using photogrammetry. The purpose of producing these 3D models is multifaceted. First, they allow for detailed mapping and documentation of the seafloor, enabling future comparisons. Second, they enhance video analysis by providing measurable data, allowing for precise measurements of marine life observed in the footage and the extraction of additional information, such as seafloor slopes along transects.

In addition to the primary central video camera (4K resolution), two additional stereo cameras (HD resolution) were mounted on top of the ROV to explore potential information gains for 3D reconstruction. The advantage of this stereo setup is that it enables direct depth extraction on a frame-by-frame basis, complementing the photogrammetric reconstruction. By combining these two techniques, a more detailed and accurate 3D representation of the recorded scenes can potentially be achieved.

1st test (ROV10): ROV track design: Vertical lines with overlap. Distance between lines was set to 2 m. The overlap was tested visually while diving by moving the ROV two m to the side and checking that a reference on the seafloor (we used a Rossellidae sponge) was still visible.

However, this gave too little overlap, at least based on only one camera. The stereo cameras were unfortunately rotated relative to each other so images from both cameras could not be used together. It is challenging to fly the ROV in a straight line. The distance between lines that is possible to have also depends on the distance from the seafloor to the camera/ area covered by FOV. The conclusion from this test was that the camera alignment should be checked on deck before the dive, and the ROV track design should aim for more overlap between dives.

2nd test (ROV22): ROV track design: Grid. We first did two normal video transects to explore the area. We found an interesting wall on the north side with diverse biology. Bryozoans, Rossellidae sponges and crinoids were dominating. ROV tracks in a grid pattern were planned for a smaller area of this wall [the track design is already described in the report but can add 1.6 m spacing between the horizontal lines]. Before starting the two HD cameras showed too much light exposure and it turned out that it is only possible to have a connection to one of the cameras at the time, with cables having to be changed at the surface. The test was performed with one overexposed camera and the other one with ok light. Next time, a pre-calibration on deck of both cameras should be done. When resurfacing it was discovered that the cameras are not identical and that it is not possible to change the settings for the other camera.

3rd test (ROV23): ROV track design: No pre-made tracks. Zig-zag lines up slopes as part of a geological exploration dive. ROV pilots tested different distances to the surface.

Location 1: Area around Jøtul hydrothermal field

Overall objectives at location 1:

The main aim for the dives in the area here was to investigate the hydrothermal deposits discovered during KH24-261 and to get a better understanding of the geology along the fault plane.

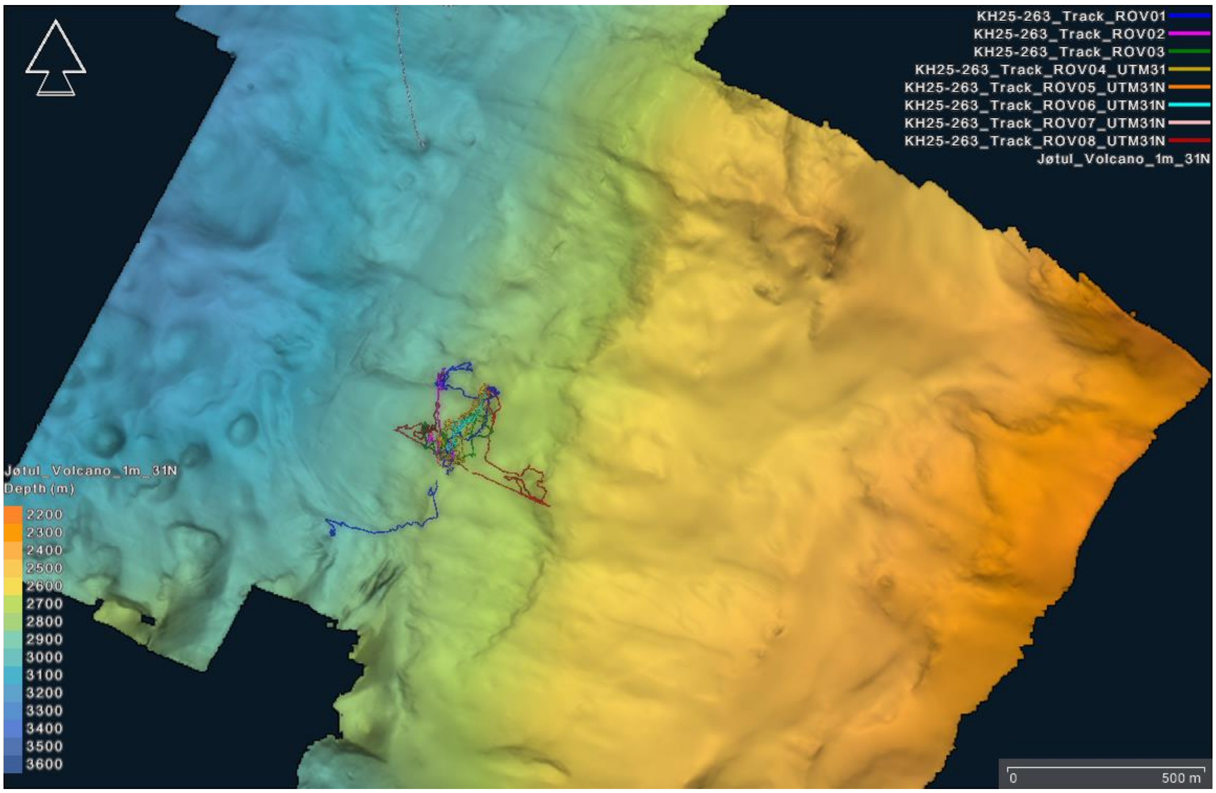

Figure 4. Map showing ROV-tracks for the conducted ROV-dives in the Jøtul area.

ROV01 – Investigation of hydrothermal deposit

77° 25.854' N, 007°42.216' E

Objectives

The goal for this dive was to locate and investigate the recently discovered hydrothermal deposit from KH24-261. From that cruise, one massive sulfide sample was recovered, but due to this being found in the last dive of the cruise, more exploring was needed. This dive was done with the Norwegian Offshore Directorate to further map the potential deposit – Gygra.

Preliminary results

The starting location was approximately 350 meters away in a south-east direction from the previously found sulfide sample from KH24-261. The dive started with flying straight east investigating areas with lots of basalts. There were large pillow basalts, both whole and broken. Also, some areas with just broken smaller pieces of basalt. The dive continued in a north/northwest direction towards the KH24 sulfide sample. No new sulfide deposits were found on the way there, but after reaching the sample site the sulfide deposit was quickly identified, and rocks were collected. The area consisted of mostly ultramafic rocks and occasional sulfides. The sulfides were both massive sulfides and weathered sulfides with oxidation rims.

ROV02 – ROV06 – Collection of sulfide samples for EMINENT

77° 25.854’ N, 007°42.216’ E

Objectives

The main objectives for these dives were all the same and that was to collect pieces of sulfide deposits for investigation of processing technologies. The sampling of larger amounts of sulfides was an overall goal for the cruise, and due to the good availability of these deposits here, a decision to gather larger quantities here was made.

Preliminary results

Many rocks were sampled during these dives consisting of larger blocks of massive sulfides and some non-massive sulfides, occasionally with high copper content. The area around the samplings sites also exposed mantle rocks. The fault planes up slope of the deposit showed nice outcrops with visible slicken slides. Several samples of talc schist were collected confirming the exposure of altered mantle rocks.

Figure 5. Massive sulfide sawed off using the grinder at the sulfide deposit during ROV06.

ROV07 – Active Jøtul hydrothermal field

77° 26.19’ N, 007°42.204’ E

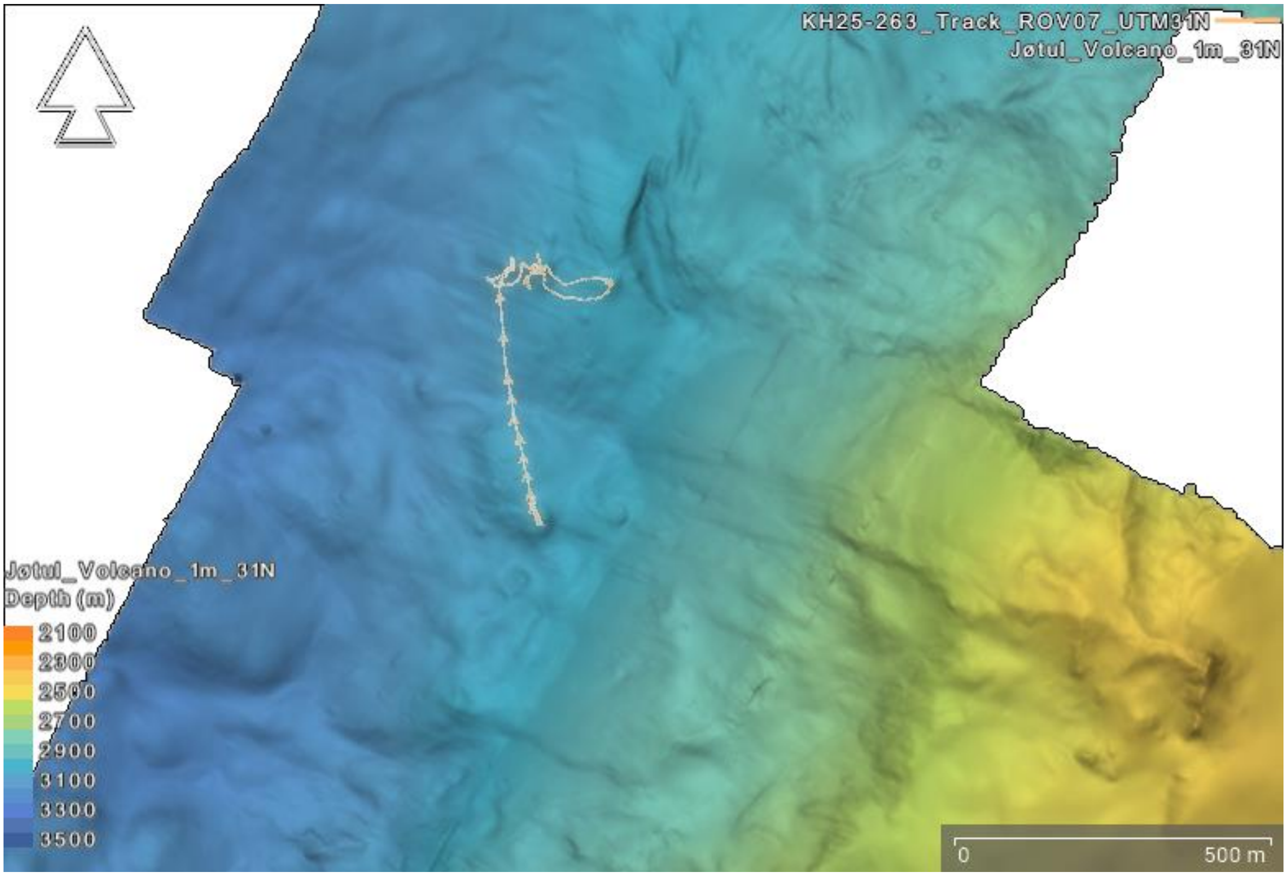

Figure 6. Map showing a location overview and the ROV track from ROV07 at the active Jøtul hydrothermal field.

Objectives

The main objective for this dive was to visit the active hydrothermal field Jøtul. This was both to show an active vent field to students and new cruise participants, and to collect some samples for EMINENT.

Preliminary results

ROV07 consisted of exploring two of the major sulfide mounds where it was filmed and pictures taken of the active black smoker. Samples were collected for EMINENT also in this location, to compare relatively young sulfides with those from an older and extinct deposit. A total of seven samples were collected from three main areas, from two different mounds.

ROV08 – Video transects and retrieval of seaguards

77° 25.836’ N, 007°42.162’ E

Objectives

The objectives for this dive were to conduct some video transects for biological mapping and to retrieve sea guard on the seafloor.

Preliminary results

During ROV08, there was taken one push core in the area where most of the sulfide sampling had been going on in previous dives. The push core hit a rock, probably due to avalanched material. Then the dive continued with two 200 m video transects moving up the slope over the sampling area and up to two shelves. The flatter area was largely covered with sediments with crinoids present. The second shelf had exposed rocks with visible striations. These rocks were sampled both by picking loose rocks and by sawing out pieces to be brought on deck. The rocks had a loose top part and very solid inner part. The dive ended with collecting the SeaGuard that was placed out during ROV05. A total of seven rock samples were collected, where many look ultramafic. The push core ended up being around 30/40cm, but the bottom part of the tube was broken after hitting some rocks.

Figure 7. Picture from the first retrieval of the SeaGuard in proximity to the sulfide deposit during ROV08.

Location 2: Deep Insight and Grøntua

72° 31.362' N, 001°29.256' E

Overall objectives at location 2:

The main objective at this location is to study and sample the newly discovered sulfide deposit. Prior to sampling, two seaguards will be placed on the seafloor to record information on the bottom currents. Comprehensive video transect, both long lines and more detailed areas, will be performed before sampling. The video transects should cover different types of seafloor material such as sediments, sulfides and volcanic features. After video documentation, the plan is to start dredging operations and conduct sampling of sulfides.

ROV 09, 10 and 15: Video transects and SeaGuards

ROV09 started with some exploration of Grøntua before two Seaguard was deployed. One southwest and another northwest to monitor the plume produced during dredging. Multiple 200 m long video transect was conducted in the area, before the ROV-based multibeam mapping of the area. Two long video transects was planned based on the created map. One transects, approximately 900 m, started in the basin north-west of Grøntua and ended in the volcanic terrane to the east. The second transect, approximately 1,2 km, crossed over all hills within the volcanic terrain and ended at Deep Insight. Mostly sedimented seafloor, with some rock exposures. One last 300 m transect over Deep Insight was performed before SeaGuards was recovered to get some preliminary data on the currents. Then a MBES survey was conducted to map the area, but these are data that needs further processing.

ROV10 was dedicated to detailed (50x50) m video surveys. Two boxes were completed, somewhat smaller than originally planned. The first box (28x40m) was done in the volcanic terrain south of Deep Insight and the last box (50x28) was from Grøntua.

ROV15 was the last dive in the area, and was set up to do multiple video transect from SeaGuard location toward areas where dredging had occurred earlier. This was done to see if there were any signs of dredging dust on living organisms. Six transects, in a fan shape towards dredging areas, was completed before the SeaGuards was retrieved for the last time in this area.

Figure 8. Map showing locations of video surveys during ROV10 and ROV15.

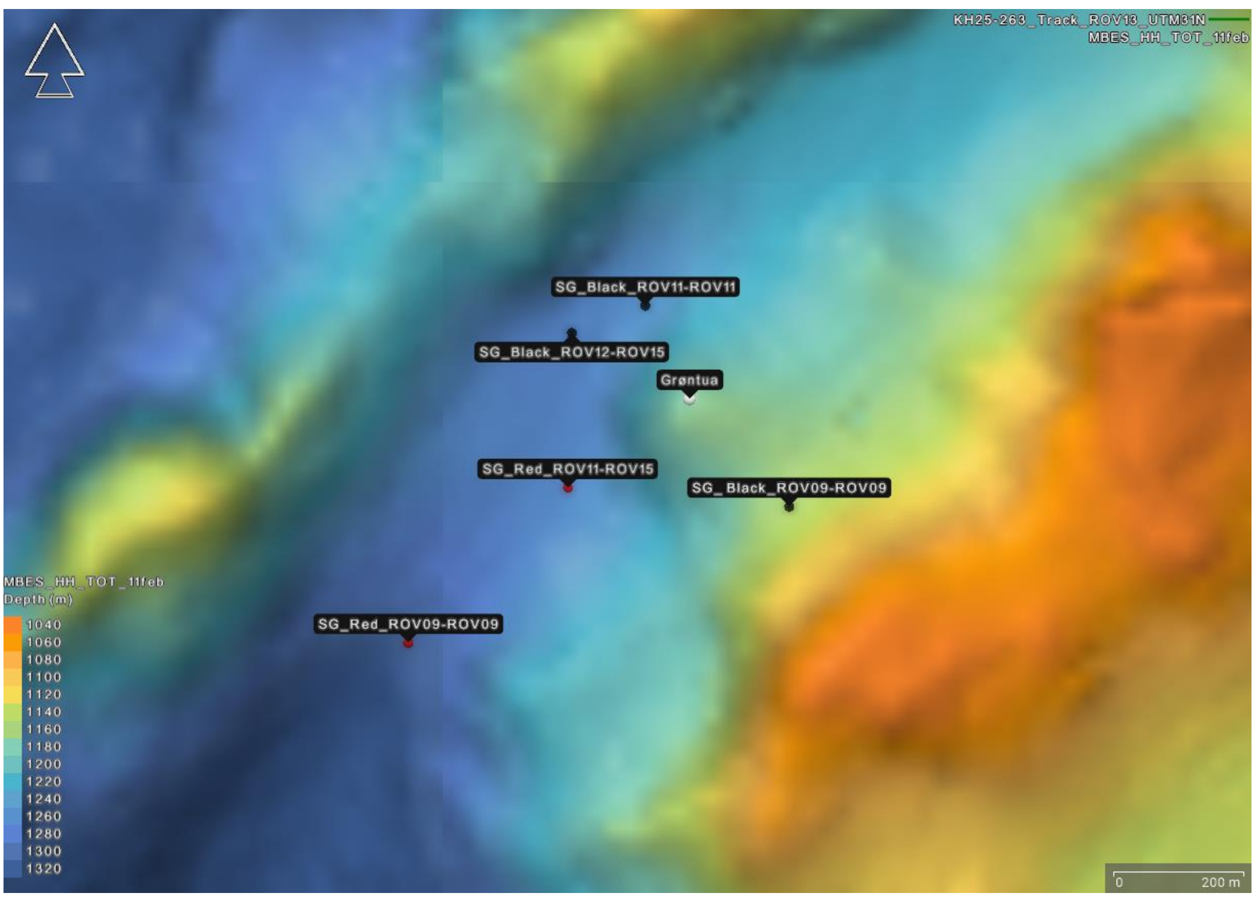

Figure 9. Map showing location for deployed seaguards and ROV dive for deployment-retrival.

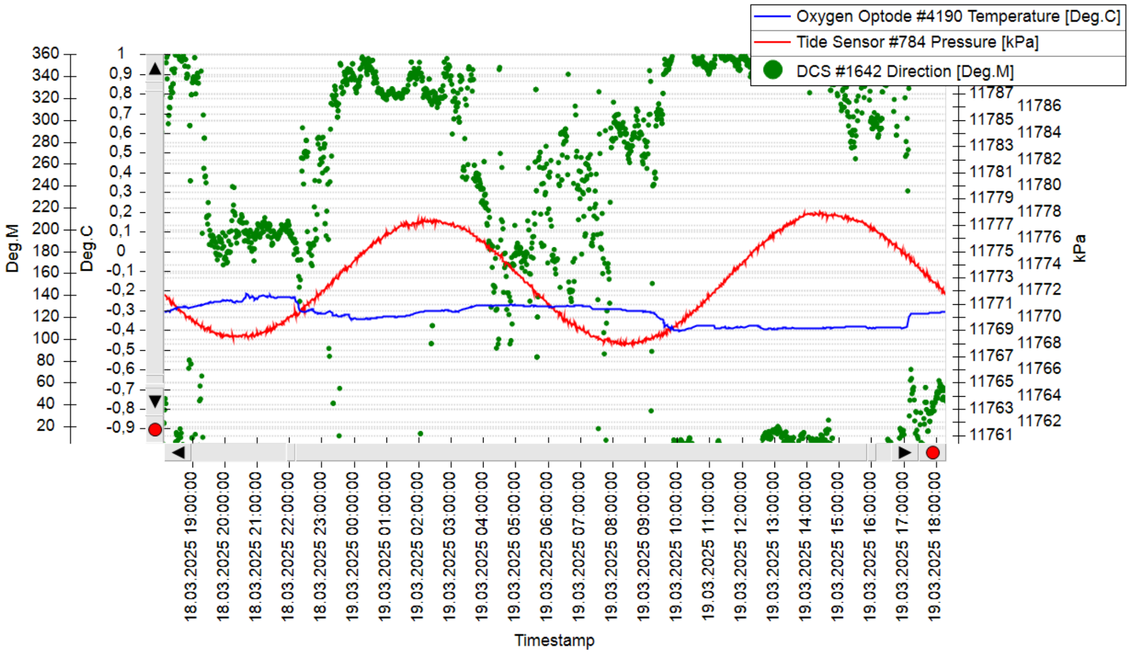

Figure 10. Example of a SeaGuard reading after being deployed for 24 hours in location "SG_Black_ROV09-ROV09" in Figure 9. The graphs show current direction, temperature and pressure.

ROV 11, 12, 13 and 14: Dredging and sampling

Dredging operations were started to remove sediments and rubble to get an impression on the underlaying substrate. Three spots were cleaned at Grøntua documenting that is it a sulfide deposit covered by sediments and drop stone. The top of the deposit is covered in meter-thick hemipelagic sediments, whereas the slope appears to consist of hydrothermal sediments and rubble. A nice exposure of redox gradients was discovered, going from an oxidized upper layer into reducing conditions underneath. Shiny sulfides and green atacamite is observed throughout the deposit. All exposure of hard rock are massive sulfides. The dive was moved to the "mound" north of Grøntua to investigate. No sulfides were observed, only basalts. Therefore, a conclusion was made on that this is an old volcanic structure. One SeaGuard was retrieved.

ROV12 was launched to collect sulfide samples for EMINENT. Sulfides were collected from Grøntua and was mostly massive and "fresh". Many of the samples was silicified. A very nice old extinct chimney was found (Figure 12), and a good sample was taken. The grinder was needed to get the solid samples loose. A push core to test the strength of the transparent short tubes was taken in the area where thoroughly dredging had been done earlier. The push core ended up being only 15-20cm after hitting rocks, but with three distinct layers, very green in the bottom.

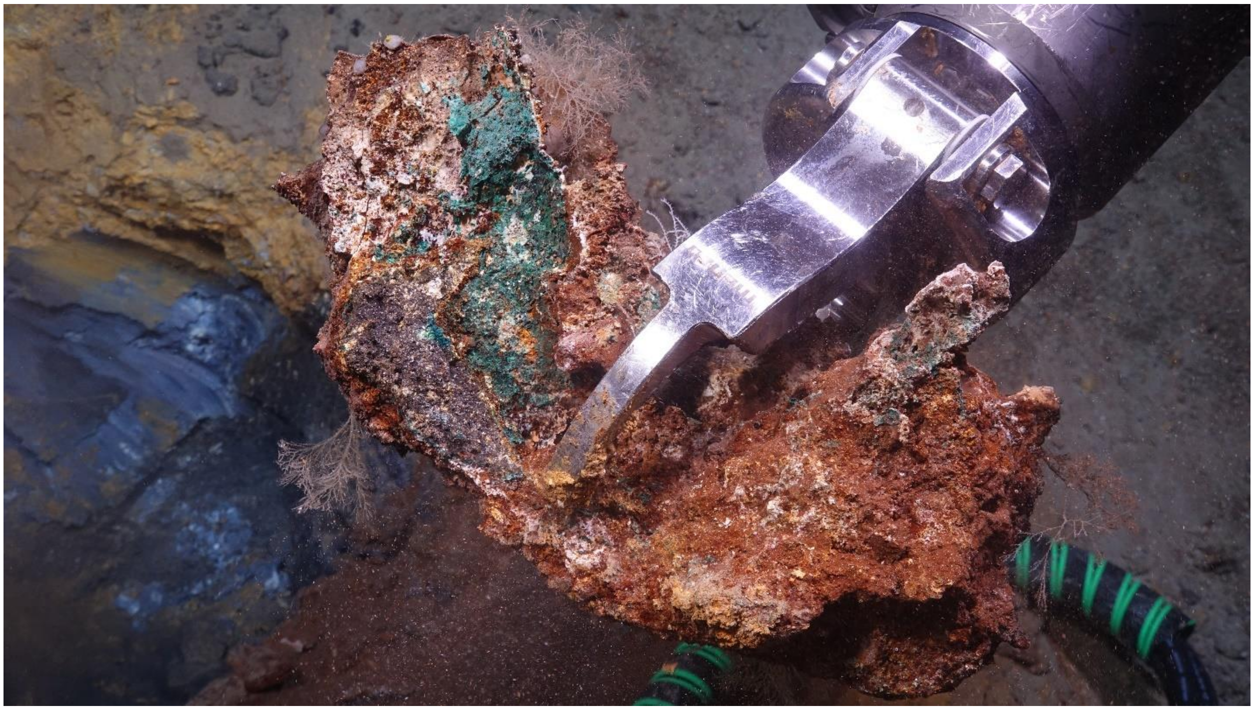

Figure 11. Image showing atacamite precipitation on one of the samples from Grøntua.

Figure 12. Image of extinct hydrothermal chimney sawed off. Oxidized rim and carbonate veins.

ROV13 was launched with the same aim at ROV12, and multiple samples of massive sulfides were collected. After, the dive continued to the first dredging spot where nice redox horizons had been observed earlier. Here, three push cores was successfully collected for pore fluids and microbiology. All cores went into the dark reduced layers. At the end, the dive moved further to the top of the mound, to the second location for dredging, to collect the hemipelagic sediments. One long core was collected, but all material was lost before we could secure the core in the holders on the TMS.

Figure 13. Image showing a close-up picture of one of the dredging holes at Grøntua.

During ROV14 one sulfide with a weathered surface was retrieved for microbial and weathering analysis at UIB. The sample was stored in a closed toolbox in the ROV drawer. Similarly, a piece of atacamite was collected and stored in another toolbox for a leaching experiment. Finally, two push cores from the top part was collected (where material was lost during a previous dive). Both cores were successful.

Figure 14. Map showing the overview and ROV-tracks from ROV11, ROV12, ROV13 and ROV14 in the Grøntua area.

Location 2: Return to Deep Insight and Grøntua

72° 31.362’ N, 001°29.256’ E

Objectives after returning to location 2:

The cruise returned to the Grøntua and DeepInsight Hill area after seamount investigations.

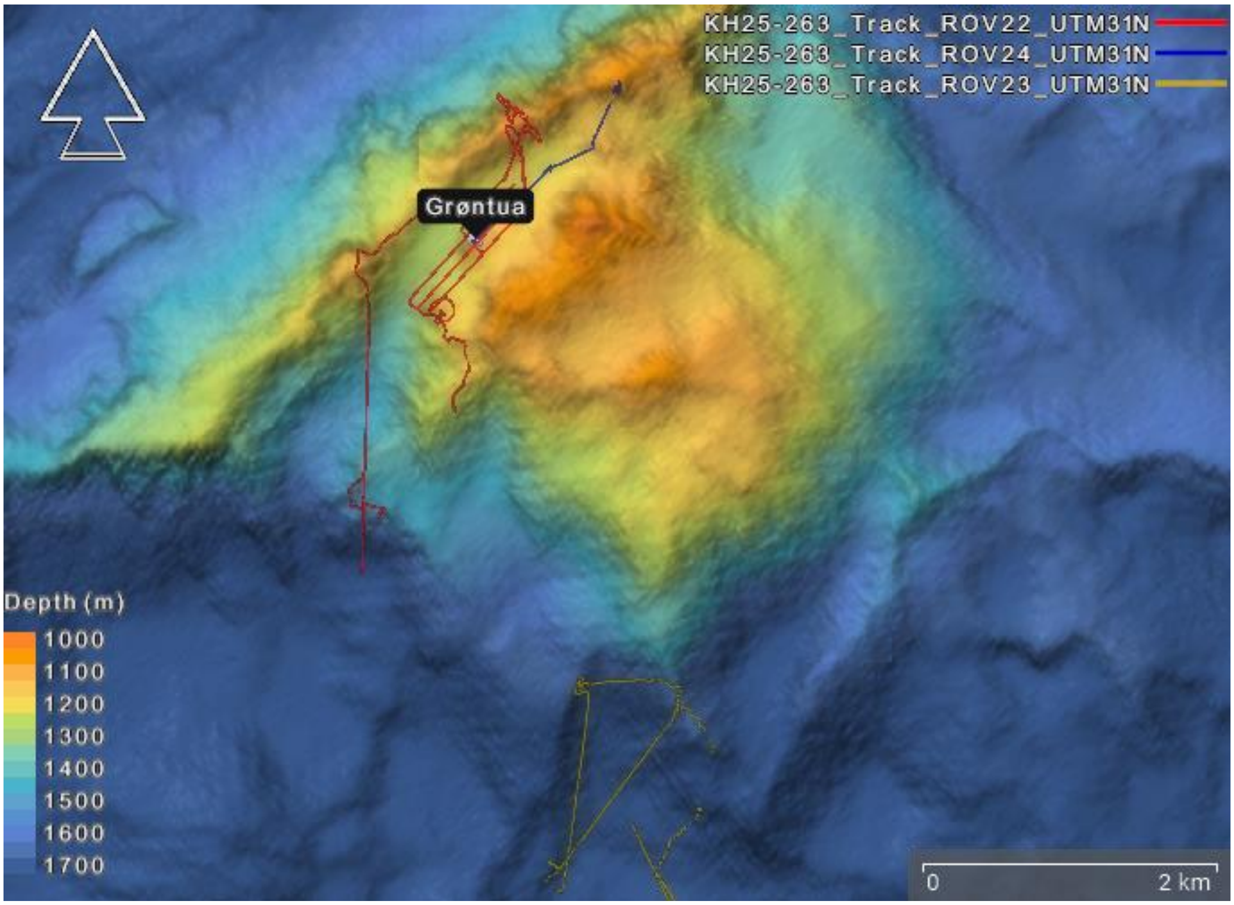

Figure 15. Map showing the overview and ROV-tracks from ROV22, ROV23 and ROV24 in the Grøntua area.

ROV 20: Sampling at Grøntua

Objectives: The objectives for this dive were to collect sediment slurry as well as taking push cores of the redox zonation seen in previous dives in the area.

Preliminary results: ROV20 started with a video transect over the volcanic terrain towards Grøntua, approximately 1 km. Moved towards the first dredge area to film sponges close to the dredging site to investigate potential changes in dust cover. Collected push cores around the first dredge site. Continued to dredge and core further deep. ROV20 collected one rock sample of a sulfide and some larger amounts of sulfide slurry for EMINENT. A total of six push cores was retrieved in the dredging area from previous dives in the Grøntua area. The push cores were collected for both geochemical and microbial investigations at UIB and some sediment cores will be analyzed at EMINENT.

Figure 16. Image showing the sulfide rich sediment sampled on ROV20.

ROV 21: Dredging at DeepInsight Hill

Objectives: The objectives for this dive were to conduct the same dredging as done on Grøntua earlier in the cruise. On Grøntua, visible redox zonation was identified and sediment slurry with high Cu values was collected. The aim for this dive was then to attempt to identify the same on DeepInsight Hill.

Preliminary results: ROV21 was launched at the top of the DeepInsight Hill structure, and dredging started immediately. Dredging in this area was very different from what was seen at Grøntua, with no visible redox zonation or sulfide slurry sediments. Overall, the sediments covering the DeepInsight Hill structure are hemipelagic sediments, and visibly not metalliferous, like on Grøntua. In some of the dredging holes, visible hard rocks were reached, this was all weathered rocks. The sediments overlaying the rocks had a thickness of around 1.5 m and consisted of some more coarse material. Sediment sampling with push cores was successful in the area, and a total of six push cores was retrieved. These were collected for analysis at UIB and NORCE.

Figure 17. Push core sampling in dredging hole at DeepInsight Hill during ROV21.

ROV22: Video transects, 3D model test and MBES over Grøntua

Objectives: Main objective for this dive was to map the Grøntua area with high resolution and to conduct video transects over the ridge formation north of Grøntua.

Preliminary results: The dive started with doing video transects up the large ridge north of Grøntua. This transect investigated mainly the biological communities here, and the slope was mostly covered in sediments with occasional avalanche material. When reaching the top of the ridge, the dive continued following the top of the ridge in an eastern direction. Then the ROV moved down on the other side of the ridge and started another transect going up towards the top again. Here, it was much steeper and more exposed rocks with higher biological diversity. A test grid survey with ROV stereo cameras was conducted in the slope of the ridge for an Bergwerk/Aker BP project, to be able to use these types of data for 3D models in the future. The test grid was 25m x 4m with five run lines and 80cm spacing.

After the test, the multibeam mapping with the ROV over Grøntua area began, with four MBES lines of approximately 1000m with 80m spacing. An increased overlap between lines was chosen due to large amounts of noise in the multibeam data.

ROV23: Geological exploration along mineralized fault plane

The dive started with a lot of sediments in the bottom of the valley where epidote and quartz crystals were found at the CDeepSea-2022 cruise. The dive started at about 2500 mbsl. and moved up the slope towards the top where the samples form 2022 were found. On the way up the slope, a lot of avalanched material was observed. A video transect with a zig-zag pattern for a 3D model was conducted within the slope. The grid of the video transect for 3D model was 20m x 20m. A lot of green rocks were seen and sampled. The samples turned out to be heavily altered and mineralized basaltic and gabbroic rocks. The green color is due to chloritization. Some of the samples are also heavily deformed and tectonized. In the middle of the slope, the dive passed over a very sedimented area with large holes in them. Here, some fish were seen with eggs hiding in the caves (Figure 19). These holes have been seen in earlier dives, but not with anything living inside. Also in this area, sedimentary sequences were nicely visible.

The dive continued up to the top of the ridge where green rocks with visible quartz crystals were seen (Figure 18). These were sampled and photographed. When starting to move down the slope on the other side, very large blocks of breccia was prominent in the slope side. The dive then crossed the valley to the west and continue with exploration and one more 20x10m grid video survey. At this side of the valley, the slopes were dominated by talus deposits, so the dive was moved back to the other side to collect more of the greenish rocks. A total of 16 rocks was collected during the dive.

Figure 18. Some of the mineralized sample locations seen during ROV23.

Figure 19. Image showing burrowing structures/caves with sedimental sequences visible in the slope of the structure investigated during ROV23. Fish inside cave with eggs.

ROV24: Push cores for eDNA

During this dive, nine short push cores was collected from three different locations. Three cores were collected from the same spot at each location. The top part of all samples will be extruded and preserved for eDNA analysis performed at NORCE as part of the EMINENT project.

Location 3: Seamount at 72.08N

72° 02.526’ N, 003°18.642’ W

Overall objectives at location 3:

The Norwegian offshore directorate was allocated the task from the Ministry of Energy to collect environmental data while mapping geology in the areas that has been opened for mineral activities in the Norwegian continental shelf.

Methods description

A pre-determined transect line was planned to follow the depth gradients from the bottom of the seamount towards the summit from the northwest and southeast. The length of the transect on the northwest was 9,5 km and 5,3 km on the southeastern part of the seamount (20). The line was set along the depth gradient to hopefully cover different benthic communities with different substrate on the seafloor.

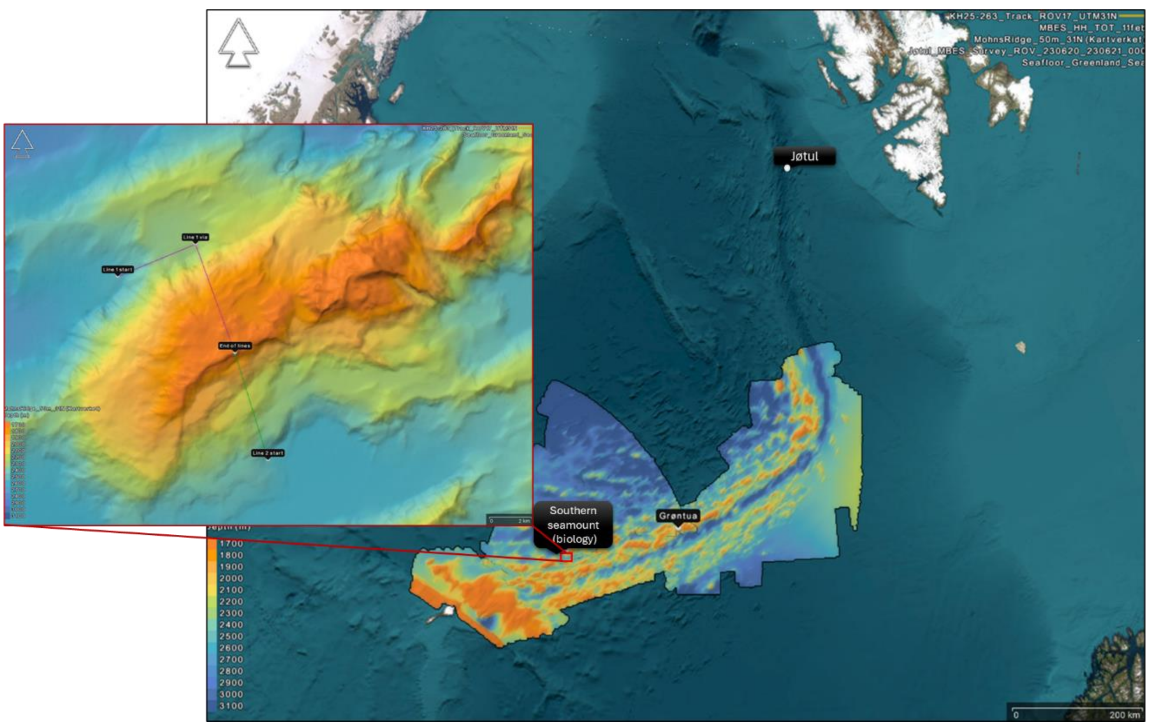

Figure 20. Overview of the transect lines across the southern seamount where we collected environmental data during ROV recordings and did annotations with Seabed Field Observer (SFO) developed by Institute of Marine Research.

Before the ROV was deployed, we followed a set-up protocol by UiB, IMR and Sodir to ensure multidisciplinary use of the collected video material and to increase the opportunities to compare data analyzed from video material between different institutes. While video recording was running along the transects, a photo was taken in the 4K-video every second. The purpose for the set-up was to provide a good quality of data for post processing purposes.

Institute of Marine Research (IMR) has developed an annotator program called Seabed Field Observer (SFO) and this was used to log biological observations and sediment types along the transects. Each observation has a georeference. Two biologists were annotating along the predetermined transects. There was also onshore support from IMR through live stream for discussions on which communities we came across along the transect. All annotations will be cleaned for errors and later be publicly available for relevant institutes.

Collecting of physical specimens

Where of interest, some biological material was brought to the surface with geological samples. The biological material was stored in absolute ethanol and sent to the University of Bergen for further identification.

General observations

Both on the northwest and southeast side of the southern seamount was dominated by soft sediments almost throughout the ROV dives. Depth gradient varied from around 2500 meter to 1500 at the summit, where we could see some changes in the benthic communities as we went shallower. On both sides of the seamount the deepest parts of the transect was dominated by *Kolga hyalina* with stalked crinoids *Bathycrinus* sp. (Figure 21). More burrows with *Neohela* sp. got more prominent at approximately 1600 meters, while *Kolga hyalina* slowly became absent. There were some areas along the transect where we encountered hard substrate such as drop stones and bed rock where we could observe more sponges and organisms associated to these.

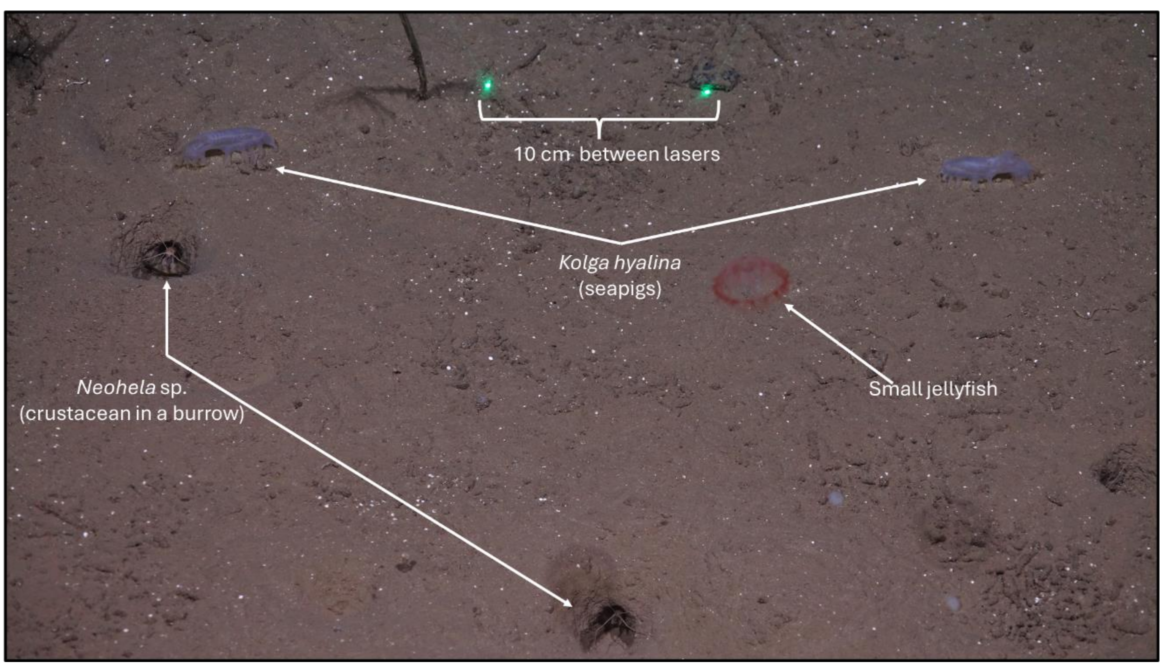

Figure 21. Example photo that shows common organisms along the transects on the southern seamount Kolga hyalina, Neohela sp. *and stalked crinoid* Bathycrinus *sp.*

General dive information and geological investigation

This location was selected by NOD to perform long video transects across a large seamount that is around 10 Ma old. This will be done in collaboration with IMR. The aim was to complete 200 m transect with exploration and sampling of geology and biology in between. In addition, the two SeaGuards will be deployed for around 1 year. Three push cores will also be collected for Mareano.

During ROV16 a video transect of 5.3km (green line in Figure 22) was conducted moving up the seamount from the southeastern side. ROV17 had a video transect of 9km purple line in Figure 22) over the flatter area and climbing up the seamount. Going from approximately 2500mbsl to 1500mbsl. ROV 17 conducted a long video transect from on the eastern part of the seamount towards the summit. Seaguard 2 was deployed on the flat summit to record bottom currents for one year. After the video transect was completed, the aim was rock sampling along the steepest cliff close to the top. A total of 11 rock samples was collected, consisting of Mn crust and serpentinites. The finding of serpentinites documents that this seamount is probably an oceanic core complex. No volcanic rock was observed.

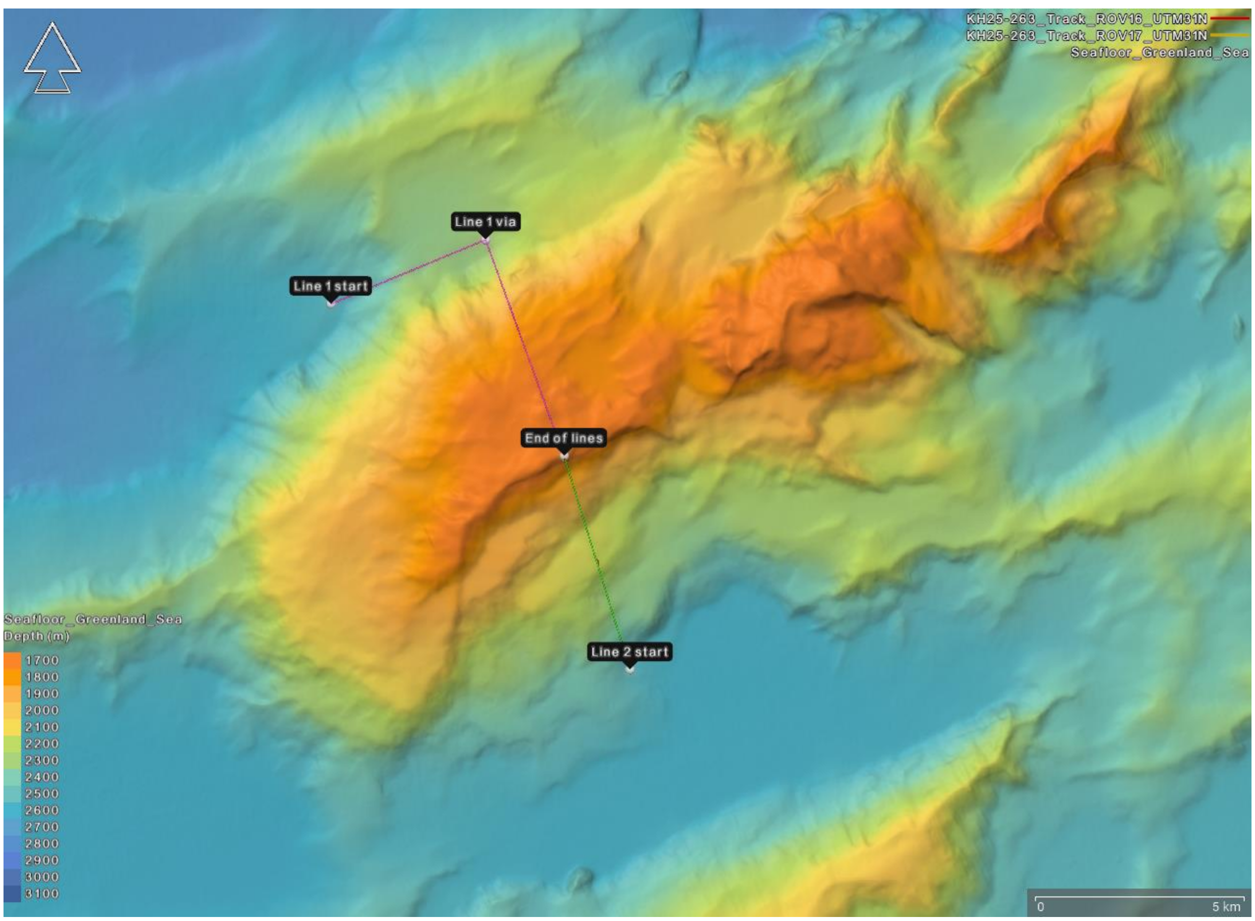

Figure 22. Map showing the overview of the planned video transect dives that was conducted during ROV16 and ROV17.

Figure 23. 4K image of serpentinites with FeMn crust found at the seamount during ROV17.

Figure 24. 4K image of serpentinites with FeMn crust found at the seamount during ROV17.

Location 4: Oblique ridge at 72.3N

72° 13.428’ N, 000°34.589’ W

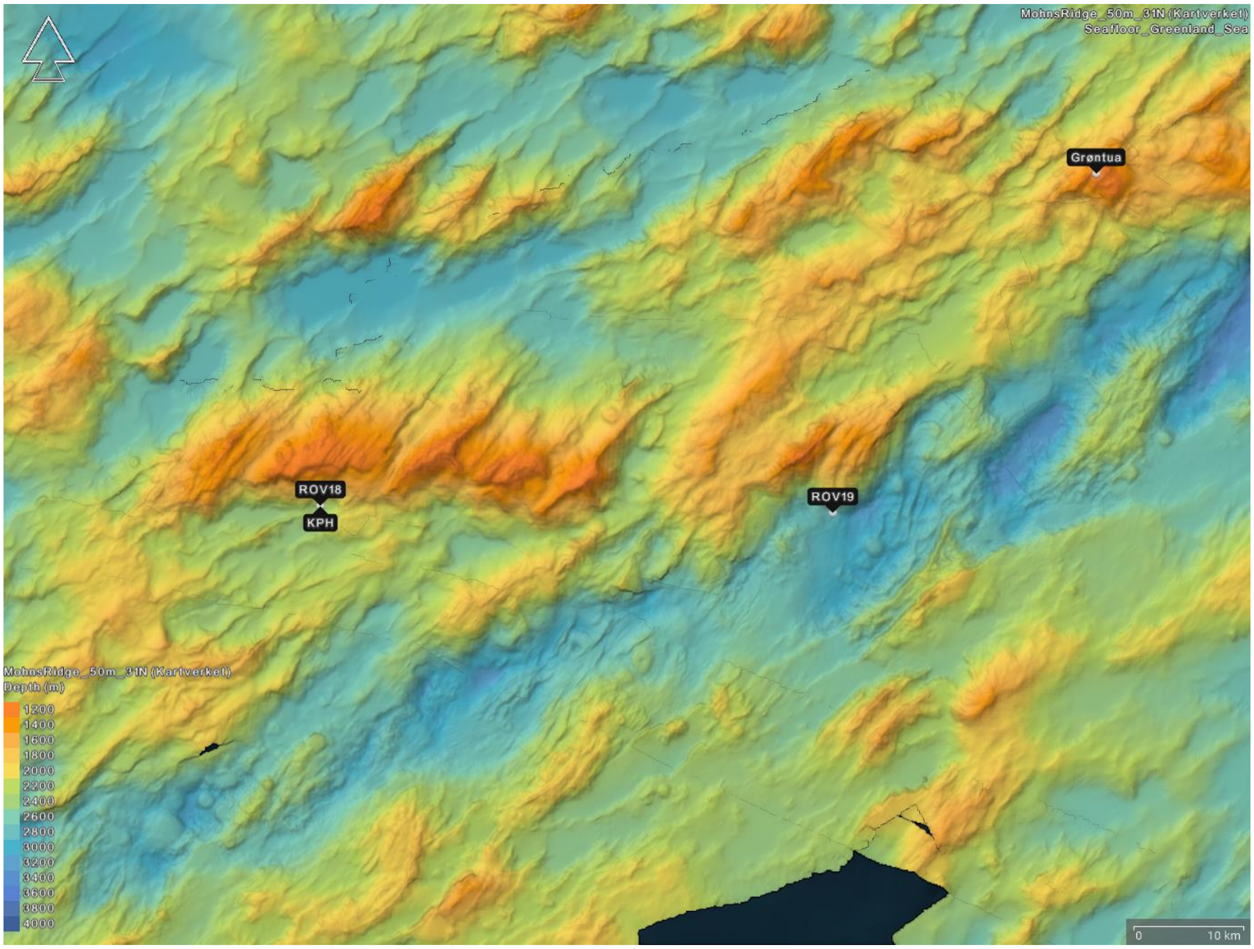

Figure 25. Map showing the location of the oblique ridge together with Grøntua for reference.

Overall objectives at location 4:

Multiple oblique ridge structures are observed in the off-axis bathymetric expression in the Greenland Sea. Recent data from NOD shed new lights on these structures. The aim was to investigate the formation of these structures by searching for evidence of tectonic movements and to document the composition of the structures by collecting rock samples at various depths.

ROV 18: Central part of the oblique ridge

Preliminary results: During the dive, a total of 11 rock samples were collected. The rocks are mainly basaltic lavas and breccia. The basaltic samples are weathered, and some contain manganese crust. One sample is a micro gabbro suggesting the possible exposure of crustal section underneath lavas. The samples were mainly collected from talus deposits. Breccias seems to be formed by dissolution of glass and precipitation of iron hydroxides gluing the basaltic fragments together. No exposures of in-situ rock were observed. Therefore, it is difficult to conclude weather these ridges are composed only of lavas or if they also expose lower crustal rocks.

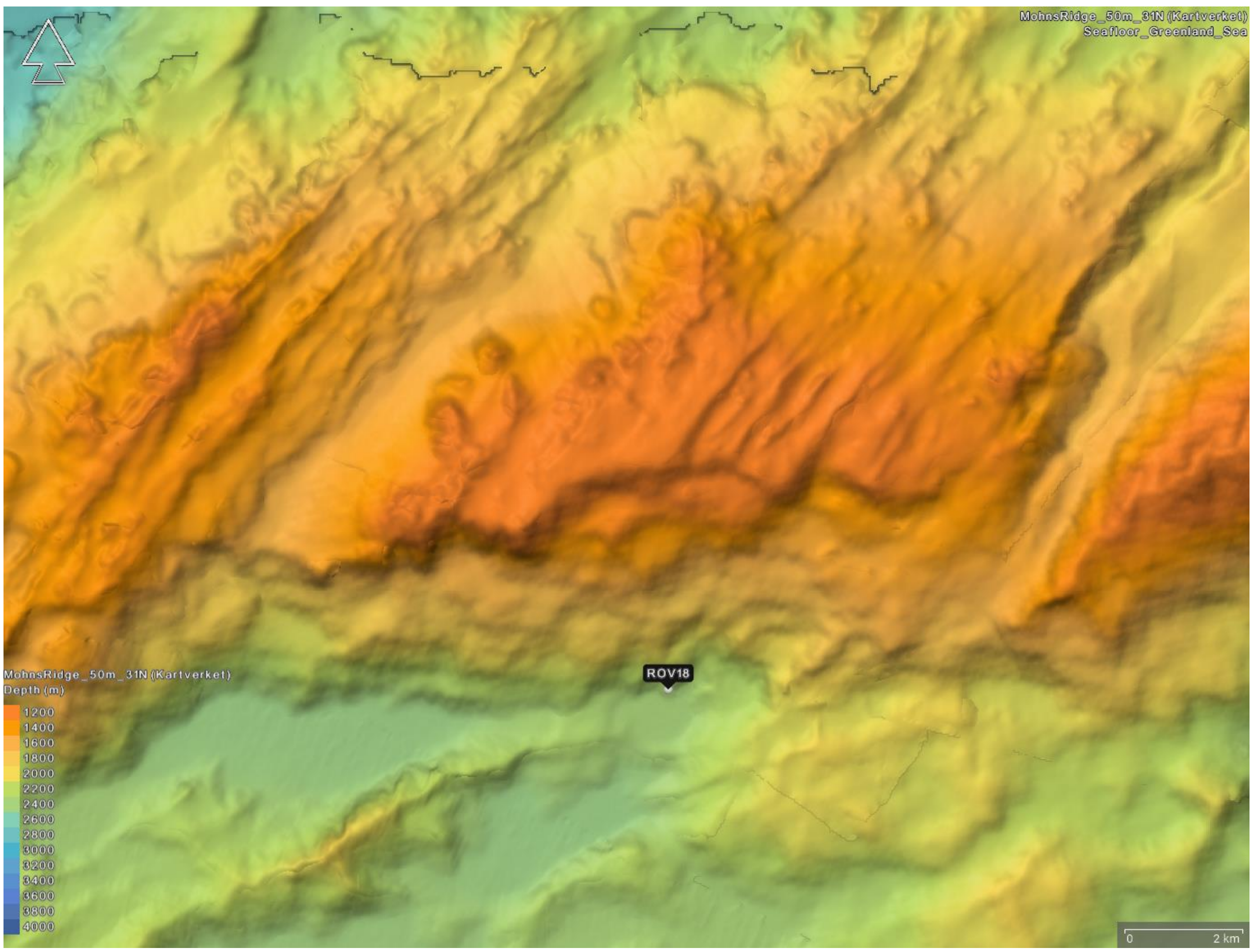

Figure 26. Map showing the starting location of ROV18 and the overall structures in the area.

ROV 19: Formation of oblique structures at the flank of the rift valley

Preliminary results: The objectives of this dive were to investigate the formation of visible oblique structures on the map.

The entire dive took place within a talus deposit exposing loose rock fragments. A total of seven rock samples were collected. All samples are basaltic, mainly plagioclase phyric to ultra phyric. The presence of plagioclase phyric rock indicate that these rocks could be sourced from a magmatically robust segment where crystals are accumulating within a magma reservoir. One of the basaltic samples shows signs of fluid flow with the presence of quartz crystals. No exposures of in-situ rock or signs of tectonic movement were observed, and more research is therefore needed to fully understand the formation of these structures.

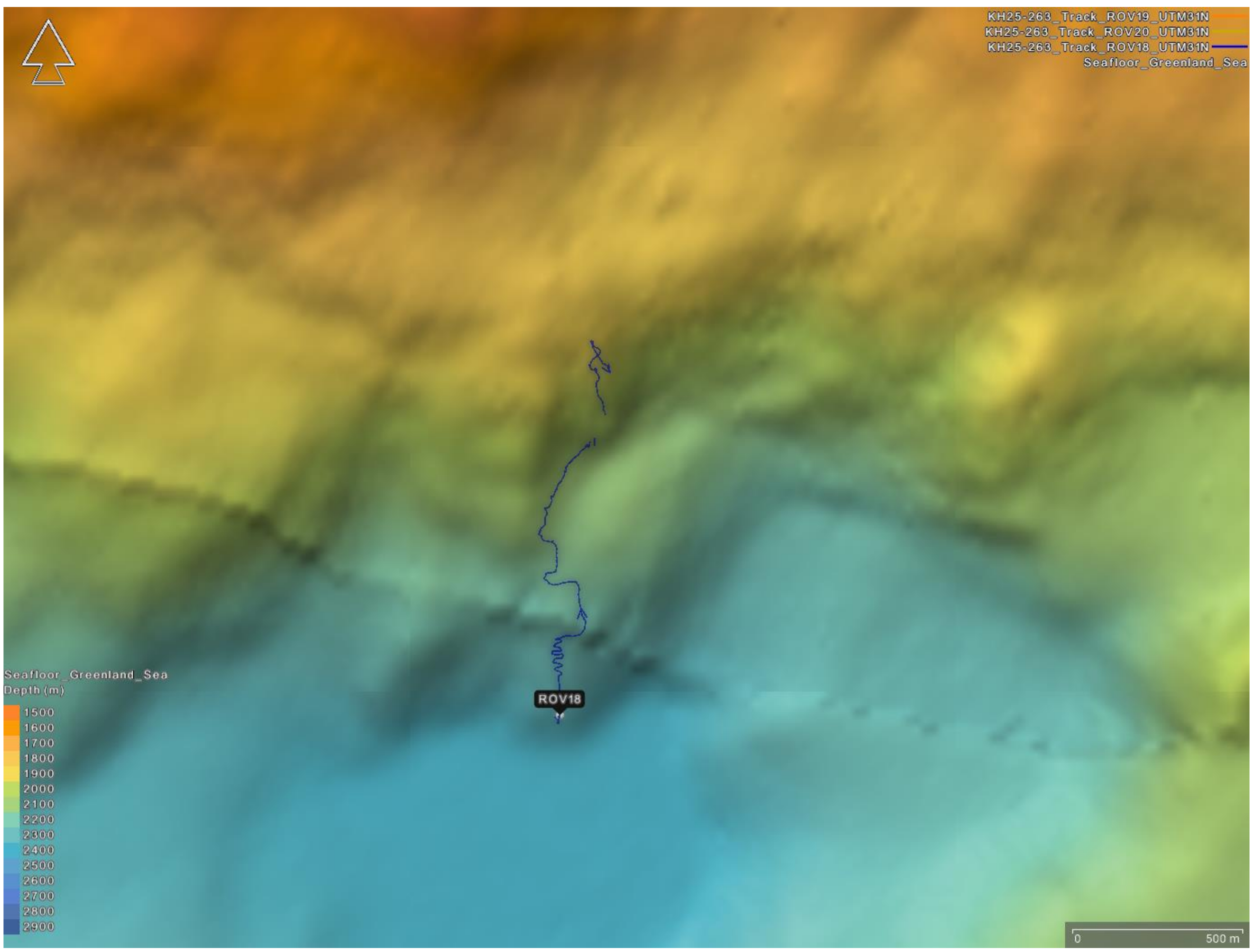

Figure 27. Map showing the ROV-track of ROV18.