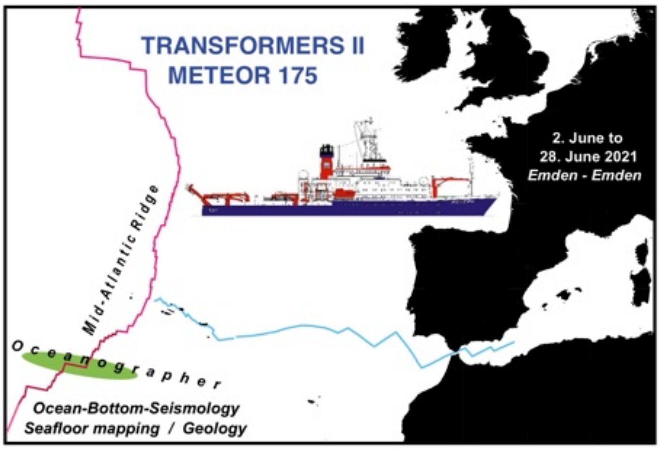
METEOR-Berichte

Geological and geophysical characterization of transform offsets, TRANSFORMERS II

Cruise No. M175

02.06.2021 – 28.06.2021
Emden (Germany) – Emden (Germany)
TRANSFORMERS II



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2024

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1 Cruise Summary

1.1 Summary in English

Recent evidence suggests that the traditional concept of oceanic transform faults being conservative and thus non-accretionary plate boundary faults may be wrong. On the contrary, bathymetric, geophysical and geological data from oceanic transform faults worldwide indicate extensional tectonics in the transform valleys, and secondary magmatism at the ridge-transform intersections (RTI). If such observations can be generalized, a paradigm change related to oceanic transform faults is expected. The M175 cruise was designed to approach this problem by investigating the Oceanographer transform fault offsetting the Mid-Atlantic Ridge to the southwest of the Azores near 35°N, thought to be a fairly typical large transform fault system in the Atlantic Ocean. M175 was a follow-up of the broken-off M170 cruise in January 2021. During M175, we performed extensive geological dredge sampling and recorded video profiles across stratigraphical borders inside the Oceanographer transform valley, sampled rocks from the valley shoulders and at the RTIs, and completed regional bathymetric mapping. We also recovered 17 ocean bottom seismometers deployed during M170. Our preliminary data reveal both erosional and constructional processes along the Oceanographer, suggesting that crustal material gets recycled into the transform fault - fracture zone system, and that secondary magmatism characterises the inside corners of the RTIs.

1.2 Zusammenfassung

Das traditionelle Konzept, welches besagt, dass Transformverwerfungen ausschließlich konservative Plattengrenzen sind, muss aufgrund von Ergebnissen neuerer Untersuchungen möglicherweise revidiert werden. Stattdessen deuten bathymetrische, geophysikalische und geologische Daten von ozeanischen Transformstörungen weltweit auf das Auftreten von Dehnungstektonik in den Transformtälern, und sekundärer Magmatismus an den Rücken-Transform Übergängen (RTI). Falls solche Beobachtungen verallgemeinert werden können, ist ein Paradigmenwechsel bezüglich ozeanische Transformstörungen zu erwarten. Die M175 Reise wurde konzipiert um genau diese Problemstellung anzusprechen, durch detaillierte Untersuchungen der Oceanographer Transformstörung, welche entlang des Mittelatlantischen Rückens südwestlich der Azoren bei 35°N liegt und als ein typisches Beispiel für eine große Transformstörung im Atlantik dient. M175 war die Fortsetzung der abgebrochenen M170-Reise im Januar 2021. Während der M715 Reise wurden umfangreiche geologische Beprobung mittels Dredgen durchgeführt, Videoprofile über geologische Grenzen im Oceanographer Transformtal aufgenommen und die regionale bathymetrische Kartierung abgeschlossen. Zusätzlich wurden 17 Ozeanbodenseismometer geborgen, die während der M170 Reise ausgelegt worden waren. Vorläufige Daten zeigen sowohl starke Erosion als auch konstruktive Prozesse entlang der Oceanographer Transformstörung. Diese Daten deuten zum einen darauf hin, dass Krustenmaterial teilweise in das Transformstörung Bruchzonen-System wieder eingearbeitet wird und zum anderen, dass sekundärer Magmatismus die inneren Ecken (inside corners) der RTIs charakterisiert

2 Participants

2.1 Principal Investigators

Name	Institution
Hansteen, Thor H., Dr. PD	GEOMAR
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2.2 Scientific Party

Name	Discipline	Institution
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Raeke, Andreas	Meteorology technician	DWD

2.3 Participating Institutions

GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
CAU	Christian-Albrechts-Universität zu Kiel
DWD	Deutscher Wetterdienst, Geschäftsfeld Seeschifffahrt

3 Research Program

3.1 Description of the Work Area

3.1.1 Scientific Background – Oceanic Transform faults

Occurrence of Transform faults

Oceanic transform faults are ubiquitous features of the seafloor, and occur in all major oceans worldwide. They represent offsets between the spreading segments of mid-ocean ridges, and are typically viewed as conservative plate boundaries connecting active segments. Each oceanic transform is bounded by two ridge-transform intersections (RTI) where tectonic stresses rotate by tens of degrees over a very short distance (Morgan and Parmentier, 1994). Contrary to this idealised view of plate tectonics, recent scientific efforts indicate that oceanic transform faults are not conservative plate boundaries (Fox and Gallo, 1984), but that they are shaped by two stages of magmatic accretion, separated by a tectonic phase stretching the transform valley while crust and lithosphere are moved along the transform fault (Grevemeyer et al., 2021). Global observations show that transform valleys are always much deeper than the associated fracture zones (FZ), suggesting that transform valleys are buried before being converted to fracture zones. The burial of transform valleys is supposed to be related to a second phase of magmatic activity as the plate moves along the RTI, which can readily be identified in seafloor imagery and seafloor geology (e.g., Sandwell et al., 2014). However, high-resolution data supporting active magmatic activity at RTIs are generally lacking as most existing data were acquired 20 to 40 years ago and detailed sampling of transform systems has not been carried out since the 1980s (e.g., Karson and Dick, 1983; Gallo et al., 1985).

Oceanic fracture zones are the regional continuations of the transform faults, showing that they are generically related. In a global study, surveying the structure of oceanic transform faults and independently of spreading rate (Fig. 3.1). This implies that oceanic transform faults do not act as conservative plate boundaries only. fracture zones, Grevemeyer et al. (2021) presented high-resolution digital bathymetric data from 41 transform faults and fracture zones worldwide, and show processes at transform faults acting

Magmatism at ridge-transform intersections

Compilations of bathymetric data from FZs worldwide show that a pronounced shallowing of the transform valley-fracture zone depth occurs near the RTI, and that such shallowing is linked to a second phase of episodic magmatic activity, as transform seafloor passes the opposing ridge axis (Grevemeyer et al., 2021) (Fig. 3.1). At fast and intermediate spreading ridges, bent ridge segments and small volcanic cones may extend across the RTI, fully or partially covering the outside corner - fracture zone region, and often terminating in the older plate (e.g., Lonsdale, 1986). This leads to the formation of RTI volcanic highs which are often covered by young lavas (Gallo et al., 1986: Barth et al., 1994). Seismic data from e.g. the Clipperton transform in the East Pacific show that crust at the eastern intersection high is approx. 1 km thicker than along the transform valley (Barth, 1994). A likely scenario at fast-spreading ridges, is that dykes propagating along the ridge axis penetrate past the transform fault into the juxtaposed old oceanic crust, curving in the direction of the transform, and locally increasing the crustal thickness (Gregg et al., 2007, Barth, 1994). Similar processes seem to also occur at slow-spreading ridges worldwide, as summarized by Grevemeyer et al. (2021). They suggest that that transform lithosphere is formed in two distinct phases, and involves three distinct processes: (i) Asymmetric crustal production at RTIs leads to the formation of magmatically starved inside-corner crust, and outside-corner crust that often preserves axial volcanic structures in the form of J-shaped ridges. (ii) Thereafter, the inside-corner crust is subject to transform-perpendicular extension and thinning as it passes along the transform, deepening the transform valley. (iii) Such extended and thinned former inside-corner crust is finally covered and possibly intruded by magmas (dykes) from the opposing ridge as it passes the second RTI. Therefore, the formation of oceanic crust near transform faults differs fundamentally from elsewhere along the spreading system.

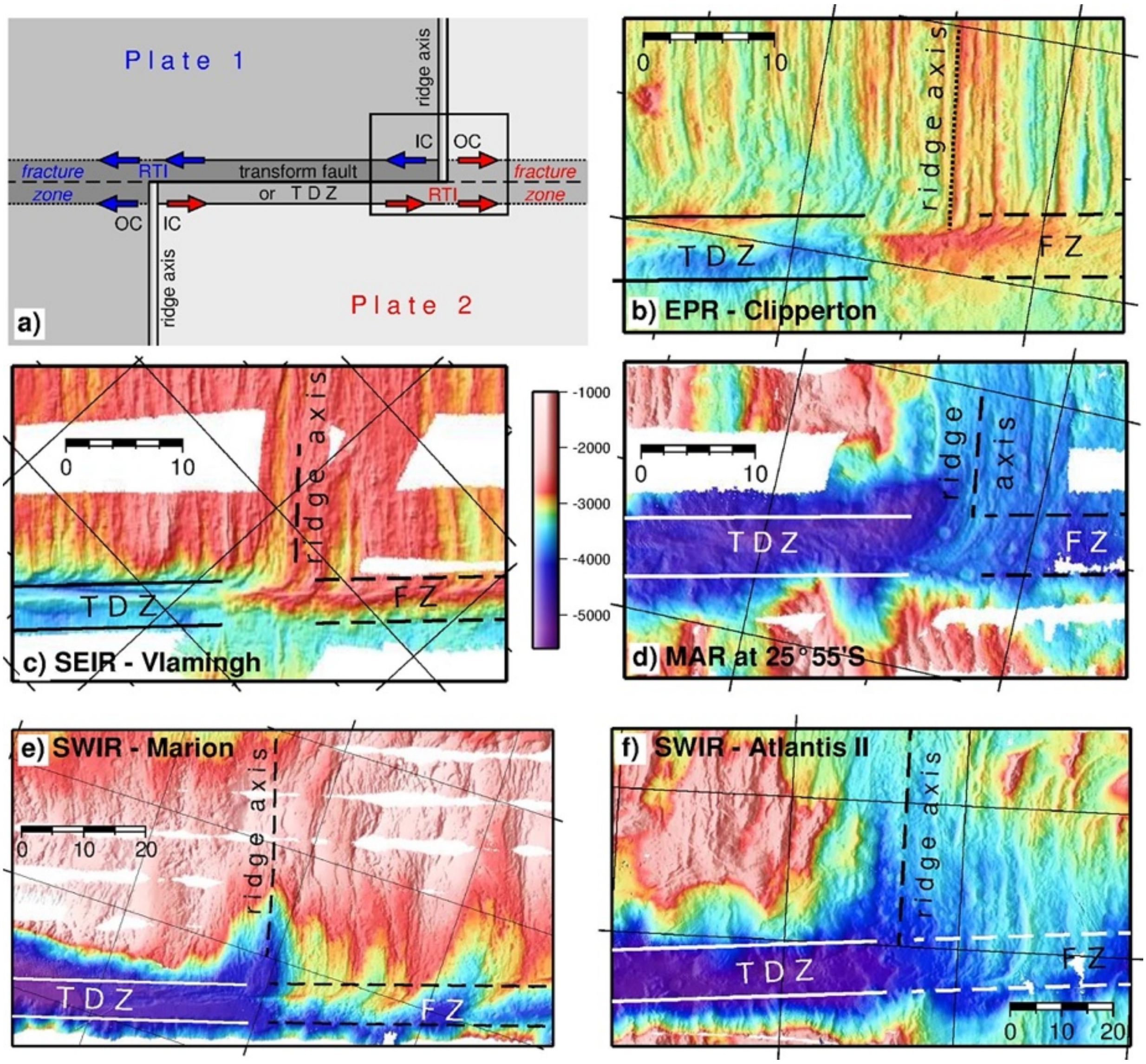

Fig. 3.1. Selected Ridge-Transform-Intersections (RTIs) at a range of spreading rates. a) Cartoon showing the geometry of a transform-fracture zone system; OC: outside corner, IC: inside corner. Bathymetry from RTIs marked by rectangle in a) is shown in b) to f).b) Eastern Clipperton RTI at the fast-spreading Northern East Pacific Rise; b) Southern RTI of the Vlamingh transform at the intermediate-spreading Southeast Indian Ridge; d) Eastern RTI of a transform fault at the slow-spreading Southern Mid-Atlantic Ridge near 25°40'S; e) northern RTI of the Marion transform at the ultraslow-spreading Southwest Indian Ridge; f) southern RTI of the Atlantis II transform at the ultraslow-spreading Southwest Indian Ridge (from Grevemeyer et al., 2021).

3.1.2 Oceanographer Transform Fault

The Mid-Atlantic Ridge (MAR) covers a distance of more than 16.000 km, and comprises hundreds of segments offset by oceanic transform faults (OTF). The most prominent offsets occur in the equatorial Atlantic, and are unique in their complexity (e.g., Searle et al., 1994; Ligi et al., 2002). However, the Mid-Atlantic Ridge between 33°N and 36°N hosts the two major, 120-140 km long Hayes and Oceanographer transform faults, suitable to test the hypothesis discussed above. We focussed on the 120 km offset Oceanographer transform fault southwest of Azores near 35°N, which represents a type-example of an OTF along the slow spreading MAR. The regional ridge spreading rate is 22 mm/yr (Cormier & Sloan, 2019). The Oceanographer transform valley is ~10 km wide and has two well-defined segments which are linked by a small pressure ridge roughly at the center of the valley (Rabain et al., 2001). The transform valley is bounded by steep cliffs, with depth differences up to about 3000m, making the area an ideal place for geological observations and sampling.

Seismic data obtained along the Oceanographer suggests that crust along the transform valley is only slightly thinner (4-5 km) compared to normal (6-7 km) oceanic crust (Ambos & Hussong, 1986). However, the velocity structure seems to be different, providing several percent slower values in the lower crust, which may suggest that magmatic crust has been overprinted from faulting and fracturing and hence would support high porosities as deduced for the Gofar OTF in the Pacific (Roland et al., 2012). Processes governing the evolution of the Oceanographer transform valley appear to include both strike-slip and extensional tectonics on various scales. Two micro-seismicity surveys conducted at the Oceanographer OTF near its eastern intersection with the Mid-Atlantic Ridge in 1974 and 1980 suggest that micro-earthquakes occur in a broad band across that corner (Rowlett, 1981; Cessaro and Hussong, 1986). The data were interpreted to reflect both extension and strike-slip motions. Visual and photographic documentation using the submersible "Alvin" revealed normal faulting along the deep central area of the Oceanographer transform valley (Fox et al., 1985). They additionally noted tectonic deformation centered along the axis of maximum depth (Fox et al. 1985). However, the interplay of processes leading to the observed transform fault evolution is poorly understood.

The Oceanographer transform fault was partly mapped during the broken-off M170 cruise in 2021 (Grevemeyer et al. 2021b). Further, a micro-earthquake survey was started during the M170 cruise, and will provide the unique chance to study the relationship between the slip of large earthquakes and the depth-distribution of smaller micro-earthquakes.

3.2 Aims of the Cruise

The main aim of the M175 cruise was to combine various types of morphological, geophysical and deep-sea camera data with extensive geological sampling to derive a concept for the evolution of the Oceanographer transform fault, offsetting the Mid-Atlantic Ridge at 35°N (see. Fig. 3.2). The background assumption was that Oceanographer represents a typical large transform fault system in the Atlantic Ocean, and can thus serve as a model system to develop a more general understanding of FZ evolution. It will thus add to our understanding of the role of oceanic transform fault-FZ systems in the morphological and compositional evolution of oceanic tectonic plates. The cruise served as a continuation of the broken-off M170 cruise in January 2021, during which ocean-bottom seismometers (OBS) and ocean-bottom hydrophones (OBH) were deployed but only partly recovered, bathymetric data were recorded, and geological sampling had begun. Accordingly, the M175 cruise focussed on detailed geological sampling and observations, and on bathymetric mapping, in addition to the recovery of OBS instruments deployed during M170.

Specific aims for M175 were:

- Detailed morphological mapping of the Oceanographer transform fault with special focus on the RTIs.

- Characterize the crustal structure along the transform valley and at the inside and outside corners of the RTI.
- Characterize magmatic activity along the transform valley and at the inside and outside corner of the RTI.
- Detect possibly young (second-stage) volcanism along the transform shoulders
- Recover all OBS instruments left from the M170 microearthquake campaign
- Reveal possible hydrothermal activity along the FZ valley floor.

M175 was thus also designed to serve as a pilot study for future detailed FZ surveys.

3.3 Agenda of the Cruise

The cruise conducted under Corona restrictions was designed to combine morphological, geophysical and geological data in order to unravel the evolution of the Oceanographer transform fault (MAR 35 to 36°N), assumed to be a typical large transform fault system in the Atlantic Ocean. Main features of the research program were:

1. Swath mapping to depict the structure of ridge-crest-discontinuities and the detailed morphology of the 140 km long Oceanographer transform fault using the ship-board EM122 swath-mapping system. Can we observe a time-dependent variability of accretion by mapping the near ridge fracture zone valleys and shoulders? What are the morphologic and structural changes along-strike of the transform fault?
2. Characterizing the lithology at RTIs, ICs (inside corners) and OCs (outside corners) and along the fracture zone using dredging. What are the along-strike changes in lithology inside the transform valley, and at what depths do characteristic lithologic changes occur?
3. Characterizing magmatic activity at the adjacent spreading segments, at the RTI and at the inside (IC) and outside corner (OC) of the RTI using the towed-camera OFOS system.
4. Detecting possibly young (second-stage) volcanism along the transform shoulders using a combination of mapping and OFOS followed by dredging. What characterises the second-stage volcanism?
5. Recovering 18 OBS instruments deployed for a micro-earthquake survey during M170, to reveal depth distribution of micro-earthquakes and their relationship to the fabric of the transform. Focal mechanisms will reveal the stress field and if the ridge offset is under extension. *This part of the study was covered by the M170 cruise report (Grevemeyer er at. 2021b).*
6. Revealing hydrothermal activity using video observations and MAPR (Miniature Autonomous Plume Recorder) deployed with the video system. What can the occurrence of hydrothermalism tell us about transform valley evolution?

The cruise did not include active seismic investigations. All research was carried out in accordance with the OSPAR code of conduct for responsible marine research, and following the CDRmare code of conduct.

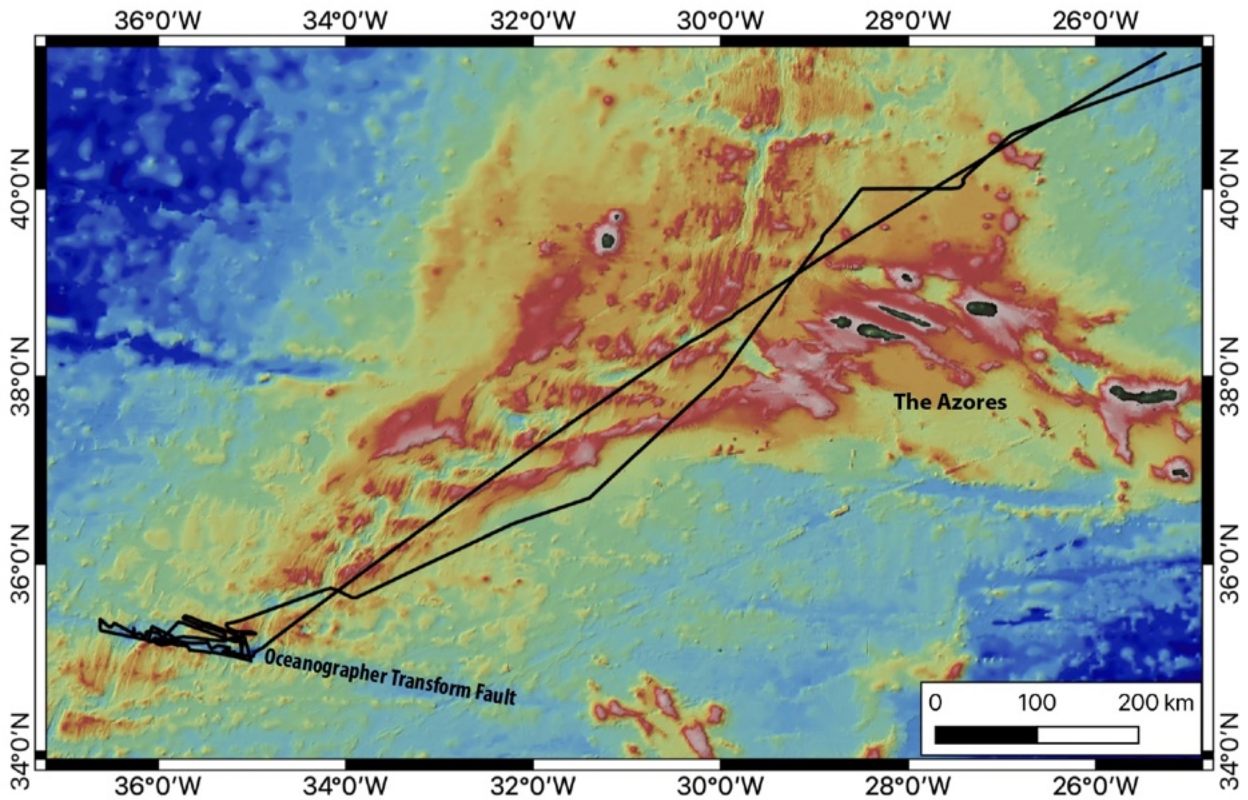

Fig. 3.2 Cruise Track of RV METEOR Cruise M175 between the Azores and the main work area at the Oceanographer Transform Fault. Bathymetry from Smith and Sandwell (1997).

4 Narrative of the Cruise

The scientific team embarked the RV METEOR in Emden in the afternoon of June 1, 2021. The ship left Emden harbour in the morning of June 2, entering and following the Ems river toward the North sea under good weather conditions. Calm weather accompanied us along the coasts of The Netherlands and Belgium. The scientists used the first two days of transit to prepare the ship´s labs, and for initial set-up of equipment needed. Entering the English Channel on June 3 brought foggy but still calm weather. We used the next couple of days for specific instructions to all cruise participants about the functioning and usage of the diverse equipment, and for explanations of planned work flows. At noon on June 6, the RV METEOR left the British EEZ off the bay of Biscay, and the underway data acquisitions were started. They included continuous EM 122 swath bathymetry, 38.5 and 75 kHz ADCP, and daily seawater bottle sampling for later thermosalinograph (TSG) analyses. The calm weather continued during transit, and helped us reach the Azores archipelago already during daytime on June 8. In the afternoon of June 9, we had crossed the submarine Azores Platform from the NE to the SW, and reached water depths of about 2500m, enough to deploy an expandable bathythermograph (XBT). The data were used to derive a local seawater thermal profile, important for correcting the multibeam echosounder bathymetry data to be obtained from the work area.

We arrived in the work area, the Oceanographer Transform Fault in the morning of June 10, and turned off the 38.5 kHz ADCP due to possible interference with other hydroacoustic equipment like the "Parasound" (sediment echosounder) and the Posidonia positioning system.

We started the recovery of 18 ocean bottom seismometers (OBS) which were deployed but not recovered in January 2021 during the broken-off M170 cruise. In the course of June 10, 9 OBS were recovered, and one re-deployed within the area of interest. The OBS were all located at the floor of the so far poorly investigated transform valley, at distances between each station of only a few nm. In order to use the allotted ship time efficiently, the transits between the OBS locations were used to record several Parasound profiles across and along the transform valley floor, giving evidence for broken-up and irregular strata. On June 10, the essential on-board EM122 multibeam echosounder had a very unusual total failure, and could only be repaired by the WTD the next day by substituting electronic boards from the computer system operating the on-board EM710 multibeam echosounder. During June 11, another 8 OBS were successfully recovered, however, one OBS confirmed its release but did not surface. We ranged and re-released this OBS again on the same day and also two days later, but it was not possible to recover it, possibly due to rough ground conditions.

In the late afternoon of June 11, the first three dredges were hauled at the western ridge-transform intersection (RTI) of the Oceanographer TF. A prominent volcanic cone and a rugged lava field were obviously blanketed by clay-like mud, as we recovered mud only. Dredging continued on June 12 at the western outside corner (OC) of the Oceanographer TF. Among the four dredge hauls here, one contained a basalt and a gabbroid, two contained basalts, and one was empty. Following a few hours transit used to complete mapping of the western part of the working area in the night between June 12 and 13, dredging continued at the western inside corner (IC) of the OTF. One dredge contained serpentinised gabbroid and basalt, and subordinate serpentinite, three further dredges contained pillow basalts, some with glassy rinds. One further dredge was hauled at the western inside corner, at a steep N-S-oriented ridge close to the RTI, and was practically empty, but contained minor rubble of biogenic carbonate. Early in the morning of June 14, dredging continued on the west part of the northern OTF shoulder, and yielded serpentinite and serpentinised gabbroids, or empty dredges. Still in the morning of June 14, the main winch was equipped with a coax cable for use with the OFOS (Ocean Floor Observations system) video camera.

The first two OFOS video tracks aimed at locating lithological boundaries in the western steep parts of the Oceanographer TF south shoulders. During all dives, the OFOS was equipped with a Posidonia system for precise positioning, and a MAPR system (Miniature Autonomous Plume Recorder), to detect possible hydrothermal fluid emanations in hindsight. Moving downhill, the first OFOS track revealed thick pillow lava sequences, slowly transitioning into gabbroids and dykes, and finally gabbroid/ serpentinite intercalations. The second, semi-parallel track revealed lavas only. The third OFOS track was aimed at detecting hydrothermal fluids in the deep western sections of the OTF by means of the MAPR system. The late night to June 15 was used to enhance the multibeam map of the eastern IC. The final two OFOS tracks were located in a scarp in the eastern IC. Moving downhill revealed a more than 400m thick lava pile, intercalated with gabbros at greater depths. Also the night to June 15 was used to enhance the multibeam map of the eastern IC. The only OBS re-deployed so far was recovered in the morning of June 16, as news emerged from the manufacturer that the system may not have enough battery power to cover the planned period of deployment.

Dredging continued on June 16 with hauls at the eastern IC, producing basalts, gabbroids and dykes. At deeper levels in the central northern OTF wall, gabbroids and pyroxenites were recovered in the morning of June 17. Four dredges distributed along the upper shoulders of the western IC produced basaltic rocks. One further dredge at greater depths delivered basalts and gabbroids. Further dredge hauls on June 18 from the eastern end of the OTF valley recovered basalts and gabbroids. The last few dredges of the cruise were hauled in the night between June 18 and 19, and recovered basalt and volcaniclastic breccias. The very last dredge from the shallowest area of the eastern IC delivered fresh basalt, probably testifying to young volcanism in this area. After a short final mapping track, RV METEOR left the main work area in the forenoon of June 19, and headed for the Azores. From here on, the 38.5 kHz ADCP and the EM 122 multibeam were used again for underway data collection.

During the transit back to Germany, on June 20 and 21, respectively, a total of four OBS were deployed on the Azores Platform inside the Portuguese EEZ, as part of a multinational effort to observe the regional-scale seismicity in the region. Helped by the excellent weather conditions, we entered the EEZ of England again in the evening of June 24, and ended the underway data acquisition of EM 122 mapping, 38.5 and 75 kHz ADCP and daily water sampling. On June 25 we entered the English Channel, and passed St. Anne islet and the Cherbourg peninsula at noon June 26 with a clear view. The RV METEOR called at the port of Emden in the morning of June 28, having successfully completed cruise M175.

5 Preliminary Results

5.1 Swath Mapping - Kongsberg EM122 Echosounder

The RV METEOR is fitted with a Kongsberg EM122 1°x2° multi-beam deep ocean echosounder, with two transducer arrays fixed to the ship's hull operating at 12 kHz. Data acquisition is based on successive transmit-receive cycles of this signal. The transmit beam is 150° wide across-track and 1° along-track direction. The system has 432 beams, sampling seafloor depth at high resolution. The beam spacing can be defined as equidistant or equiangular, and the maximum seafloor coverage fixed or adjusted according to seabed and weather conditions. The raw depth data are processed to obtain depth contour maps, and the acoustic amplitude processed to obtain backscatter amplitudes. Swath bathymetry and backscatter data were acquired within the survey area at the Oceanographer transform fault and fracture zones and during transit in international waters (see Fig. 3.5). The acquired bathymetric data set complements the one obtained during the M170 cruise and comprises an overlapping area.

Tracks for swath mapping were chosen as to complement the data obtained during M170. Fig. 5.1a shows the seafloor morphology at the Oceanographer OTF using all data available, including tracks of opportunity from the BSH archive and the NOAA archive. Several morphologic features are characteristic for the working area:

a) Both inside corners are by far the shallowest areas along the transform fault shoulders, and are covered by semi-linear volcanic ridges with a youthful morphology. The ICs are comparable in elevation to the off-axis volcanoes close to the central areas of the adjacent spreading axes (Fig. 5.1);
b) J-shaped ridges at Oceanographer extend well onto the older plate, suggesting plate boundary cutting magmatism;

c) The probably most dramatic feature is the cliffs occurring along both ICs close to the RTIs (Fig. 5.1). In the east, the cliffs have a terraced nature, and stepwise grade into the deep of the nodal basin. However, going towards the transform valley at the western IC, the strike of the very steep cliffs gradually shifts away from the direction of seafloor spreading in a curved fashion (Fig. 5.1b). In both cases, the respective morphologies indicate substantial mass wasting into the adjacent nodal basins at the ICs, which in spite of such depositional processes remained deep;
d) The transform valley shoulders are bordered by cliffs of variable steepness, indicating long-term erosional processes;
e) Elevation differences between the transform valley shoulders and the central nodal basins is on the order of 3000 m. Combined with the observed transform valley width of 5-10 km, this strongly indicates mass wasting into the nodal basing and concomitantly into the deeper parts of the transform system.

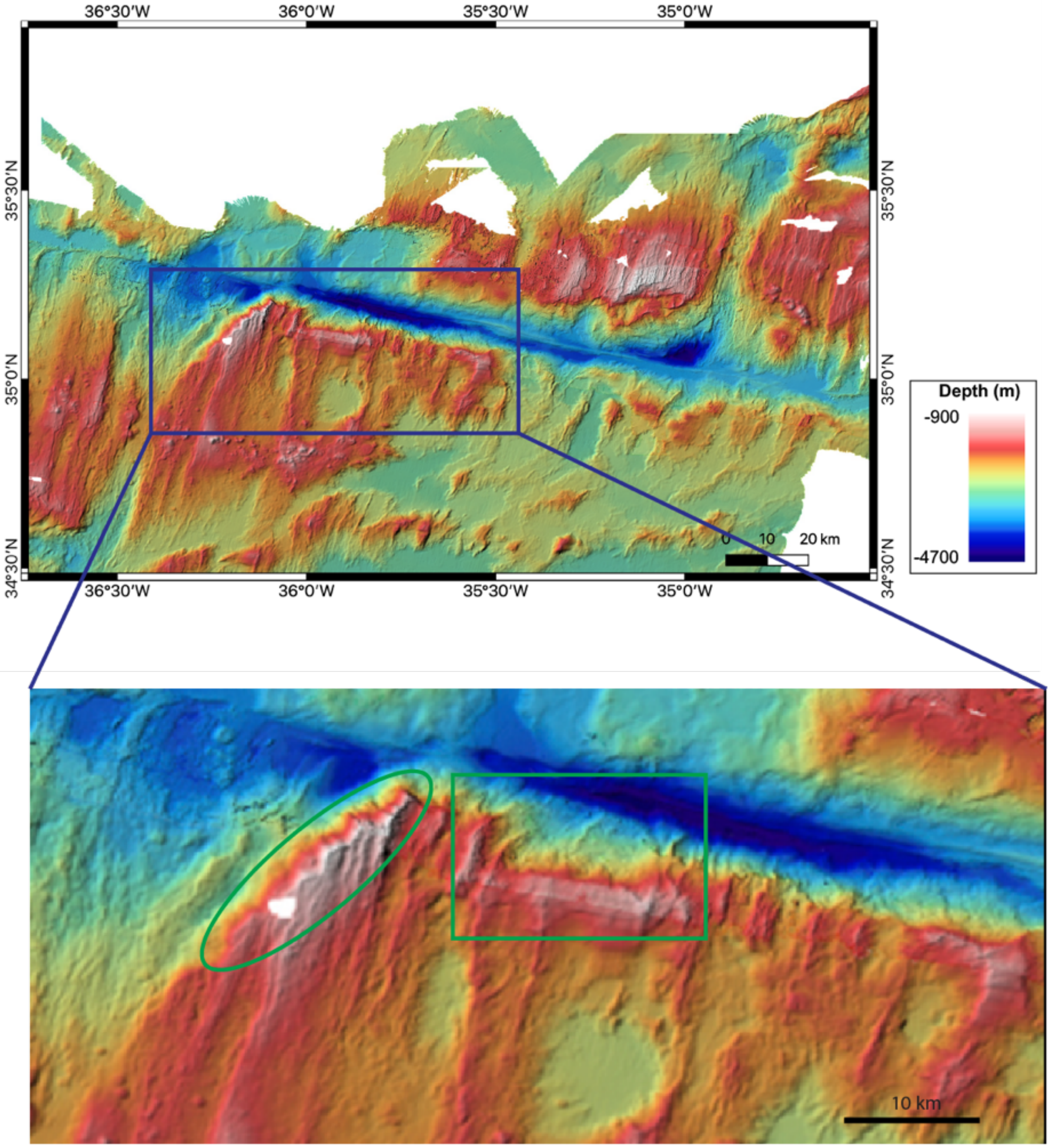

Fig. 5.1 (Top) Bathymetric coverage of the Oceanographer transform fault from M170 and M175, merged with data of opportunity from the US American NOAA archive and the German BSH archive. (Bottom) Detail of the western RTI including the western Inside Corner (IC). Towards the transform valley, the strike direction of the steep IC cliffs gradually shifts away from the direction of seafloor spreading (green oval). An inferred core complex is indicated by a green box, as explained in Fig. 5.7. Please note that the transform shoulders along the nodal basin to the east show abundant erosional cliffs.

Observations from detailed bathymetric mapping of the Oceanographer transform fault suggest both constructional and erosional processes to occur along the transform fault. Morphologically young volcanic ridges topping both ICs are strong evidence of second-stage magmatism in the respective areas. Second-stage magmatism has also been suggested for the nearby Hayes fracture zone (Grevemeyer et al. 2021b (M170 report)). Further, J-shaped ridges both at Oceanographer and Hayes OFZs extend well onto the older plate, suggesting plate boundary cutting magmatism (Grevemeyer et al. 2021b), in line with our results

Erosional features are clearly focused on the ICs, but are also obvious along the entire transform valley, and demonstrate that abundant mass wasting is an important process. This leaves us with a major challenge to explain the fate of the eroded material. A possible hypothesis would be that the gradually eroded materials collect in the nodal basins, and concomitantly get worked into the transform fault and thus get buried through tectonic processes at the transform plate boundary. This would further imply that the eroded materials are worked into the transform plate boundaries, and moved along the oceanic fracture zones. Demonstrating such processes would have major consequences for our understanding of oceanic transform fault – fracture zone systems, and would further demonstrate that such plate boundaries are by no means passive.

5.2 Sediment Echosounder - Atlas Parasound DS3 P-70

(J. Klein, T.H. Hansteen)

RV METEOR is equipped with an Atlas Parasound DS3 P-70 parametric deep-sea sediment echosounder for full ocean depth. Parasound is a narrow beam sediment echo sounder with an opening angle of 4.5° x 5.0°. Taking advantage of the so-called parametric effect, the systems allows for the imaging of internal structures of the sedimentary seabed along the ship's track.

By emitting two primary, constructively interfering signals of higher frequencies the system generates a very low secondary frequency which may penetrate the upper sedimentary layers of the seabed. The Parasound system transmits two independent pulse-modulated harmonic signals via the same transducer array. To generate and utilize the parametric effect these signals must be generated with extremely high amplitudes. At such signal levels the seawater does not only serve as a propagation medium for the original signals but also generates additional new signal components at different frequencies. During M175 the primary high frequencies (PHF) were 18 kHz and 22 kHz. The resulting secondary low frequencies (SLF) are 4 kHz and 40 kHz. For sediment penetration the secondary low frequency is of particular interest.

Most of the time, Parasound transmitted in a quasi-equidistant transmission sequence but a few profiles were run with rectangular transmission sequence and a time interval of 1200 ms. The receiver band width for both high frequencies was 66 % and for both low frequencies 33% of the output sample rate (12.2 kHz). The sound velocity was manually set to 1500 m/s.

All raw data were stored in the ASD data format (Atlas Hydrographic), which contains the data of the full water column of each ping for all four frequencies as well as the full set of system parameters. Additionally, a 200 m-long reception window centered on the seafloor of the primary high and the secondary low frequencies was recorded in the compressed PS3 data format. This format is in wide usage in the PARASOUND user community, and the limited reception window provides a detailed view of sub bottom structures. All data were converted to SEG-Y format during the cruise using the software package ps32sgy version 15.9 (Hanno Keil, Uni Bremen). The software re-fits the different time windows, allows generation of one SEG-Y file for longer time periods, frequency filtering (low cut 2 kHz, high cut 6 kHz, two iterations), and the subtraction of mean. In this format the seismic interpretation software IHS Kingdom can easily read and display the Parasound data.

During M175 we collected approximately 17 km of Parasound profiles, all acquired during the transits between the OBS stations located along the transform valley.

Parasound profiles along the central regions of the western nodal basin at Ocenographer TF produced largely undisturbed to semi-continuous sedimentary layered sequences to typically tens of meters depths (Fig. 5.2), occasionally intercepted by fault lines. Three profiles obliquely across and along the central pressure ridge reveled a multitude of stratified sediment blocks appearing to be tilted as coherent entities in a near-random pattern. Du to their location on the pressure ridge, they are interpreted as breaking-up of consolidated sedimentary strata due to tectonic strike-slip movements at the plate boundary. The seemingly random dip angles of strata between adjacent blocks appear to be the result of block transposition in a complex pattern, reflecting ongoing deformation at the diffuse plate boundary. – To some extent, intermittent technical problems forced us to shorten several profiles and partly took their toll on the data quality.

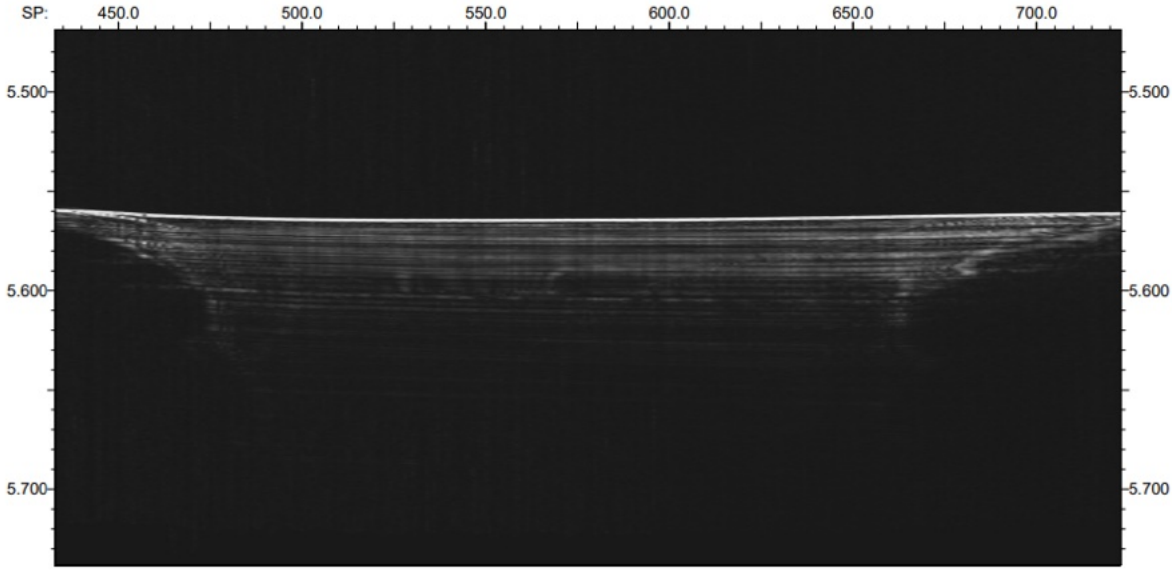

Fig. 5.2 Parasound profile from the western Nodal basin in the Oceanographer Transform fault. The seafloor is strong upmost reflector. Below, a sedimentary basin can be identified to several tens of meters depths.

5.3 Micro-Seismicity Survey at the Oceanographer Transform Fault

The seismological network set up during M170 consisted of 6 Trillium Compact OBS, 12 short-period (4.5 Hz geophone) OBS and 11 OBH (Fig. 5.3) of the GEOMAR OBS/OBH pool. The network was operated between January 21 and 31, 2021, monitoring seismicity along the Oceanographer Transform Fault. After an incident on January 31, it was decided to leave the study area earlier and to recover only those 11 OBH stationsthat would automatically surface on February 4, 2021. Please note that the preliminary results from these stations were described in the M170 cruise report (Grevemeyer er at. 2021b). Of the 19 OBS remaining on the seafloor, 18 were successfully recovered in June 2021 during the M175 cruise. The preliminary analysis reveals that the eastern inside corner of the ridge-transform intersection is a major hotspot of seismic

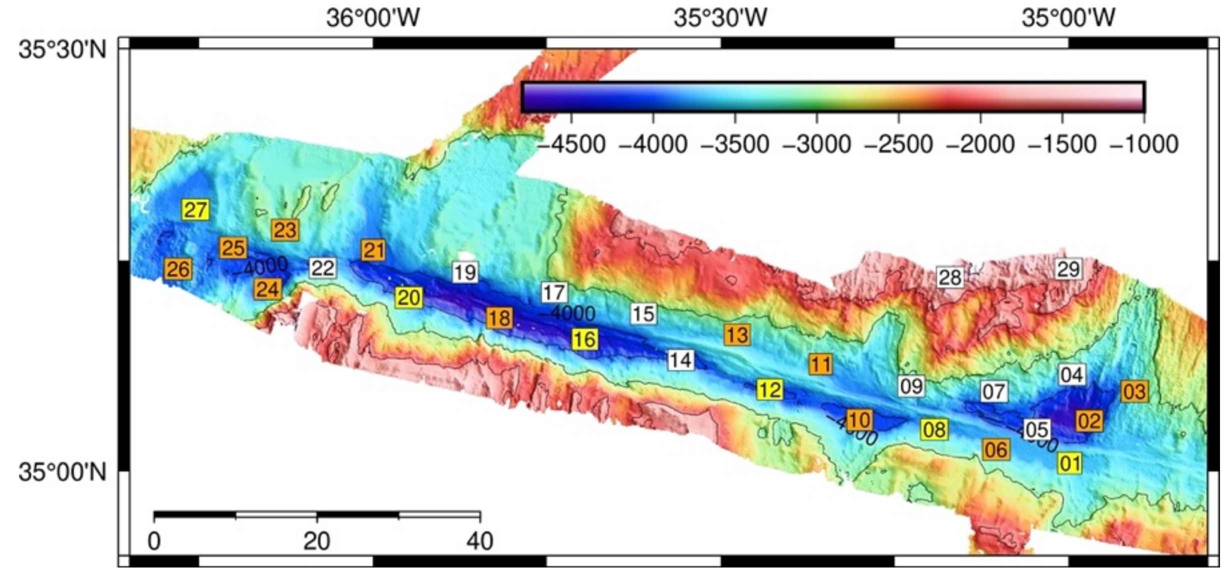

Fig. 5.3 Layout of the seismic network. Seismic stations are numbered squares, colour indicates instrument type; white OBH; orange: short-period OBS; yellow: broadband OBS.

activity (Fig. 5.4; from Grevemeyer et al. 2021b). However, please note that the eastern RTI had the best coverage by OBHs (white numbered squares in Fig. 5.3), while the coverage with OBH was much poorer elsewhere along the transform fault. Further, additional activity occurred along the surface trace of the transform fault, while the walls of the transform were seismically inactive, at least away from the RTIs. We refer to the M170 cruise report for further interpretations.

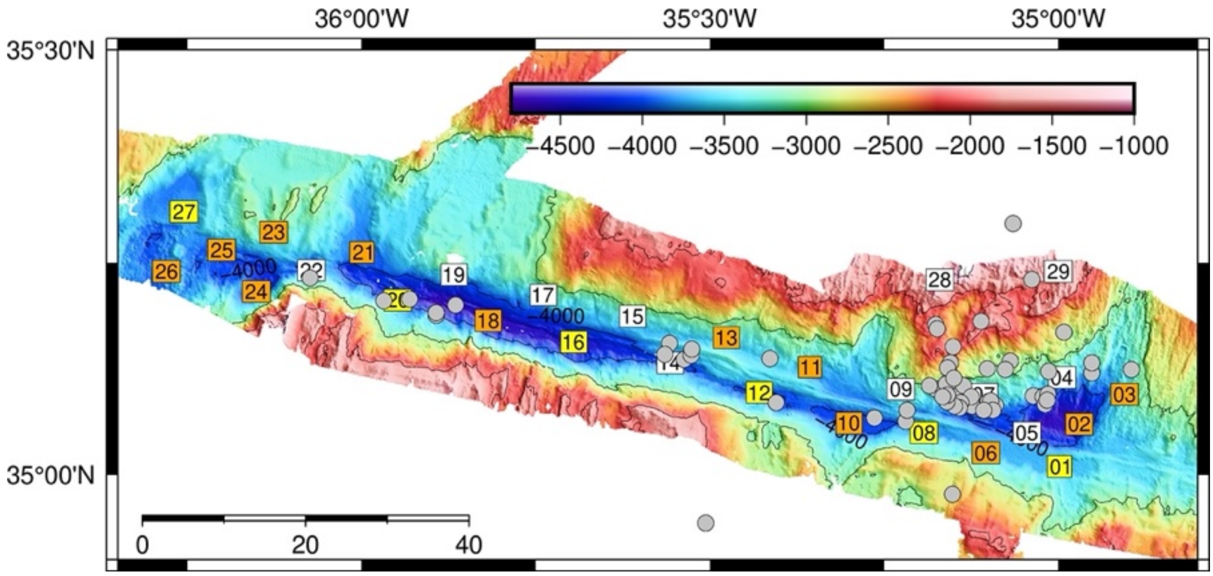

Fig. 5.4 Seismic events (grey dots) recorded at OBHs only (OBH are marked by white numbered squares).

5.4 Rock Sampling at the Oceanographer Transform Fault and Fracture Zone

Igneous and sedimentary samples were collected by a chain bag dredge. Sample locations were chosen with the help of bathymetry data collected during both M170 and M175. The dredge tracks were located mostly on steep slopes and high backscatter intensity areas to avoid thick sediment cover. A total of 33 dredge hauls were performed recovering a total of 168 rock samples (Appendix 12.1). Fig. 5.5 shows an overview of the dredge locations at the Oceanographer TF, and Fig. 5.6. an overview of all station work. The main goal of the rock sampling at the Oceanographer TF was to characterize the lithology and geological structures of a major transform system in detail, in order to get a better understanding of the magmatic processes, and to identify the tectonic evolution of the area.

Thus, sampling was performed over a range of depths both inside and along the shoulders of the transform valley, and included the steep valley walls, and less rugged terrain associated with the RTIs. Also the shallowest pillow lava sequences covering both ICs were sampled. Dredge tracks within the transform valley were done uphill and kept as short as possible, in order to exert some depth control on the sampling sites.

The Oceanographer TF was sampled at 33 dredge stations of which 22 recovered rocks (Table 5.1). 14 of the 22 dredges contained basaltic lava samples only, with occasional basaltic breccias. Four dredges comprised mixtures of basaltic and variably altered gabbroid rocks, one dredge contained a mixture of gabbroid and pyroxenitic rocks, and a further dredge contained a mixture of altered gabbroid rocks and serpentinised ultramafic rocks, the latter interpreted as former upper mantle rocks. Only one dredge contained all the three lithologies basalt, gabbroids and serpentinised ultramafic rocks, and one single dredge recovered carbonate rocks only. The samples recovered during M175 can therefore be coarsely grouped as serpentinised ultramafic rocks, gabbroids, basalts and occasional carbonate rocks.

On board, representative samples were cut with a rock saw and thus prepared for detailed descriptions and later thin section production. All relevant samples were described, and packed for later petrological and geochemical analyses. Sample descriptions with photos are included as an appendix to this report (Appendix 12.1). Also included is the rock sample list from the companion cruise M170 (Appendix 12.2).

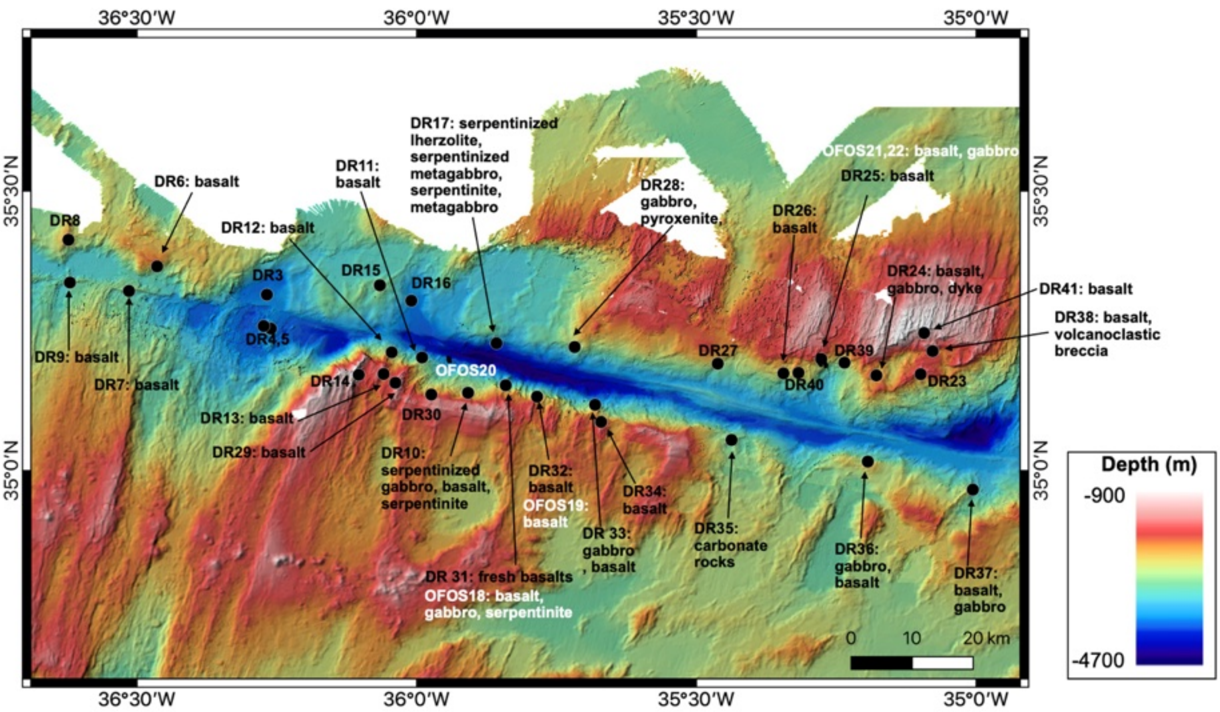

Fig. 5.5 Dredge and OFOS/ MAPR sites and main rock types recovered and observed at the Oceanographer Transform Fault and adjacent areas. Rock types recovered are listed in Table 5.1.

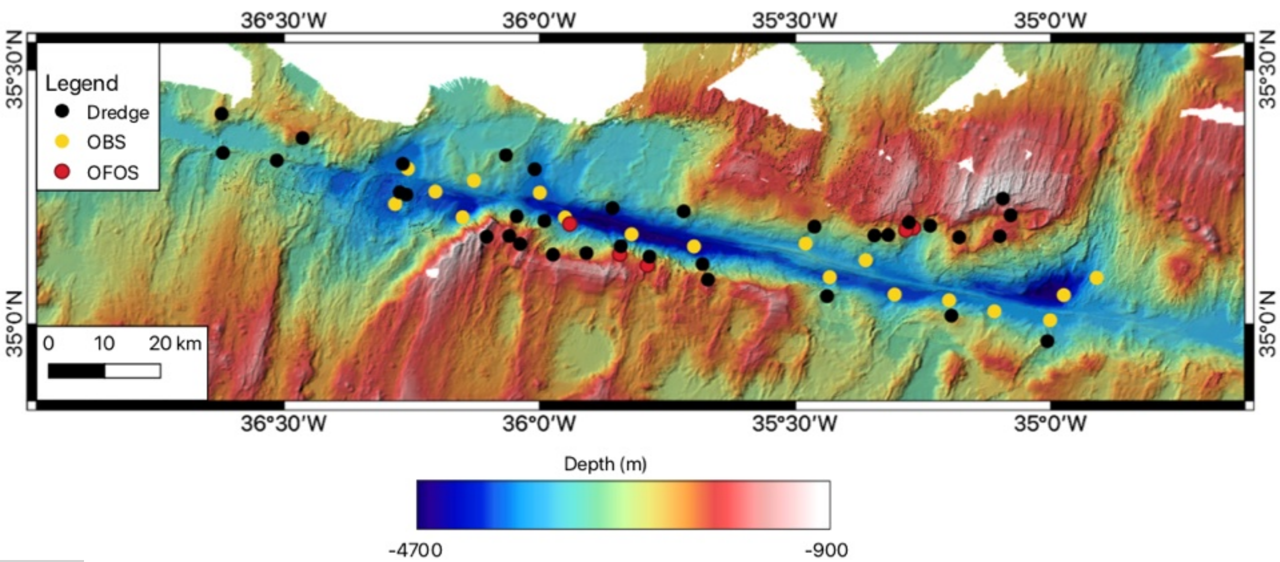

Fig. 5.6 Station work at the Oceanographer Transform Fault during M175. Black symbols represent dredge locations, yellow symbols OBS locations, and red symbols starting points for OFOS deep-tow camera tracks.

Dredge sampling was aimed at both identifying the variable along-strike lithological boundaries inside the transform valley, and at sampling the youngest volcanism in each area of interest. The search for locations and depths of lithologic boundaries were focused on the inside corners, using a combination of short dredge hauls and OFOS camera observations (see next chapter for the OFOS observations).
Assuming that the formation of oceanic crust at a mid-ocean ridge is dominated by magmatic processes, the lithologic boundaries between the lava and dyke sequences and the gabbroid rocks, and between gabbroid rocks and ultramafic rocks representing the upper mantle sequence, should smoothly deepen away from the spreading axis (e.g. Barth, 1994). At the Oceanographer TF, however, the depths of such characteristic lithologic boundaries in at least two cases show large deviations over distances of a few km (Fig. 5.7). At the western IC, dredge (DR) 10 with a depth range of 2551-2338 mbsl contained both gabbroid and ultramafic rocks in addition to basalts (Table 5.1). About 10 km to the west, DR11 contained only basalts at 3320-2746 mbsl, and DR31 about 5 km to the east of DR 10 also contained basalts only at 2824-2398 mbsl. The comparatively shallow depths of gabbroids and mantle rocks inferred from DR10 were additionally confirmed by in-situ OFOS observations of a gradual gabbroid-serpentinite transition at 2670-2720 mbsl at station 18, only 6 km away from DR10. The simplest interpretation would be that the area between DR11 and DR31 represents a core complex at least 10 km wide, that has been uplifted at least several hundred meters relative to the adjacent blocks. This strongly indicates that at the western IC, periods of mainly magmatic crustal accretion alternated with a period of lower magma supply and thus extensional tectonics and concomitant listric faulting. At the eastern IC, the occurrence of both gabbroids and lavas in DR24 with an off-bottom depth of 2278-2117 mbsl indicates a lithologic boundary at more than 2278 mbsl. This compares well with a gradual volcanics/ gabbroid transition at 2230 to 2375 mbsl observed by OFOS at Station 21 and 22, about 9 km to the west of DR24.

On both ICs of the Oceanographer FZ, thick sequences of fresh to moderately altered pillow basalts occur as spreading-parallel ridges and local valleys, and thus define the characteristic morphology of the ICs. The differences in recovery depths between the deepest and shallowest basalt samples taken during M175 at each of the ICs are about 900 m. Further, each of the ICs are covered by volcanic ridges with elevations 400m or more above our shallowest dredge locations (Fig. 5.5). Taken at face value, our data and observations indicate total lava pile thicknesses up to 1400m at the Oceanographer ICs. Typical lava sequence thicknesses in the Central and South Atlantic are in the range 760±290m (Estep et al., 2019). Our data thus strongly support the notion of second-stage magmatism at the Oceanographer FZ, in line with earlier observations (Grevemeyer et al. 2021b).

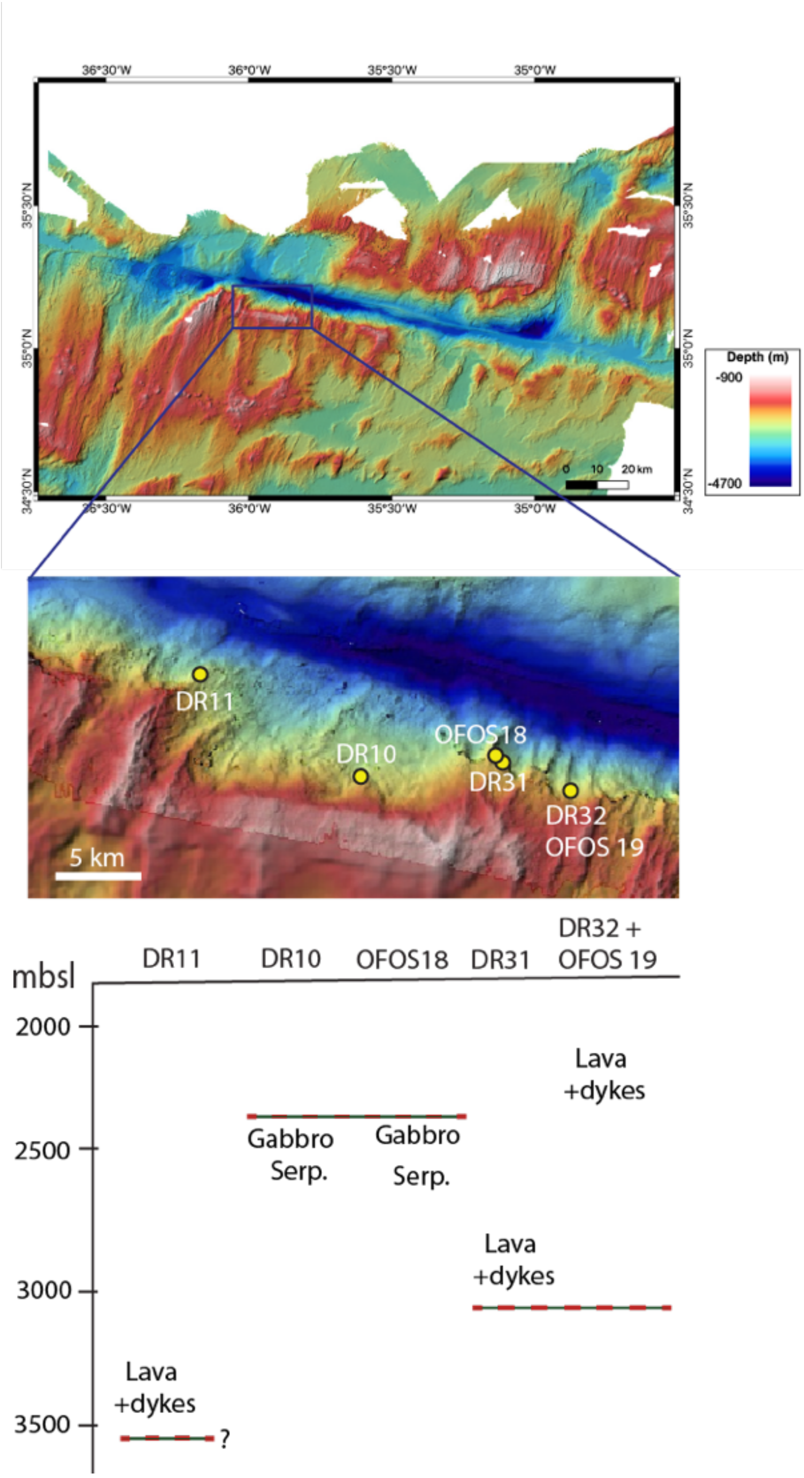

Fig. 5.7 Location of inferred core complex close to the western RTI. (Top) Reference map. (Center). Locations of dredge and OFOS stations marked on the enlarged portion of the bathymetric map. (Bottom) Depths of recovered dredge samples or visual observations (OFOS) at the respective localities. The dashed lines tentatively indicate the approximate locations of the local lava+ dykes to gabbroid transitions.

5.5 Deep-Towed Camera (OFOS) Observations From the Fault Zone Walls and Floor

The main goal of the OFOS camera deployments along Oceanographer OTF was to identify lithological boundaries inside the transform valley. During all dives, the OFOS was equipped with a Posidonia system for precise positioning, and a MAPR system, situated on the main cable some tens of meters above the rig, to detect possible hydrothermal fluid emanations in hindsight. A total of four OFOS profiles were dedicated to identifying lithological transitions (OFOS stations 18, 19, 21 and 22; Fig. 5.5). A fifth OFOS and MAPR profile (OFOS station 20) was done inside the southwestern part of the west nodal basin to search for hydrothermal activity, close to our OBS station 12 (OBS 20; Fig. 5.4). At this station, the orange plastic flag on the OBS recovered after 5 months on the seafloor, had obviously been completely bleached by the action of a chemical agent.

The stratigraphic deployments along the steep transform valley walls were done by slowly lowering the rig and interactively adjusting the ship´s position. In practical terms, the ship was typically moving at slow but steady speeds in the downhill direction, and stopped at cliff edges along the terraced terrain, until a good optical image was attained below the respective cliff.

The OFOS profile at station 18, located about 25 km from the western IC, showed a gradual transition from gabbroids to serpentinite layers at depths between 2670 and 2720 mbsl (Fig. 5.8) which fits well with the depths of dredge hauls from the same general area (please see previous section). The nearby OFOS station 19 showed only basalts and dykes down to2200 mbsl. The OFOS profiles at stations 21 and 22, about 20 km from the eastern IC, showed dominantly basalt and dykes in the depth range 1750 to 2230 mbsl, but also dispersed gabbroids at the deepest levels. This fits well with the dredge results from the same general area with lavas only dredged down to 2295 mbsl (DR25), and thus complemented well the dredge sampling efforts.

The OFOS profile at station 20, dedicated to the search of hydrothermal fluids by a combined MAPR and camera survey, did not succeed in finding focused hydrothermal venting. However, this does not preclude the existence of more diffuse fluid emanations, as indicated by the one bleached plastic flag on a recovered OBS instrument.

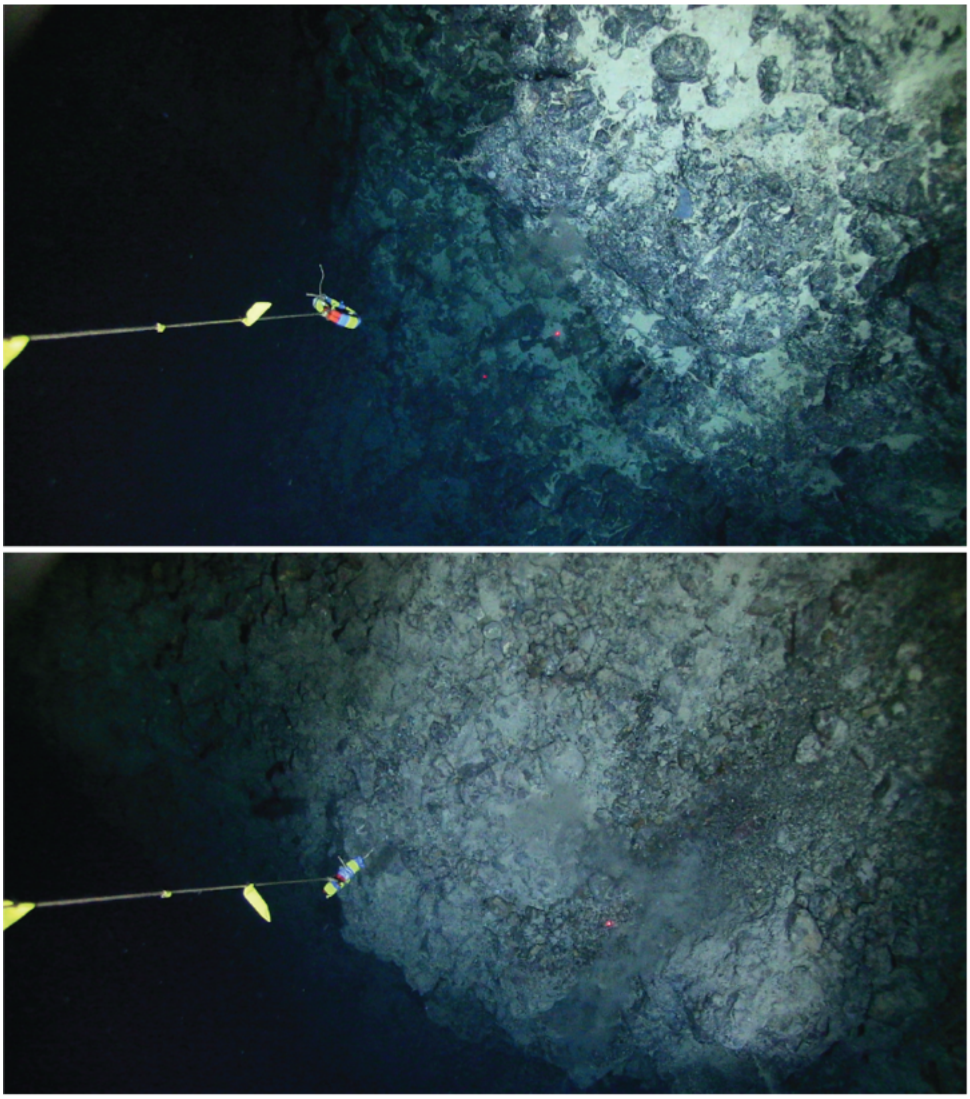

Fig. 5.8 OFOS still photos of changing lithology moving downward along the S transform valley wall at Station 18. The upper photo shows outcropping coarse-graine gabbroid rocks at 2670 mbsl; the lower picture shows a partly layered serpentinite cliff at 2720 mbsl. For scale, the red laser points in the upper picture are 30 cm apart; the lower picture has a similar scale.

5.6 MAPR Missions

The main goal of the MAPR deployments was to search for possible hydrothermal activity along the Oceanographer TF. As described above, the MAPR deployment was always combined with the OFOS camera operations. Only one OFOS track was dedicated to visually discovering hydrothermalism (close to OBS 20, at station 12, as described above). During all of the five OFOS/ MAPR dives, no obvious surface hydrothermal activity could be detected, neither by the chemical sensors nor optically. This does not, however, preclude diffuse hydrothermal activity, as suspected by the bleached flag on the recovered OBS 20.

6 Ship's Meteorological Station

(A. Raeke)

On the morning of 02/06/2021, RV METEOR left the port of Emden.
At the beginning of the voyage, the cruising area was on the eastern edge of a low pressure system with its centre over Brittany. The wind initially came from northeast with 3 to 4 Bft, occasionally with 5 to 6 Bft. In the English Channel, on 03/06/2021, the vessel reached the back of the depression and the wind direction backed west to southwest with 3 to 4 Bft. The significant wave height was 1.0 m with a swell from southwest. In addition, fog occurred in the morning with a visibility below 200 m.

After leaving the English Channel on 04/06/2021, RV METEOR was under the influence of further low pressure systems. These caused occasional precipitation until 07/06/2021. The wind initially blew from the northwest, later from southwesterly directions with 4 to 5 Bft, occasionally up to 6 Bft. The significant wave height was slightly higher than 2.0 m, with a swell from west to west-northwest of 2.0 m. From 08/06/2021 RV METEOR, whilst approaching the Azores, was on the front side of a low pressure zone, which extended from Iceland to Newfoundland. Until reaching the working area southwest of the Azores on 10/06/2021, the wind blew from southwest to the west with initially 5 to 6 Bft. The significant wave height decreased from 2.0 m to 1.0 m with an also decreasing swell from west.

Over the next 10 days, RV METEOR was, while in the research area, primarily under the influence of the Azores High, which caused mainly sunny weather with weak, occasionally circulating, winds. The significant wave height was approx. 1.0 m primarily consisting of a swell from northwesterly directions of up to 1.0 m height.

Partly humid and slightly unstable air was brought in by the westerly air flow of a low pressure trough on 17/06/2021. In the further course of the day, this low moved southwards over the working area and brought light precipitation with it. The wind initially blew from west, later from northwest with 4 to 5 Bft. The significant wave height was up to 2.0 m with a swell of 1.5 m from west-northwest to northwest.

From 18/06/2021 until the start of the journey home to Emden on 19.06.2021, high pressure again prevailed with clear weather. The wind veered to northeast and decreased to 3 to 4 Bft

The transit to Emden began with easterly winds, up to 5 Bft, decreasing during the day to 3 Bft. The significant wave height was 1.5 m and later decreased to 1.0 m with a north-easterly swell of 1.5 to 1.0 m.

On 25/06/2021, a trough from a low pressure system over the British Isles moved over the area of the transit route and brought rain with it. The wind came from west-northwest and increased to 4 to 5 Bft. This caused a wind sea of 0.5 m, the swell was initially weak at 0.5 m from the west-northwest and later increased up to 1.0 m.

The English Channel was crossed on 26th and 27th of June 2021 with weak winds from easterly directions and with a significant wave height of 0.5 m. At the end of the voyage, the wind on the North Sea increased to 5 to 6 Bft from northeast in the afternoon of 27/06/2021. The significant wave height was approx. 1.5 m with a swell of 1.0 m from northeast.

These weather conditions persisted until the arrival at the port of Emden in the morning of 28/06/2021.

7 Station List M175

Station	Action	Latitude	Longitude	Depth (m)	OBS Type	Comment
M175_1-1	OBS03 on deck	35° 05,532' N	034° 54,416' W	2989	Design-02	
M175_1-2	OBS02 on deck	35° 03,640' N	034° 58,318' W	4344	Design-02	
M175_1-3	OBS01 on deck	35° 00,844' N	034° 59,983' W	3678	LOBSTER	
M175_1-4	OBS06 on deck	35° 01,210' N	035° 06,469' W	3667	Design-02	
M175_2-1	OBS101 deployed	35° 01,571' N	035° 06,224' W	3667	Design-02	
M175_1-5	OBS08 on deck	35° 02,994' N	035° 11,884' W	3520	LOBSTER	
M175_1-6	OBS10 on deck	35° 03,425' N	035° 19,258' W	3727	Design-02	
M175_1-7	OBS11 on deck	35° 07,561' N	035° 21,673' W	3613	Design-02	
M175_1-8	OBS12 on deck	35° 05,531' N	035° 25,957' W	3927	LOBSTER	
M175_1-9	OBS13 on deck	35° 09,431' N	035° 28,587' W	3508	Design-02	
M175_1-10	OBS16 on deck	35° 09,013' N	035° 41,401' W	4419	LOBSTER	
M175_1-11	OBS18 not recovered	35° 10,555' N	035° 49,040' W	4564	Design-02	no recovery
M175_1-12	OBS20 on deck	35° 11,965' N	035° 56,663' W	4247	LOBSTER	
M175_1-13	OBS21 on deck	35° 15,522' N	035° 59,584' W	3902	Design-02	
M175_1-14	OBS23 on deck	35° 16,598' N	036° 07,249' W	3316	Design-02	
M175_1-15	OBS24 on deck	35° 13,054' N	036° 08,875' W	4162	Design-02	
M175_1-16	OBS25 on deck	35° 15,643' N	036° 11,687' W	3980	Design-02	
M175_1-17	OBS26 on deck	35° 14,055' N	036° 16,447' W	3787	Design-02	
M175_1-18	OBS27 on deck	35° 18,064' N	036° 15,611' W	4012	LOBSTER	
M175_3-1	Dredge on bottom	35° 18,822' N	036° 16,102' W	3789		empty
M175_4-1	Dredge on bottom	35° 15,214' N	036° 15,654' W	3813		empty
M175_5-1	Dredge on bottom	35° 15,498' N	036° 16,455' W	3761		empty
M175_6-1	Dredge on bottom	35° 21,881' N	036° 27,880' W	2516		
	Off bottom	35°22,194' N	36°27,840' W	2247		
M175_7-1	Dredge on bottom	35° 19,247' N	036° 30,851' W	3066		
	Off bottom	35°19,453' N	36°31,120' W	2781		
M175_8-1	Dredge on bottom	35° 24,741' N	036° 37,354' W	2256		empty
M175_9-1	Dredge on bottom	35° 20,185' N	036° 37,175' W	3156		
	Off bottom	35°20,516' N	36°37,425' W	3078		
M175_10-1	Dredge on bottom	35° 08,453' N	035° 54,549' W	2551		
	Off bottom	35°08,187' N	35°54,719' W	2338		
M175_11-1	Dredge on bottom	35° 12,154' N	035° 59,462' W	3320		
	Off bottom	35°11,734' N	35°59,618' W	2746		
M175_12-1	Dredge on bottom	35° 12,681' N	036° 02,705' W	2748		
	Off bottom	35°12,393' N	36°02,822' W	2430		
M175_13-1	Dredge on bottom	35° 10,380' N	036° 03,557' W	2042		
	Off bottom	35°10,381' N	36°03,888' W	2326		
M175_14-1	Dredge on bottom	35° 10,297' N	036° 06,212' W	1542		empty
M175_14-2	Dredge on bottom	35° 10,292' N	036° 06,223' W	1526		empty
M175_15-1	Dredge on bottom	35° 19,906' N	036° 03,978' W	3021		empty
M175_16-1	Dredge on bottom	35° 18,257' N	036° 00,588' W	3787		empty

Station	Action	Latitude	Longitude	Depth (m)	OBS Type	Comment
M175_17-1	Dredge on bottom	35° 13,746' N	035° 51,461' W	3754		
	Off bottom	35°13,762' N	35°51,569' W	3533		
M175_18-1	OFOS Profile 1 start	35° 09,116' N	035° 50,603' W	2489		
M175_19-1	OFOS Profile 2 start	35° 07,771' N	035° 47,381' W	2097		
M175_20-1	OFOS Profile 3 start	35° 11,787' N	035° 56,469' W	3787		
M175_21-1	OFOS Profile 4 start	35° 12,426' N	035° 16,977' W	2028		
M175_22-1	OFOS Profile 5 start	35° 12,028' N	035° 16,918' W	2230		
M175_1-19	OBS101 on deck	35° 01,521' N	035° 06,457' W	3977	Design-02	
M175_23-1	Dredge on bottom	35° 10,339' N	035° 05,940' W	2027		empty
M175_24-1	Dredge on bottom	35° 10,245' N	035° 10,722' W	2278		
	Off bottom	35°10,260' N	35°11,019' W	2117		
M175_25-1	Dredge on bottom	35° 11,963' N	035° 16,606' W	2296		
	Off bottom	35°12,228' N	35°16,873' W	1970		
M175_26-1	Dredge on bottom	35° 10,447' N	035° 20,678' W	2717		
	Off bottom	35°10,737' N	35°20,601' W	2421		
M175_27-1	Dredge on bottom	35° 11,484' N	035° 27,727' W	2836		empty
M175_28-1	Dredge on bottom	35° 13,296' N	035° 43,031' W	3000		
	Off bottom	35°13,542' N	35°43,067' W	2777		
M175_29-1	Dredge on bottom	35° 09,426' N	036° 02,258' W	1848		
	Off bottom	35°19,340' N	36°01,976' W	1430		
M175_30-1	Dredge on bottom	35° 08,135' N	035° 58,417' W	2117		empty
M175_31-1	Dredge on bottom	35° 09,144' N	035° 50,465' W	2824		
	Off bottom	35°08,894' N	35°50,686' W	2398		
M175_32-1	Dredge on bottom	35° 07,889' N	035° 47,190' W	2424		
	Off bottom	35°07,788' N	35°47,437' W	2139		
M175_33-1	Dredge on bottom	35° 07,081' N	035° 40,913' W	3057		
	Off bottom	35°06,746' N	35°10,878' W	2550		
M175_34-1	Dredge on bottom	35° 05,232' N	035° 40,283' W	1999		
	Off bottom	35°04,960' N	35°40,169' W	1852		
M175_35-1	Dredge on bottom	35° 03,275' N	035° 26,339' W	2964		
	Off bottom	35°03,528' N	35°26,427' W	2677		
M175_36-1	Dredge on bottom	35° 00,954' N	035° 11,678' W	2716		
	Off bottom	35°00,782' N	35°11,641' W	2469		
M175_37-1	Dredge on bottom	34° 57,940' N	035° 00,420' W	3041		
	Off bottom	34°58,052' N	35°00,755' W	2710		
M175_38-1	Dredge on bottom	35° 12,805' N	035° 04,716' W	2040		
	Off bottom	35°13,137' N	35°04,684' W	1743		
M175_39-1	Dredge on bottom	35° 11,621' N	035° 14,168' W	2607		empty
M175_40-1	Dredge on bottom	35° 10,520' N	035° 19,072' W	2322		empty
M175_41-1	Dredge on bottom	35° 14,727' N	035° 05,662' W	1366		
	Off bottom	35°15,024' N	35°05,781' W	1059		
M175_42-1	Site 17 OBS deployed	36° 41,995' N	031° 24,027' W	2637	LOBSTER	
M175_43-1	Site 19 OBS deployed	37° 59,998' N	030° 00,011' W	1925	LOBSTER	

Station	Action	Latitude	Longitude	Depth (m)	OBS Type	Comment
M175_44-1	Site 12 OBS deployed	40° 00,000' N	028° 29,980' W	2249	LOBSTER	
M175_45-1	Site X25 OBS deployed	40° 35,426' N	026° 52,712' W	2633	LOBSTER	

8 Data and Sample Storage and Availability

Seismic data will be available after 1st of January 2023 at the PANGAEA World Data Centre, Bremerhaven (http:// http://www.pangaea.de).

Bathymetric data recorded during the survey M175 are available at the Bathymetric Data Centre of the the Bundesamt für Seeschifffahrt und Hydrographie, Rostock (http://www.bsh.de/en/Marine_data/Hydrographic_surveys_and_wreck_search/Bathymetry). Underway data (Thermosalinograph, ADCP, bathymetry) are available at PANGAEA.

Dredge samples are stored in GEOMAR's Lithothek.

Table 8.1 Overview of data availability

Type	Database	Available	Free Access	Contact
EM122	BSH	30.04.21	30.04.23	bathymetrie@bsh.de
ADCP	PANGAEA	01.12.21	01.12.21	robert.kopte@ifg.uni-kiel.de
Thermo-salino-graph	PANGAEA			mschlundt@geomar.de
Seismo-logical data	PANGAEA	30.06.22	31.12.23	igrevemeyer@geomar.de
Hard rock dredge samples	PANGAEA / GEOMAR Lithothek	01.01.22	30.06.24	thansteen@geomar.de

9 Acknowledgements

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11 Abbreviations

OTF oceanic transform fault

RTI ridge-transform intersection

IC inside corner

OC outside corner

OBS – Ocean-Bottom-Seismometer

OBH – Ocean-Bottom-Hydrophone

12 Appendices

12.1 Sample Descriptions and Photos M175

12.2 Sample Descriptions and Photos M170

<table>
<tr><td colspan="2">

M175-DR06
Locality: Oceanographer Transform Fault, Western Fracture Zone, Older Plate
Date: 12th June 2021
Coordinates on bottom: 35°21,921' N 36°27,841' W Depth: 2516 m
Coordinates off bottom: 35°22,194' N 36°27,840' W Depth: 2247 m
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Lithology: slightly to moderately altered porphyric lava

Size, shape, color: 10 x 8 x 6, rounded to subequant, grey

Texture, matrix, vesicularity: fine crystallized matrix, 1% vesicles

Phenocrysts: Cpx (plurimm, 5%); alterated yellowish crystals on border (plurimm); Ol (mm)

Comments: Mn-crust (1-3 mm); fractures (filled with material); alteration in the fractures
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Lithology: Mn-crust

Size: 20 x 17 x 3
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Lithology: sedimentary rock

Size: 5 x 13 x 11

Comments: carbonatic; organic; bioturbation; Mn- crust (1 mm)
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M175-DR07

Locality: Oceanographer Transform Fault, Outside Corner of the RTI

Date: 12th June 2021

Coordinates on bottom: 35°19,279' N 36°30,868' W Depth: 3066 m

Coordinates off bottom: 35°19,453' N 36°31,120' W Depth: 2781 m

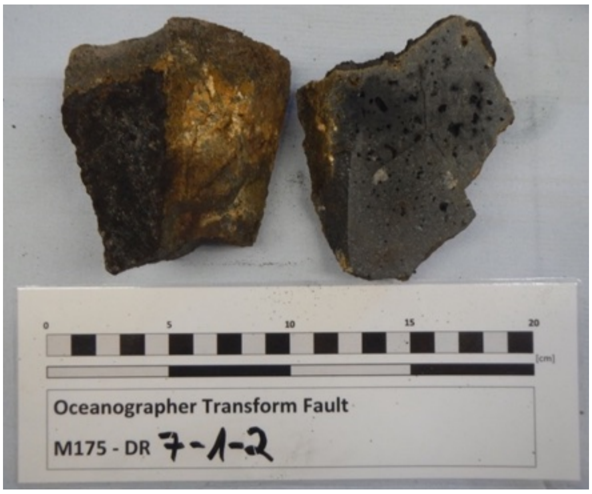
Lithology: slightly to moderately altered porphyric basalt

Size, shape, color: block, pillow lava, grey

Texture, matrix, vesicularity: fine crystallized matrix, 5% vesicles

Phenocrysts: Plg (1 mm needles); altered Ol 1%

Comments: Mn-crust (1 mm); reddish alteration in vesicles



Lithology: sparsely to moderate altered porphyric basalt

Size, shape, color: block, pillow lava, grey

Texture, matrix, vesicularity: fine crystallized matrix, 5% vesicles

Phenocrysts: Plg (plurimm needles); altered Ol; Fe-altered crystals

Comments: Mn-crust (2 mm)

Lithology: slightly altered porphyric lava basalt

Size, shape, color: 17 x 11 x 9, rounded to angular, dark grey

Texture, matrix, vesicles: fine crystallized matrix, 5 % vesicles

Phenocrysts: Cpx; Plg < 1mm; phenocryst greenish alteration

Comments: very thin Mn-crust; concentric alteration 3 rings

	Lithology: slightly altered phyric lava basalt Size, shape, color: 20 x 9 x 8, rounded to angular, grey (some darker spots) Texture, matrix, vesicles: fine crystallized matrix, 1 % vesicles Phenocrysts: Ol (1%, altered and fresh), Plg (1%, needles) Comments: Mn-crust (2 mm), reddish alteration in vesicles
	Lithology: slightly altered phyric lava basalt Size, shape, color: 18 x 14 x 4, rounded to angular, greyish Texture, matrix, vesicles: fine crystallized matrix, 5 % vesicles Phenocrysts: Plg (mm, 5 %); Ol (altered, 1%); Cpx Comments: Mn-crust (1mm)
	Lithology: slightly altered phyric lava basalt Size, shape, color: 7 x 3 x 1, rounded to angular, dark grey Texture, matrix, vesicles: fine crystallized matrix, 10 % vesicles Phenocrysts: Ol (plurimm); Plg (mm, 1%) Comments: very thin Mn-crust; concentric alteration (3 zones); reddish alteration in vesicles on border

Lithology: slightly altered phyric lava basalt

Size, shape, color: 7 x 7 x 4, rounded to angular, greyish grey

Texture, matrix, vesicles: fine crystallized matrix, 5 % vesicles

Phenocrysts: Plg (5 %)

Comments: very thin Mn-crust; concentric alteration 3 rings; Fe-alteration

M175-DR09

Locality: Oceanographer Transform Fault, Outside Corner of the Western RTI

Date: 12th June 2021

Coordinates on bottom: 35°20,186' N 36°37,190' W Depth: 3170 m

Coordinates off bottom: 35°20,516' N 36°37,425' W Depth: 3078 m

Lithology: slightly altered basalt

Size, shape, color: 20 x 20 x 7, angular, greyish

Texture, matrix, vesicles: aphyric, fine crystallized matrix, 1% vesicles

Phenocrysts: -

Comments: Mn-crust (1-10 mm); carbonates in vesicles

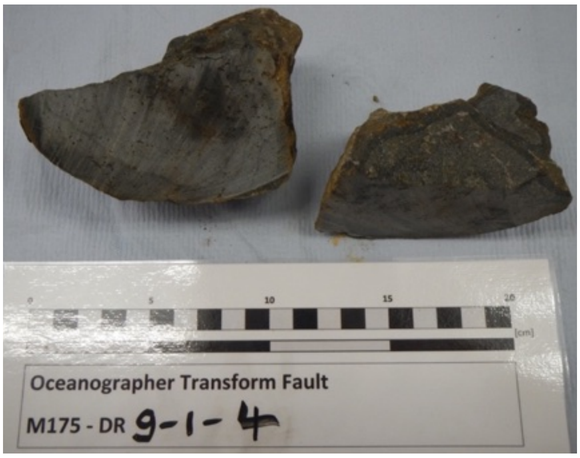
Lithology: slightly altered porphyritic basalt

Size, shape, color: 25 x 25 x 8, angular, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 1 % vesicles

Phenocrysts: Cpx (mm, 3%); Plg (mm, 1%); Ol xenocrysts

Comments: Mn-crust; carbonates in vesicles; orange/reddish alteration zones

	<u>Lithology:</u> altered porphyritic basalt <u>Size, shape, color:</u> 17 x 14 x 7, round-subangular, dark grey <u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, 10 % vesicles <u>Phenocrysts:</u> Plg (mm, 10%); Cpx (mm) <u>Comments:</u> Mn-crust (1-15 mm); coral crust (1-10 mm); concentric alteration zone around the core
	<u>Lithology:</u> altered basalt <u>Size, shape, color:</u> 14 x 10 x 6, round, grey <u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, 2% vesicles <u>Phenocrysts:</u> Plg (mm, 1%); Cpx (mm) <u>Comments:</u> Mn-crust (3 mm); yellowish alteration of minerals
	<u>Lithology:</u> altered porphyritic basalt <u>Size, shape, color:</u> 10 x 9 x 5, rounded-subangular, slightly dark grey <u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, 5 % vesicles <u>Phenocrysts:</u> Plg (plurimm, 5%); Cpx (plurimm) <u>Comments:</u> Mn-crust (2 mm); carbonates in vesicles; alteration inside vesicles orange; concentric alteration (3 zones)

Lithology: altered basalt

Size, shape, color: 10 x 5 x 7, rounded, grey

Texture, matrix, vesicles: nearly aphyric, fine crystallized matrix, 5 % vesicles

Phenocrysts: very few <1% altered phenocrysts

Comments: Mn-crust (3 mm); different alteration areas; orange alteration inside vesicles

M175-DR10

Locality: Oceanographer Transform Fault, Inside Corner of the Western RTI, Core Complex

Date: 12th June 2021

Coordinates on bottom: 35°08,459' N   35°54,533' W   Depth: 2560 m

Coordinates off bottom: 35°08,187' N   35°54,719' W   Depth: 2338 m

Lithology: gabbro

Size, shape, color: 11 x 10 x 11, subangular to rounded, greyish

Texture, matrix, vesicles: equigranular

Phenocrysts: Px (mm, plurimm, 50%); Plg (mm, plurimm, 50%)

Comments: slightly altered

Lithology: slightly altered gabbro

Size, shape, color: 13 x 7 x 4, subangular to rounded, greyish

Texture, matrix, vesicles: equigranular

Phenocrysts: Px (mm, plurimm, 50%); Plg (mm, plurimm, 50%)

Comments: green alteration minerals in fracture

	Lithology: serpentinite Size, shape, color: 11 x 10 x 11, subrounded, grey Texture, matrix, vesicles: porphyric irregular texture Phenocrysts: serpentine minerals: black (mm-cm, 60%); green (mm, 20%) Comments: high serpentinization
	Lithology: serpentinized gabbro Size, shape, color: block, rounded, greenish-black Texture, matrix, vesicles: porphyric Phenocrysts: Px (mm-cm 80%); Plg (mm-cm 20%); serpentinization Comments: green alteration minerals and in fractures; striation visible
	Lithology: highly serpentinized gabbro Size, shape, color: 15 x 12 x 5, subangular-rounded, greenish-black Texture, matrix, vesicles: porphyric Phenocrysts: Px (mm-plurimm, 50%); Plg (mm, 10%); high serpentinization; black and green serpentinite minerals Comments: striation visible

	<u>Lithology:</u> basalt and gabbro <u>Size, shape, color:</u> 13 x 7 x 9, subangular, grey <u>Texture, matrix, vesicles:</u> different melts, one crystallized matrix, one aphyric matrix, no vesicles, <u>Phenocrysts:</u> Px (mm-plurimm, 80%); Plg (mm-cm, 20%); greenish alteration <u>Comments:</u> small fractures
	<u>Lithology:</u> slightly altered basalt <u>Size, shape, color:</u> 15 x 8 x 10, subangular, grey <u>Texture, matrix, vesicles:</u> almost aphyric, fine crystalline matrix, no vesicles <u>Phenocrysts:</u> Px <1%, Plg <1%; Fe-alteration phenocrysts <u>Comments:</u> slightly altered fractures
	<u>Lithology:</u> serpentinized gabbro <u>Size, shape, color:</u> 35 x 20 x 8, angular/irregular shape, white-black gabbro surrounded by greyish matrix <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> Px (mm-cm, 30%); Plg (mm-cm ,70%) <u>Comments:</u> serpentinite alteration; greenish alteration of Px; green serpentinite minerals in fractures

	<u>Lithology:</u> moderate altered gabbro <u>Size, shape, color:</u> 20 x 20 x 20, subangular shape <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> Px (mm-cm, 40%); Plg (mm-cm, 60%) <u>Comments:</u> serpentinization; fractures with green minerals (hydrothermal); hydrothermal green minerals on Plg
	<u>Lithology:</u> serpentinized gabbro <u>Size, shape, color:</u> 25 x 20 x 13, angular shape, white greenish black matrix <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> Px (mm-cm, 40%); Plg (mm-cm, 60%) <u>Comments:</u> serpentinization; striations; fractures with magnetites
	<u>Lithology:</u> serpentinized gabbro <u>Size, shape, color:</u> block, angular shape, white greenish black matrix <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> different melting zones (sometimes plagio-granite or other very Px rich); Px (mm-cm, 40%); Plg (mm-cm, 60%) <u>Comments:</u> serpentinization; striations; fractures with magnetites; green alteration minerals

	Lithology: serpentinized gabbro Size, shape, color: block, greenish grey matrix, different melting zones Texture, matrix, vesicles: porphyric texture Phenocrysts: Px (mm-cm, 60%); Plg (mm-cm, 40%) Comments: plagiogranite melt; serpentinization mineral alteration; striations; fractures with magnetites; hydrothermal alteration (black and green)
	Lithology: serpentinized gabbro Size, shape, color: 12 x 11 x 8, subangular to rounded, greenish to grey Texture, matrix, vesicles: crystalline matrix Phenocrysts: Px 60%; Plg (mm-plurimm, 40%) Comments: different melting zones more or less mafic melts; serpentinized in fracture zone
	Lithology: gabbro Size, shape, color: 10 x 7 x 8, subangular to rounded, greenish to grey white Texture, matrix, vesicles: equigranular Phenocrysts: Px (mm, 60%); Plg (mm, 40%) Comments: Plg-granite intrusions; greenish alteration mineral fractures; striation

	<u>Lithology:</u> gabbro <u>Size, shape, color:</u> 20 x 14 x 10, angular, grey white <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> Px (mm-cm, 40%); Plg (mm-cm, 60%) <u>Comments:</u> fracture with magnetite; small 0.5 cm large basaltic dykes with small vesicles and phenocrysts (<0.1 mm)
	<u>Lithology:</u> serpentinite <u>Size, shape, color:</u> 20 x 25 x 10, subangular, greenish-black <u>Texture, matrix, vesicles:</u> - <u>Phenocrysts:</u> serpentinite minerals: black (mm-cm, 60%); green (mm, 20%) <u>Comments:</u> Mn-crust (2 mm); high serpentinization
	<u>Lithology:</u> serpentinized gabbro <u>Size, shape, color:</u> 10 x 15 x 5, subangular to rounded, greenish-grey <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> Px (mm, 50%); Plg (mm, 50%) <u>Comments:</u> small fractures; serpentinized; striation

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<td><u>Lithology:</u> serpentinite

<u>Size:</u> 16 x 12 x 10

not cut</td>
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<tr>
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</td>
<td><u>Lithology:</u> serpentinite

<u>Size:</u> 18 x 5 x 16

not cut</td>
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<tr>
<td colspan="2">M175-DR11
<u>Locality:</u> Oceanographer Transform Fault, Inside Corner of the Western RTI
<u>Date:</u> 13th June 2021
<u>Coordinates on bottom:</u> 35°12,149' N 35°59,444' W <u>Depth:</u> 3285 m
<u>Coordinates off bottom:</u> 35°11,734' N 35°59,618' W <u>Depth:</u> 2746 m</td>
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<td><u>Size, shape, color:</u> block, rounded, grey

<u>Lithology:</u> pillow basalt

<u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, 10% vesicles

<u>Phenocrysts:</u> Cpx (mm, <1%); Ol (mm, 1%)

<u>Comments:</u> Mn-crust; glass</td>
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<td><u>Lithology:</u> moderate altered basalt

<u>Size, shape, color:</u> 11 x 25 x 7, subangular to rounded, grey

<u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, 5% vesicles

<u>Phenocrysts:</u> Cpx (mm, 3%); Ol (mm, <0.1%); Plg (mm, 2%)

<u>Comments:</u> Fe altered phenocrysts, altered Ol</td>
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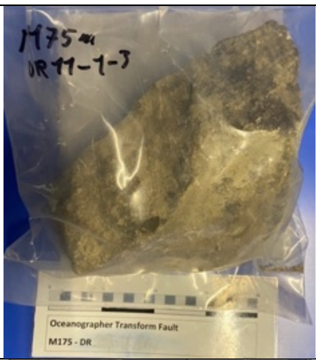	Back up sample
	Back up sample
	Lithology: slightly altered basalt Size, shape, color: 15 x 7 x 7, angular, grey Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, no vesicles Phenocrysts: Cpx (mm, <0.1%); Plg (mm, 0.1%) Comments: Mn-crust; concentric alteration; Fe-alteration in fracture altered Ol
	Lithology: slightly to moderate altered basalt Size, shape, color: 20 x 13 x 4, subangular, dark grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, 1% vesicles Phenocrysts: Cpx (mm-cm, 10%); Plg (mm, <1%); Ol (mm, 1%) Comments: thin Mn-crust; altered phenocrysts

	Lithology: slightly altered basalt Size, shape, color: 15 x 6 x 6, rounded to subangular, grey Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, 1% vesicles Phenocrysts: Cpx (mm, 0.1%); Plg (mm, <1%) Comments: Fe alteration
	Lithology: altered basalt Size, shape, color: 20 x 11 x 18, angular, dark grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, 3% vesicles Phenocrysts: Cpx (mm-pluri, 2%); Plg (mm, <1%) Comments: orange alteration in vesicles
	Size, shape, color: 15 x 20 x 4, angular, dark grey-yellowish Lithology: slightly altered basalt Texture, matrix, vesicles: porphyric, fine crystallized matrix, 20% vesicles Phenocrysts: Px (pluri-mm, 5%); Plg (mm, 1%); Ol (mm, 1%); Px and Ol altered Comments: orange alteration in vesicles

M175-DR12

Locality: Oceanographer Transform Fault, Inside Corner of the Western RTI

Date: 13th June 2021

Coordinates on bottom: 35°12,699' N 36°02,686' W Depth: 2778 m

Coordinates off bottom: 35°12,393' N 36°02,822' W Depth: 2430 m

	Lithology: basalt Size, shape, color: 20 x 10 x 5, angular, greyish Texture, matrix, vesicles: porphyric, fine crystallized matrix, 5-10% vesicles Phenocrysts: Px (plurimm, 5%); Plg (mm, 5%); Ol (plurimm, 3%) Comments: thin Mn-crust; orange-reddish alteration in the fractures
	Lithology: moderate altered basalt Size, shape, color: block, subangular, dark grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, 10% vesicles Phenocrysts: Px (plurimm, 5%); Plg (mm, 10%) Comments: thin Mn-crust; altered and fractured Px; orange-reddish alteration in the fractures
	Lithology: slightly altered basalt Size, shape, color: 20 x 12 x 5, subangular, grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, 1% vesicles Phenocrysts: - Comments: 0.5 cm Mn-crust; carbonate in vesicles

	<u>Lithology:</u> slightly altered basalt <u>Size, shape, color:</u> 10 x 15 x 10, rounded, grey <u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, 5% vesicles <u>Phenocrysts:</u> Plg (plurimm, 5%); Cpx (plurimm, 5%); Ol (mm, 1%); (maybe xenocrysts) <u>Comments:</u> orange alteration crust
	<u>Lithology:</u> porphyric basalt <u>Size, shape, color:</u> block, angular, grey <u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, 5% vesicles <u>Phenocrysts:</u> Cpx (plurimm, 5%); Plg (mm, 3%); Ol (mm, 1%) <u>Comments:</u> glass crust; Mn-crust; alteration zone on the border
	<u>Lithology:</u> aphyric basalt <u>Size, shape, color:</u> block, angular, grey <u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, no vesicles <u>Phenocrysts:</u> - <u>Comments:</u> thin Mn-crust; concentric alteration

Lithology: slightly altered basalt

Size, shape, color: 19 x 11 x 11, angular, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 1% vesicles

Phenocrysts: Plg (mm, 2%); Cpx (mm, 2%); Ol (mm, 1%, xenocrysts)

Comments: Mn-crust; Fe altered phenocrysts

Size, shape, color: 25 x 15 x 8, angular, grey

Lithology: slightly altered basalt

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 5% vesicles

Phenocrysts: Plg (mm, 3%); Cpx (plurimm, 5%); Ol (mm, 1%); altered Ol and Cpx

Comments: thin Mn-crust

M175-DR13

Locality: Oceanographer Transform Fault, Inside Corner of the Western RTI

Date: 13th June 2021

Coordinates on bottom: 35°10,380' N 36°03,558' W Depth: 2033 m

Coordinates off bottom: 35°10,381' N 36°03,888' W Depth: 2326 m

Lithology: slightly altered basalt

Size, shape, color: 11 x 11 x 10, rounded, dark grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 5% vesicles

Phenocrysts: Plg (mm, 5%); Cpx (plurimm, <1%); Ol (mm, <1%)

Comments: orange alteration crust (1 cm); Mn-crust (around 0.5 cm); fracture with Mn-crust; coral crust

M175-DR17 Locality: Oceanographer Transform Fault, Transform Valley Date: 14th June 2021 Coordinates on bottom: 35°13,684' N 35°51,472' W Depth: 3754 m Coordinates off bottom: 35°13,762' N 35°51,569' W Depth: 3533 m	
 	Lithology: serpentinized lherzolite-pyroxenite Size, shape, color: 20 x 9 x 12, angular, grey-greenish Texture, matrix, vesicles: porphyroclastic, no vesicles Phenocrysts: serpentine group mineral; yellowish mineral; dark green; white (Ol/Px) Comments: high serpentinization; concentric zones with different alteration grade
 	Lithology: serpentinized metagabbro Size, shape, color: 15 x 6 x 7, irregular shape, brown greenish Texture, matrix, vesicles: equigranular Phenocrysts: Phlogopite; grey mineral (former Ol); brown mineral Comments: Mn-crust; high serpentinization; fractures with magnetite and carbonate

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<td>
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<td><u>Lithology:</u> serpentinized peridotite

<u>Size, shape, color:</u> 20 x 10 x 8, angular, grey-greenish

<u>Texture, matrix, vesicles:</u> porphyroclastic, equigranular

<u>Phenocrysts:</u> serpentine group mineral; grey and orange-brownish minerals

<u>Comments:</u> thin Mn-crust</td>
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<tr>
<td>
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<td><u>Lithology:</u> serpentinite

<u>Size, shape, color:</u> 12x10x6, subangular, grey-greenish

<u>Texture, matrix, vesicles:</u> crystalline-clastic texture

<u>Phenocrysts:</u> serpentine group mineral, brown alterated clasts surrounded by phenocryst layer

<u>Comments:</u> -</td>
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<td><u>Lithology:</u> serpentinite

<u>Size, shape, color:</u> 10 x 6 x 8, subangular, grey-greenish

<u>Texture, matrix, vesicles:</u> crystalline-clastic texture

<u>Phenocrysts:</u> serpentine group mineral

<u>Comments:</u> -</td>
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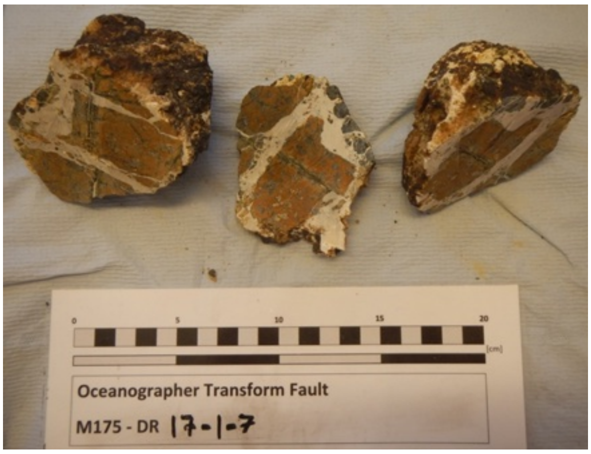
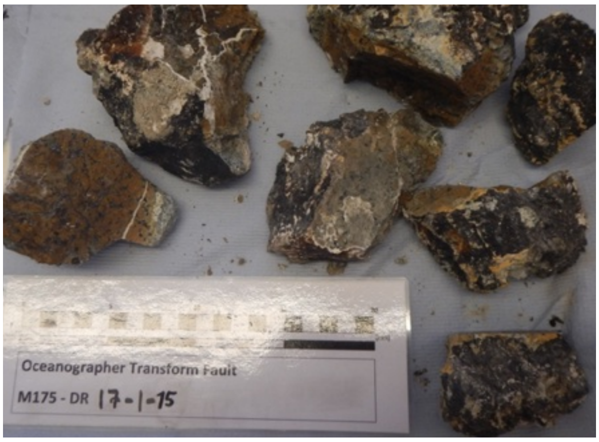
	Lithology: serpentinized metagabbro Size, shape, color: 10 x 7 x 10, subangular, brownish to orange Texture, matrix, vesicles: porphyroclastic Phenocrysts: serpentine group mineral; phlogopite; Px (mm, 10%) Comments: -
	Lithology: clastic serpentinized metagabbro Size, shape, color: 10 x 7 x 7, subangular, brownish to orange Texture, matrix, vesicles: clastic texture with porphyroclastic clasts Phenocrysts: serpentine group mineral; phlogopite; Px (mm to cm, 10%) Comments: thin Mn-crust; cemented carbonate in fractures
	Size, shape, color: 10 x 9 x 4, subangular, brownish to orange Lithology: serpentinized metagabbro Texture, matrix, vesicles: porphyroclastic Phenocrysts: serpentine group mineral; phlogopite; Px (10%, mm) Comments: thin Mn-crust

	Size, shape, color: 7 x 4 x 5, rounded, green-brown Lithology: gabbro-serpentinite Texture, matrix, vesicles: crystalline structure, transition between 2 lithologies Phenocrysts: serpentine group mineral; phlogopite; Px (30%, plurimm); Plg (60%, plurimm) Comments: serpentine minerals and carbonate in fractures
	Lithology: highly serpentinized peridotite Size, shape, color: 14 x 6 x 9, subangular, grey-green Texture, matrix, vesicles: porphyroclastic Phenocrysts: serpentine group mineral Comments: thin Mn-crust; concentric alteration zone
	Size, shape, color: 12 x 10 x 6; angular; brown-greenish and white Lithology: carbonatic conglomerate with metagabbro and serpentinized peridotite Texture, matrix, vesicles: cemented porphyroclastic clasts Phenocrysts: serpentine group mineral; phlogopite Comments: thin Mn-crust

	Lithology: metapyroxenite with Plg Size, shape, color: 14 x 9 x 7, angular, green-grey Texture, matrix, vesicles: equigranular Phenocrysts: serpentine group mineral; phlogopite, Comments: thin Mn-crust; carbonates ins fractures
	Size, shape, color: 8 x 5 x 5, subangular, light grey Lithology: serpentinized basalt Texture, matrix, vesicles: porphyric, fine crystallized matrix, no vesicles Phenocrysts: Ol (1%, mm-cm); Plg (1%, mm); Px (1%, mm) Comments: -
	Lithology: serpentinized basalt Size, shape, color: 8 x 5 x 5, subangular, light grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, no vesicles Phenocrysts: Ol (1%, mm-cm); Plg (1%, mm); Px (1%, mm) Comments: -



Lithology: metagabbro

Size, shape, color: 25 x 25 x 9, subangular, brown

Texture, matrix, vesicles: equigranular

Phenocrysts: phlogopite (1%, mm-plurimm); black minerals

Comments: thin Mn-crust; gabbroic layer on border; carbonates in fractures

M175-DR24

Locality: Oceanographer Transform Fault, Inside Corner of the Eastern RTI

Date: 16th June 2021

Coordinates on bottom: 35°10,222' N   35°10,694' W   Depth: 2334 m

Coordinates off bottom: 35°10,260' N   35°11,019' W   Depth: 2117 m

Lithology: altered porphyric basalt

Size, shape, color: 10 x 9 x 8, subangular, dark grey-black

Texture, matrix, vesicles: porphyric, fine crystallized matrix, no vesicles

Phenocrysts: Plg (mm-cm, 1%); Px (mm-cm, 2%)

Comments: thin Mn-crust; orange alteration layer on border

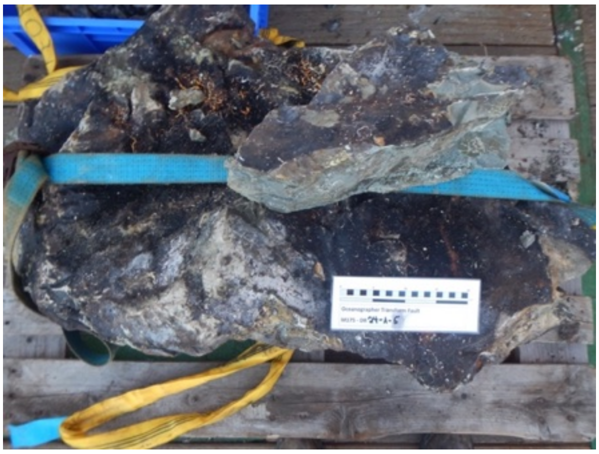
Lithology: gabbro

Size, shape, color: 25 x 14 x 12, angular, grey

Texture, matrix, vesicles: equigranular

Phenocrysts: Plg (mm, 50%); Px (mm, 50%)

Comments: thin Mn-crust; orange alteration layer on border

	Lithology: altered gabbro Size, shape, color: 20 x 11 x 5, angular, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (plurimm, 40%); Cpx (plurimm, 40%); Mv (mm, 10%) Comments: thin Mn-crust; slight orange-red oxidation; small fractures
	Lithology: slightly altered basalt Size, shape, color: 18 x 4 x 11, angular, grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, no vesicles Phenocrysts: Plg 1-2%; Cpx 5%, Comments: thin Mn-crust; alteration fractures; slight Fe-oxidation
	Lithology: gabbro basalt transition Size, shape, color: big block 130 x 100 x 30, subangular, grey Texture, matrix, vesicles: gabbro: equigranular; basalt: aphyric, fine crystallized matrix, no vesicles Phenocrysts: Plg (mm, 60%); Px (mm to plurimm, 40%) Comments: thin Mn-crust

	Lithology: slightly altered basalt Size, shape, color: 7 x 7 x 9, angular, grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, no vesicles Phenocrysts: - Comments: thin Mn-crust; alteration fractures
	Lithology: altered gabbro Size, shape, color: 13 x 6 x 7, angular, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (plurimm-cm); Px (plurimm-cm); Mv (plurimm) Comments: thin Mn-crust; slight Fe-alteration fractures
	Lithology: altered gabbro Size, shape, color: 14 x 7 x 3, elongated, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (mm-plurimm, 45%); Px (mm-plurimm, 55%); Mv (mm-plurimm, 3%) Comments: thin Mn-crust; small fractures
	Lithology: altered gabbro Size, shape, color: 12 x 8 x 3, angular, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (plurimm, 30%); Px (plurimm, 60%); Mv (mm, 1%) Comments: thin Mn-crust; Fe alteration

	Lithology: gabbro Size, shape, color: bloc, angular, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (mm-plurimm 45%); Px (mm-plurimm 50%); Bt (mm-cm, 5%) Comments: thin Mn-crust; biogenic carbonates
	Lithology: basalt Size, shape, color: 11 x 6 x 6, subangular, grey Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, 10% vesicles Phenocrysts: very small and few Px, Comments: thin Mn-crust; yellow fractures; different concentric alteration
	Lithology: basalt Size, shape, color: 9 x 6 x 3, angular, grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, no vesicles Phenocrysts: - Comments: thin Mn-crust; orange red alteration on the border
	Lithology: altered gabbro Size, shape, color: 10 x 5 x 5, angular-rounded, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (plurimm-cm, 40%); Px (plurimm-cm, 50%); Mv (plurimm, 5%) Comments: thin Mn-crust, small fractures

<table>
<tr><td>
</td><td><u>Lithology:</u> moderately altered basalt

<u>Size, shape, color:</u> 8 x 7 x 5, round, grey

<u>Texture, matrix, vesicles:</u> almost aphyric, fine crystallized matrix, no vesicles

<u>Phenocrysts:</u> Plg (mm, 1%) ,Px (mm, 1%)

<u>Comments:</u> thin Mn-crust; fractures</td></tr>
<tr><td>
</td><td><u>Lithology:</u> altered basalt

<u>Size, shape, color:</u> 7 x 6 x 4, irregular, grey

<u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, no vesicles

<u>Phenocrysts:</u> -

<u>Comments:</u> thin Mn-crust; fractures filled with Plg; carbonate crust (about 0,5 cm large)</td></tr>
<tr><td colspan="2">M175-DR25
<u>Locality:</u> Oceanographer Transform Fault, Inside Corner of the Eastern RTI
<u>Date:</u> 16th June 2021
<u>Coordinates on bottom:</u> 35°11,971' N 35°16,613' W <u>Depth:</u> 2292 m
<u>Coordinates off bottom:</u> 35°12,228' N 35°16,873' W <u>Depth:</u> 1970 m</td></tr>
<tr><td>
</td><td><u>Lithology:</u> basalt

<u>Size, shape, color:</u> 11 x 8 x 7, rounded, dark grey-black

<u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, 5% vesicles

<u>Phenocrysts:</u> -

<u>Comments:</u> thin Mn-crust; concentric alteration brown layer</td></tr>
</table>

Lithology: basaltic breccia

Size, shape, color: 9 x 6 x 2, rounded to subangular

Texture, matrix, vesicles: carbonate matrix, small vesicles in clasts

Phenocrysts: -

Comments: Mn-crust; clasts in carbonatic cement

M175-DR26

Locality: Oceanographer Transform Fault, Inside Corner of the Eastern RTI

Date: 16th June 2021

Coordinates on bottom: 35°10,448' N   35°20,679' W   Depth: 2723 m

Coordinates off bottom: 35°10,737' N   35°20,601' W   Depth: 2421 m

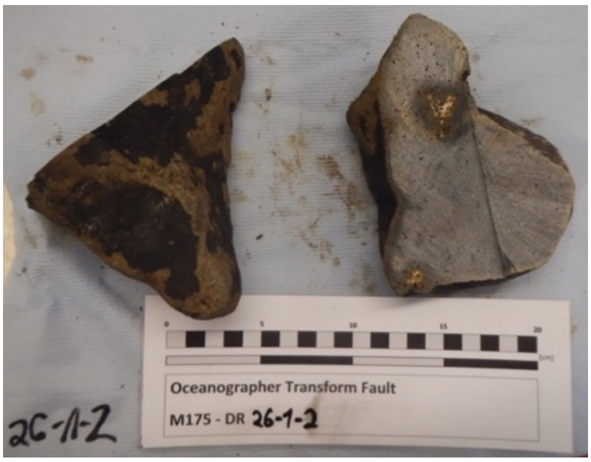
Lithology: basalt slightly altered

Size, shape, color: 20 x 15 x 14, angular, grey

Texture, matrix, vesicles: aphyric, fine crystallized matrix, 15% vesicles

Phenocrysts: -

Comments: thin Mn-crust; orange-red Fe-alteration; white veins; light-grey rim



Lithology: basalt slightly altered

Size, shape, color: 18 x 16 x 10, subangular, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, vesicles 10%

Phenocrysts: Plg (cm, 5%)

Comments: thin Mn-crust; orange-red Fe-alteration around Plg crystals

	Lithology: basalt slightly altered Size, shape, color: 20 x 12 x 8, subangular, grey Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, vesicles 20% Phenocrysts: Plg 1-2%; Cpx 1% Comments: thin Mn-crust; orange oxidation on the edges; light to dark grey rim (0,5 cm)
	Lithology: basalt slightly altered Size, shape, color: 8 x 8 x 4, subangular, grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, 15% vesicles Phenocrysts: Plg 10% Comments: thin Mn-crust; slight Fe-alteration; dark grey rim (1 cm)
	Lithology: altered basalt with sediment crust Size, shape, color: 10 x 7 x 3, grey and white Texture, matrix, vesicles: round basalt clast, porphyric, fine crystallized matrix, vesicles 5%,white sedimented crust with small rock fragments Phenocrysts: Plg 40% Comments: thin Mn-crust; sedimented crust with oxidized fragments

	Lithology: slightly altered basalt Size, shape, color: 9 x 7 x 5, subangular, grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, 10% vesicles Phenocrysts: Plg 5% Comment: fractured; thin Mn-crust; light grey rim (1,5 cm); minor Fe-oxidation
	Size, shape, color: 8 x 7 x 3, subangular, grey Lithology: altered basalt Texture, matrix, vesicles: porphyric, fine crystallized matrix, 10% vesicles Phenocrysts: Plg 20% Comments: thin Mn-crust; light grey rim 1 cm; minor Fe-oxidation
	Size, shape, color: 14 x 12 x 12, subangular, grey Lithology: basalt Texture, matrix, vesicles: porphyric, fine crystallized matrix, 10% vesicles Phenocrysts: Plg 30%; Cpx 10% Comments: thin Mn-crust; light grey rim (0,2 cm); minor Fe-oxidation

Lithology: altered basalt

Size, shape, color: 17 x 14 x 10, subangular, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 20% vesicles

Phenocrysts: Plg 20%; Cpx 20%,

Comments: fracture minor Fe-oxidized; thin Mn-crust; dark grey rim (1 cm)

Lithology: altered basalt

Size, shape, color: 14 x 12 x 9, subangular, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 10% vesicles

Phenocrysts: Plg 10%

Comments: Fe-oxidized fractures; thin Mn-crust; light grey rim (1 cm); thin sediment crust

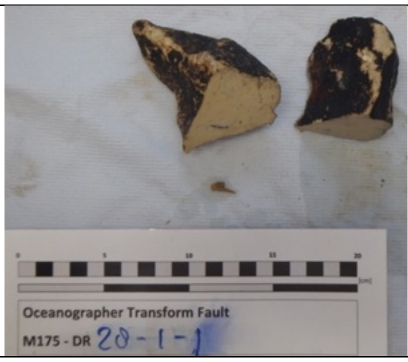
M175-DR28

Locality: Oceanographer Transform Fault, Transform Valley

Date: 17th June 2021

Coordinates on bottom: 35°13,316' N 35°43,072' W Depth: 3030 m

Coordinates off bottom: 35°13,542' N 35°43,067' W Depth: 2777 m



Size, shape, color: 15 x 6 x 5, subangular, white-grey

Lithology: carbonate

Comments: thin Mn-crust; small fractures

	Lithology: gabbro Size, shape, color: 9 x 6 x 3, subangular, white-grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg 45%; Px 50% Comments: thin Mn-crust
	Lithology: carbonate chalk Size, shape, color: 12 x 9 x 8, rounded, white yellowish Comments: thin Mn-crust
	Lithology: gabbro Size, shape, color: 10 x 9 x 5, rounded, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (cm, 40%); Px (cm, 50%); Mv (cm, 10%) Comments: thin Mn-crust
	Lithology: basaltic-gabbroic breccia Size, shape, color: 9 x 5 x 7, subangular-rounded, red Texture, matrix, vesicles: red fine matrix Phenocrysts: Plg and Px in clasts Comments: thin Mn-crust

	Size, shape, color: 20 x 9 x 8, irregular rounded, black Lithology: pyroxenite with plagioclase Texture, matrix, vesicles: equigranular Phenocrysts: Plg with mica formation (mm-plurimm, 10%); Px (mm-plurimm, 90%) Comments: thin Mn-crust; fractures, green alteration of Px; small carbonate formations on border
	Lithology: hydrothermally and veined altered plagioclase pyroxenite Size, shape, color: 11 x 10 x 11, irregular rounded, red Texture, matrix, vesicles: red matrix Phenocrysts: Plg with mica formation (plurimm, 5%); Px (plurimm, 5%); Mg (mm, 1%) Comments: mineralized tectonic fractures
	Size, shape, color: 12 x 8 x 6, angular, grey Lithology: gabbro Texture, matrix, vesicles: equigranular Phenocrysts: Plg (mm-cm, 60%); Px (mm-cm, 40%) Comments: thin Mn-crust; greenish alteration

	Lithology: hydrothermal crystals on gabbro Size, shape, color: 6 x 6 x 6, irregular, grey-greenish Phenocrysts: Plg mm; Px mm; mica mm Comments: crystals growing from small gabbroic layer
	Lithology: carbonate layer and volcanoclastic sandstone layer Size, shape, color: 15 x 13 x 7, subangular-rounded, white-brownish Texture, matrix, vesicles: fine matrix Phenocrysts: - Comments: thin Mn-crust; orange alteration in volcanoclastic layer; biogenic formation on surface
	Lithology: volcanoclastic breccia Size, shape, color: 5 x 7 x 5, rounded, red Texture, matrix, vesicles: sedimentary cemented matrix, no vesicles Phenocrysts: Plg (mm-pluricm, 70%) Comments: oxidized matrix; altered clasts
	Size, shape, color: block, angular/irregular, grey to white, Lithology: gabbro Texture, matrix, vesicles: equigranular Phenocrysts: Plg (cm, 10%); Px (cm, 70%); mica (mm to cm, 10%) Comments: thin Mn-crust; plg-granite-zones

M175-DR29

Locality: Oceanographer Transform Fault, Inside Corner of the Western RTI
Date: 17th June 2021
Coordinates on bottom: 35°09,433' N 36°02,286' W Depth: 1851 m
Coordinates off bottom: 35°19,340' N 36°01,976' W Depth: 1430 m

Lithology: moderate altered aphyric basalt

Size, shape, color: 14 x 13 x 7, subangular, beige rim, inside grey,

Texture, matrix, vesicles: aphyric, fine crystallized matrix, vesicles 2%

Phenocrysts: -

Comments: thin Mn-crust; outer alteration zone; fractures filled with white minerals

M175-DR31

Locality: Oceanographer Transform Fault, Inside Corner of the Western RTI, near core complex
Date: 17th June 2021
Coordinates on bottom: 35°09,160' N 35°50,460' W Depth: 2837 m
Coordinates off bottom: 35°08,894' N 35°50,686' W Depth: 2398 m

Lithology: aphyric basalt

Size, shape, color: block, angular, grey-black

Texture, matrix, vesicles: aphyric, fine crystallized matrix, 1% vesicles

Phenocrysts: -

Comments: fractures

	Lithology: aphyric basalt Size, shape, color: 13x7x8 angular, grey-black Texture, matrix, vesicles: aphyric, fine crystallized matrix, 2% vesicles Phenocrysts: - Comments: thin glass layer; alteration fractures
	Lithology: slightly altered basalt Size, shape, color: 10 x 10 x 5, angular, grey-black Texture, matrix, vesicles: aphyric, fine crystallized matrix, 2% vesicles Phenocrysts: less than 1% phenocrysts Ol, Px, Plg Comments: thin glass layer; fractures
	Lithology: slightly altered basalt Size, shape, color: 13 x 11 x 7, angular, grey-black Texture, matrix, vesicles: aphyric, fine crystallized matrix, 2% vesicles Phenocrysts: less than 1% phenocrysts Ol, Px, Plg Comments: thin glass layer; fractures

<table>
<tr><td>
</td><td><u>Lithology:</u> slightly altered basalt

<u>Size, shape, color:</u> 15 x 9 x 10, angular, grey-black

<u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, 1% vesicles

<u>Phenocrysts:</u> less than 1% phenocrysts Ol, Px, Plg

<u>Comments:</u> thin glass layer, fractures</td></tr>
<tr><td>
</td><td><u>Lithology:</u> slightly altered basalt

<u>Size, shape, color:</u> 18 x 10 x 9, angular, grey-black

<u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, 1% vesicles on border

<u>Phenocrysts:</u> -

<u>Comments:</u> thin glass layer; fractures</td></tr>
<tr><td>
</td><td><u>Lithology:</u> altered basalt

<u>Size, shape, color:</u> 8 x 5 x 5, angular, grey-black

<u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, 2% vesicles

<u>Phenocrysts:</u> Px (mm, 1%); Plg (mm, 1%)

<u>Comments:</u> thin glass layer</td></tr>
</table>

<table>
<tr>
<td>
</td>
<td><u>Lithology:</u> aphyric basalt

<u>Size, shape, color:</u> 13 x 10 x 6, angular, grey-black

<u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, 1% vesicles

<u>Phenocrysts:</u> -

<u>Comments:</u> thin glass layer; carbonate in vesicles</td>
</tr>
<tr>
<td>
</td>
<td><u>Lithology:</u> aphyric basalt

<u>Size, shape, color:</u> 6 x 6 x 5, rounded, grey-black

<u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, 1% vesicles

<u>Phenocrysts:</u> -

<u>Comments:</u> glass in alteration crust</td>
</tr>
<tr>
<td>
</td>
<td><u>Lithology:</u> volcanoclastic breccia

<u>Size, shape, color:</u> 10 x 6 x 5, angular, orange

<u>Texture, matrix, vesicles:</u> breccia texture, carbonatic matrix, vesicles 1%

<u>Phenocrysts:</u> -

<u>Comments:</u> glass clasts; orange-red alteration</td>
</tr>
</table>

	Lithology: altered basalt Size, shape, color: block, angular, dark-grey Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, 3% vesicles Phenocrysts: altered Px (mm, 1%) Comments: vesicles filled with carbonate
	Lithology: aphyric basalt Size, shape, color: 13 x 11 x 10, angular, grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, 10% vesicles Phenocrysts: - Comments: carbonate in vesicles and on surface
	Lithology: altered basalt Size, shape, color: 15 x 7 x 8, angular, grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, 1% vesicles Phenocrysts: - Comments: glass pocket with red-orange alteration; carbonates on surface

Lithology: pillow basalt

Size, shape, color: 20 x 14 x 10, rounded to subangular, grey-black

Texture, matrix, vesicles: aphyric, fine crystallized matrix, 5% vesicles

Phenocrysts: -

Comments: thin glass layer; fractures and alteration

M175-DR32

Locality: Oceanographer Transform Fault, Transform Valley

Date: 17th June 2021

Coordinates on bottom: 35°07,943' N 35°47,109' W Depth: 2493 m

Coordinates off bottom: 35°07,788' N 35°47,437' W Depth: 2139 m

Lithology: altered pillow basalt

Size, shape, color: 20 x 15 x 10, rounded to subangular, grey-black

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 7% vesicles

Phenocrysts: Px (mm-plurimm, 5%); Plg (mm, 10%)

Comments: glass rim

Lithology: altered basalt

Size, shape, color: 20 x 15 x 13, angular, dark grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 5% vesicles

Phenocrysts: Px (mm to plurimm, 5%); Plg (mm, 10%)

Comments: glass crust; carbonate crust

M175-DR33

Locality: Oceanographer Transform Fault, Transform Valley

Date: 17th June 2021

Coordinates on bottom: 35°07,072' N   35°40,880' W   Depth: 3011 m

Coordinates off bottom: 35°06,746' N   35°10,878' W   Depth: 2550 m

Lithology: altered gabbro

Size, shape, color: 12x10x7, angular, grey to white and red

Texture, matrix, vesicles: equigranular

Phenocrysts: Plg (mm-cm, 40%); Cpx (mm-cm, 40%); Bt (mm-cm, 20%)

Comments: Fe-oxidation; Plg veins fractures

Lithology: gabbro

Size, shape, color: 10 x 4 x 7, subangular, grey/white

Texture, matrix, vesicles: equigranular

Phenocrysts: Plg (mm-cm, 50%); Cpx (mm-cm, 40%); Bt (mm-plurimm, 10%)

Comments: Fe-oxidation

Lithology: gabbro

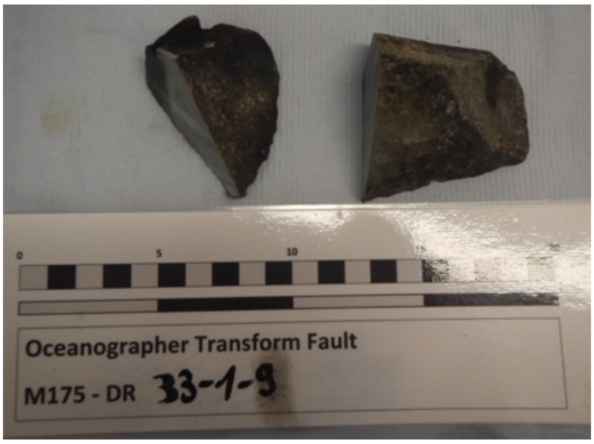
Size, shape, color: 14 x 12 x 6, subangular, grey reddish

Texture, matrix, vesicles: equigranular

Phenocrysts: Plg (mm-plurimm, 60%); Cpx (mm-plurimm, 40%)

Comments: thin Mn-crust; minor Fe-oxidation; fractures

	<u>Lithology:</u> slightly altered basalt <u>Size, shape, color:</u> 16 x 16 x 9, subangular, grey <u>Texture, matrix, vesicles:</u> aphyric, fine crystallized matrix, no vesicles <u>Phenocrysts:</u> - <u>Comments:</u> thin Mn-crust fractures; white veins
	<u>Lithology:</u> altered gabbro <u>Size, shape, color:</u> 13 x 10 x 5, subangular, grey <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> Plg (plurimm-cm, 45%); Cpx (mm-plurimm, 45%); Bt (mm-plurimm, 10%) <u>Comments:</u> thin Mn-crust; fractures
	<u>Lithology:</u> altered gabbro <u>Size, shape, color:</u> 24 x 15 x 8, subangular, grey and white parts <u>Texture, matrix, vesicles:</u> equigranular <u>Phenocrysts:</u> black parts: Plg (mm-cm, 45%); Cpx (mm-cm, 45%); Bt (mm-plurimm, 10%); white parts: Plg (mm-plurimm, 80%); Px (mm-plurimm, 20%) <u>Comments:</u> thin Mn-crust; Fe-oxidation in fractures

	Lithology: basalt pebble and sediment Size, shape, color: 9 x 7 x 5, subangular, grey, beige/orange sediment Texture, matrix, vesicles: porphyric, fine crystallized matrix, 20% vesicles Phenocrysts: Plg 10%; Cpx 5% Comments: thin Mn-crust; rock fragments in sediment crust; grey-greenish rim
	Lithology: gabbro Size, shape, color: 17 x 8 x 4, subangular, grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (mm-cm, 50%); Cpx (mm-cm, 45%); Bt (mm-cm, 5%) Comments: thin Mn-crust
	Lithology: basalt Size, shape, color: 11 x 5 x 3, angular, grey Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, no vesicles Phenocrysts: very small Plg and Cpx Comments: thin Mn-crust; small white veins

Lithology: altered gabbro

Size, shape, color: 15 x 7 x 6, angular, grey, white layer,

Texture, matrix, vesicles: equigranular

Phenocrysts: Plg (mm-cm, 50%); Cpx (mm-cm, 45%); mica (mm, 5%)

Comments: thin Mn-crust; heavily fractured; minor Fe-oxidation

Lithology: basalt

Size, shape, color: 14 x 11 x 7, subangular, grey

Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, no vesicles

Phenocrysts: very small Plg and Cpx

Comments: thin Mn-crust; white veins

M175-DR34

Locality: Oceanographer Transform Fault, Transform Valley
Date: 18th June 2021
Coordinates on bottom: 35°05,235' N 35°40,238' W Depth: 2070 m
Coordinates off bottom: 35°04,960' N 35°40,169' W Depth: 1852 m

Lithology: altered basalt

Size, shape, color: 14 x 12 x 6, subrounded, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 5% vesicles on border

Phenocrysts: Plg 20%; Px 5%

Comments: Mn-crust; light grey rim (1 cm); Px oxidation

Lithology: altered basalt

Size, shape, color: 9 x 7 x 5, rounded to subangular, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 5% vesicles

Phenocrysts: Plg (mm, 3%); Px (mm, 5%)

Comments: Mn-crust (1 cm); concentric alteration

Lithology: altered pillow basalt

Size, shape, color: 24 x 12 x 10, subangular, grey-greenish

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 2% vesicles

Phenocrysts: Plg 20%; Px 5%

Comments: thin Mn-crust; oxidized crust; light grey rim (1 cm); fractured; glass

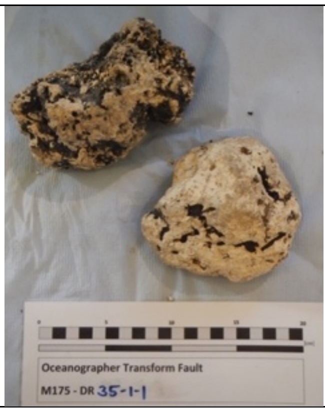
M175-DR35

Locality: Oceanographer Transform Fault, Transform Valley

Date: 18th June 2021

Coordinates on bottom: 35°03,272' N 35°26,313' W Depth: 2855 m

Coordinates off bottom: 35°03,528' N 35°26,427' W Depth: 2677 m



Lithology: carbonate rock

Size: 11 x 15 x 6

Comments: thin Mn-crust; holes and tunnels

M175-DR36

Locality: Oceanographer Transform Fault, Eastern RTI, Older Plate

Date: 18th June 2021

Coordinates on bottom: 35°00,982' N 35°11,634' W Depth: 2767 m

Coordinates off bottom: 35°00,782' N 35°11,641' W Depth: 2469 m

<table>
<tr>
<td>
</td>
<td><u>Lithology:</u> basalt

<u>Size, shape, color:</u> 16 x 12 x 6, subangular, grey

<u>Texture, matrix, vesicles:</u> 2 zones(aphyric, crystalline), fine crystallized matrix, no vesicles

<u>Phenocrysts:</u> Px (mm-plurimm, 5%)

<u>Comments:</u> thin Mn-crust; carbonate biogenic formation on surface</td>
</tr>
<tr>
<td>
</td>
<td><u>Lithology:</u> slightly altered gabbro

<u>Size, shape, color:</u> 18 x 15 x 6, angular, grey-greenish

<u>Texture, matrix, vesicles:</u> equigranular

<u>Phenocrysts:</u> Plg (white, mm, 40%); Px (black, mm, 50%); Bt (mm,10%)

<u>Comments:</u> Plg veins; Fe-oxidation</td>
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<td><u>Lithology:</u> basalt with gabbro intrusions

<u>Size, shape, color:</u> 20 x 11 x 8, subangular-rounded, dark grey-black

<u>Texture, matrix, vesicles:</u> porphyric with crystalline intrusions

<u>Phenocrysts:</u> porphyric part: Plg (mm-plurimm, 5%); Px (plurimm, 3%); crystalline part: Plg (mm-plurimm, 50%); Px (mm-plurimm, 50%)

<u>Comments:</u> thin Mn-crust (2 mm); white veins; carbonate biogenic formation on surface</td>
</tr>
</table>

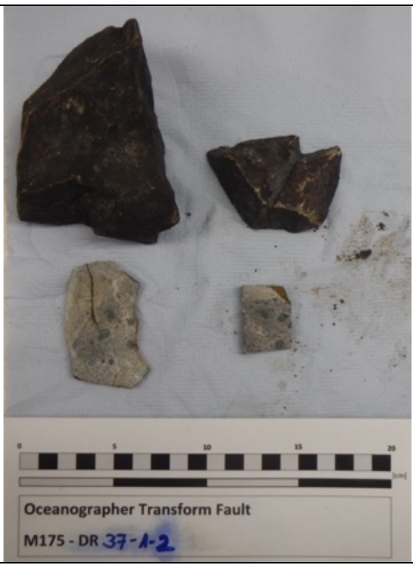
	Lithology: altered microgabbro Size, shape, color: 13 x 8 x 6, angular, grey-greenish Texture, matrix, vesicles: Phenocrysts: Plg (mm, 50%); Px (black, mm, 50%) Comments: thin Mn-crust; orange Fe-alteration; very altered texture
	Lithology: gabbro Size, shape, color: 20 x 10 x 7, subangular to rounded, grey-blue-green Texture, matrix, vesicles: equigranular Phenocrysts: Plg (mm-plurimm, 65%); Px (mm-plurimm, 35%) Comments: thin Mn-crust
	Lithology: altered gabbro Size, shape, color: 16 x 8 x 9, subangular-rounded, grey-blue Texture, matrix, vesicles: equigranular Phenocrysts: Plg (mm-plurimm, 30%); Px (mm-plurimm, 70%) Comments: thin Mn-crust; carbonate biogenic formation on surface

	Lithology: gabbro Size, shape, color: 30 x 20 x 7, subangular-rounded, two zones: dark-grey zone, grey-white zone Texture, matrix, vesicles: porphyric and equigranular Phenocrysts: porphyric: Plg (mm-plurimm, 70%); Px (mm-cm, 30%); crystalline: Plg (mm, 5%); Px (mm-plurimm, 95%) Comments: Mn-crust (2 mm); carbonate biogenic formation on surface

M175-DR37

Locality: Oceanographer Transform Fault, Eastern RTI, Older Plate
Date: 18th June 2021
Coordinates on bottom: 34°57,966' N 35°00,372' W Depth: 3093 m
Coordinates off bottom: 34°58,052' N 35°00,755' W Depth: 2710 m

	Lithology: basalt with basaltic xenoliths Size, shape, color: 10 x 5 x 7, angular, grey Texture, matrix, vesicles: aphyric, fine crystalline matrix, no vesicles Phenocrysts: - Comments: thin Mn-crust; fractures; Fe-alteration; tectonically affected; mixing contact of partial melts

<table>
<tr><td>
</td><td><u>Lithology:</u> microgabbro with basalt dike and xenolithes feldspar-gabbro

<u>Size, shape, color:</u> 10 x 8 x 7, angular, grey

<u>Texture, matrix, vesicles:</u> microcrystalline texture, basalt dike

<u>Phenocrysts:</u> aphyric basaltic clasts

<u>Comments:</u> thin Mn-crust; carbonate biogenic formation on surface; Fe-alteration</td></tr>
<tr><td>
</td><td><u>Lithology:</u> basalt

<u>Size, shape, color:</u> 10 x 9 x 9, angular, grey-greenish

<u>Texture, matrix, vesicles:</u> almost phyric, fine crystalline matrix, no vesicles

<u>Phenocrysts:</u> Plg (mm, 1%); Px (mm, 5%)

<u>Comments:</u> thin Mn-crust; fractures, Fe-alteration</td></tr>
<tr><td>
</td><td><u>Lithology:</u> microgabbro

<u>Size, shape, color:</u> block, angular, grey-green

<u>Texture, matrix, vesicles:</u> ophitic

<u>Phenocrysts:</u> Plg (mm, 40%); Px (mm, 60%)

<u>Comments:</u> -</td></tr>
</table>

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<tr>
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<td><u>Lithology:</u> very altered basalt

<u>Size, shape, color:</u> block, irregular, dark-grey

<u>Texture, matrix, vesicles:</u> porphyric, fine crystallized, 5% vesicles

<u>Phenocrysts:</u> Plg (mm-plurimm); Px (cm)

<u>Comments:</u> high alteration, Fe-oxidation</td>
</tr>
<tr>
<td>
</td>
<td><u>Lithology:</u> very altered basalt

<u>Size, shape, color:</u> 9 x 5 x 7, subangular, dark-grey

<u>Texture, matrix, vesicles:</u> porphyric, fine crystallized matrix, no vesicles

<u>Phenocrysts:</u> Plg (mm-plurimm); Px (mm-plurimm)

<u>Comments:</u> thin Mn-crust; high alteration, Fe-oxidation</td>
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<td><u>Lithology:</u> basalt + plagiogranite

<u>Size, shape, color:</u> 9 x 8 x 4, subangular, two zones: dark-grey (aphyric), white-brown (equigranular)

<u>Texture, matrix, vesicles:</u> porphyric, fine crystallized, no vesicles, equigranular

<u>Phenocrysts:</u> Plg (mm, 80%); Px (mm, 20%)

<u>Comments:</u> fractures; fault (dextral movement)</td>
</tr>
</table>

	Lithology: basalt with small gabbro Size, shape, color: 13 x 10 x 5, subangular, dark-grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, no vesicles, equigranular Phenocrysts: gabbro: Plg 60%; Px 40% Comments: thin Mn-crust
	Lithology: basalt + gabbro + metagabbro/migmatite Size, shape, color: 20 x 12 x 6, subangular, dark-grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, 5% vesicles, equigranular Phenocrysts: gabbro: Plg (mm, 45%); Px 55% Comments: Mn-crust (1-2 mm); gabbro xenolith
	Lithology: gabbro Size, shape, color: 15 x 8 x 10, angular, dark-grey Texture, matrix, vesicles: equigranular Phenocrysts: Plg (mm, 30%); Px (mm, 70%) Comments: flow structures; thin Mn-crust; Fe alteration; magnetite in fractures

Lithology: basalt

Size, shape, color: block, angular, grey

Texture, matrix, vesicles: aphyric, fine crystallized matrix, no vesicles,

Phenocrysts: -

Comments: thin Mn-crust, Fe-alteration, fractures

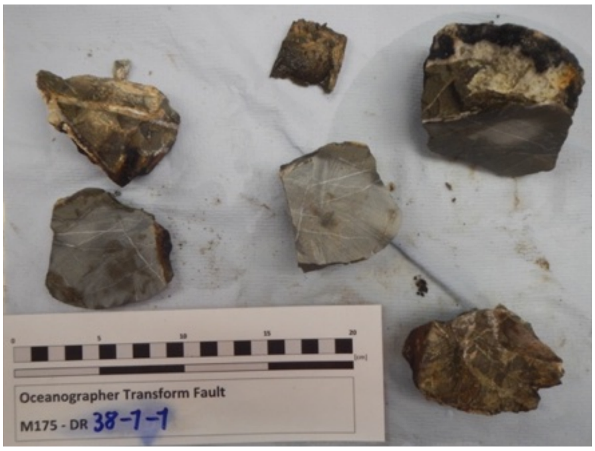
M175-DR38

Locality: Oceanographer Transform Fault, Inside Corner of the Eastern RTI

Date: 18th June 2021

Coordinates on bottom: 35°12,800' N 35°04,714' W Depth: 1996 m

Coordinates off bottom: 35°13,137' N 35°04,684' W Depth: 1743 m



Lithology: very altered basalt

Size, shape, color: 17 x 7 x 11, angular, grey

Texture, matrix, vesicles: aphyric, fine crystallized matrix, no vesicles

Phenocrysts: -

Comments: thin Mn-crust; calcitic filled fractures; Fe-alterations

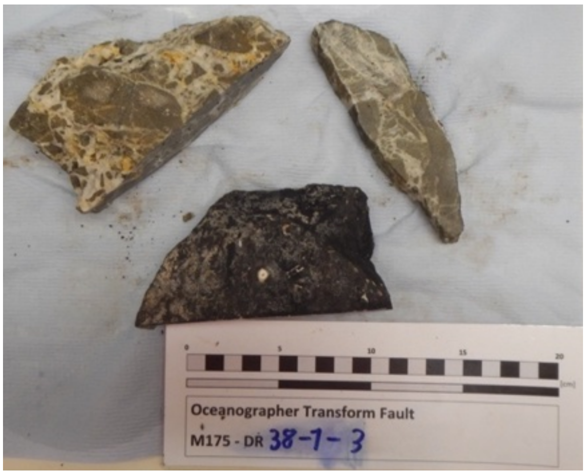
Lithology: volcanoclastic breccia

Size, shape, color: 13 x 7 x 8, angular, grey-green

Texture, matrix, vesicles: basaltic clast: aphyric fine crystallized matrix, no vesicles

Phenocrysts: -

Comments: thin Mn-crust; calcitic filled fractures; Fe-alterations in fractures



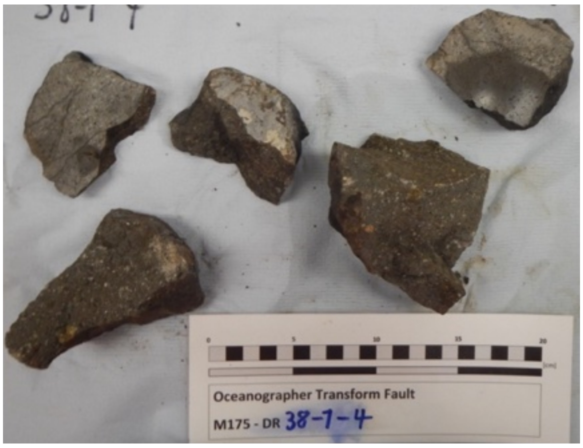
Lithology: volcanoclastic breccia

Size, shape, color: 17 x 14 x 13, rounded, grey and white

Texture, matrix, vesicles: calcitic cement (aragonite), basaltic clasts: aphyric, fine crystallized matrix, no vesicles

Phenocrysts: -

Comments: thin Mn-crust; calcic biogenic formation



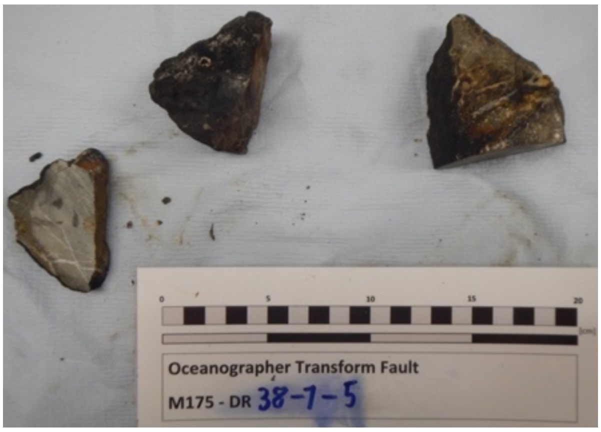
Lithology: altered basalt (ankaramite)

Size, shape, color: 20 x 8 x 6, angular, grey

Texture, matrix, vesicles: porphyric, fine crystallized matrix, 5% vesicles

Phenocrysts: Px (mm, 20%)

Comments: thin Mn-crust; fractures; filled vesicles



Lithology: basalt

Size, shape, color: 13 x 6 x 5, rounded, grey

Texture, matrix, vesicles: aphyric, fine crystallized matrix, no vesicles

Phenocrysts: -

Comments: Mn-crust (1-2 mm); calcitic fractures (aragonite)

M175-DR41

Locality: Oceanographer Transform Fault, Inside Corner of the Eastern RTI

Date: 19th June 2021

Coordinates on bottom: 35°14,737' N 35°05,661' W Depth: 1375 m

Coordinates off bottom: 35°15,024' N 35°05,781' W Depth: 1059 m

	Lithology: pillow lava basalt Size, shape, color: block, angular, dark-grey to black Texture, matrix, vesicles: porphyric, fine crystallized matrix, 15% vesicles Phenocrysts: Px (mm, 10%); Plg (mm, 5%) Comments: Fe-alteration in vesicles; glass
	Lithology: basalt Size, shape, color: 13 x 10 x 10, subangular to rounded, dark-grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, 10% vesicles Phenocrysts: Px Comments: very thin Mn-crust; Fe-alteration in vesicles
	Lithology: altered basalt Size, shape, color: 6 x 5 x 4, rounded, grey Texture, matrix, vesicles: aphyric, fine crystallized matrix, 10% vesicles Phenocrysts: - Comments: calcitic filled fractures and vesicles; concentric alteration

	Lithology: slightly altered basalt Size, shape, color: 20 x 18 x 15, subangular, dark-grey to black Texture, matrix, vesicles: aphyric, fine crystallized matrix, 5% vesicles Phenocrysts: - Comments: Fe-alteration in vesicles; biogenic carbonate on surface
	Lithology: altered basalt Size, shape, color: 25 x 14 x 10, subangular to rounded, grey Texture, matrix, vesicles: almost aphyric, fine crystallized matrix, 1% vesicles Phenocrysts: Plg 1% Comments: Fe-alteration; concentric alteration
	Lithology: altered basalt Size, shape, color: 10 x 10 x 10, angular, grey Texture, matrix, vesicles: porphyric, fine crystallized matrix, 15% vesicles Phenocrysts: Px (mm-plurimm; 5%) Comments: thin Mn-crust; calcitic filled fractures and vesicles; Fe-alteration; concentric alteration; glass

M170-DR009

Locality: Oceanographer Transform Fault, Eastern Fracture Zone, Older Plate
Date: 23th January 2021
Coordinates on bottom: 34°53,720' N   34°36,050' W   Depth: 2981 m
Coordinates off bottom: 34°53,741' N   34°28,772' W   Depth: 2883 m

Lithology: serpentinite

Description: black alteration; greenish inside; harnish (slickenslide) → frictional movement

Lithology: serpentinite

Description: black alteration; greenish inside; harnish (slickenslide) → frictional movement

Lithology: serpentinite - lherzolite

Description: black alteration; greenish inside;
phenocrysts → Opx, Cpx
harnish (slickenslide) → frictional movement

Lithology: basalt breccia

Description: light colored matrix; dark grains;
phenocrysts → Opx, Cpx;
Mn-crust

Lithology: basalt breccia

Description: light colored matrix; dark grains;
phenocrysts → Cpx;
Mn-crust

Lithology: basalt breccia

Description: light colored matrix; dark grains;
phenocrysts → Cpx;
Mn-crust

Lithology: carbonate

Description: outside black; inside white;
Mn-crust (1,5 cm)

M170-DR010

Locality: Oceanographer Transform Fault, Eastern RTI Outside Corner, Eastern Fracture Zone, abyssal hill
Date: 24th January 2021
Coordinates on bottom: 35°21,921' N 36°27,841' W Depth: 2906 m
Coordinates off bottom: 35°22,194' N 36°27,840' W Depth: 3014 m

Lithology: vesicular basalt

Description: aphyric, graded vesicles

M170-DR011

Locality: Oceanographer Transform Fault, Eastern RTI Outside Corner (Eastern Fracture Zone), J-shaped Abyssal Hill
Date: 24th January 2021
Coordinates on bottom: 34°57,234' N 34°33,037' W Depth: 3213 m
Coordinates off bottom: 34°57,311' N 34°33,554' W Depth: 3035 m

Lithology: basalt

Description: dark grey; vesicles (2 mm); Mn-crust

Lithology: basalt

Description: dark grey to black; green alteration; vesicles; phenocrysts: Ol; Mn-crust (5 mm)

Lithology: basalt

Description: dark grey to black; green alteration; few vesicles; phenocrysts: Ol (1 mm); Mn-crust (2 mm)

Lithology: basalt

Description: dark grey to black; green alteration; few vesicles; phenocrysts: Ol (1 mm); Mn-crust (2 mm)

	Lithology: basalt Description: dark grey to black; green alteration; few vesicles; phenocrysts: Ol (1 mm); Mn-crust (2 mm)
	Lithology: basalt Description: dark grey to black; green alteration; few vesicles; phenocrysts: Ol (1 mm); Mn-crust (2 mm)

M170-DR012

Locality: Oceanographer Transform Fault, Eastern RTI Outside Corner (Eastern Fracture Zone), J-shaped Abyssal Hill
Date: 24th January 2021
Coordinates on bottom: 34°57,741' N   34°35,147' W   Depth: 3243 m
Coordinates off bottom: 34°35,470' N   34°35,470' W   Depth: 3061 m

	Lithology: basalt breccia Description: dark clasts; brown matrix; vesicles; one porphyric clast: Ol (plurimm), Px (plurimm); Mn-crust (8 mm)
	Lithology: chalk Description: very fine grain size

M170-DR014

<u>Locality:</u> Oceanographer Transform Fault, Eastern RTI Outside Corner, Seamount?
<u>Date:</u> 24th January 2021
<u>Coordinates on bottom:</u> 35°04,037' N 34°44,039' W <u>Depth:</u> 2300 m
<u>Coordinates off bottom:</u> 35°04,037' N 34°44,467' W <u>Depth:</u> 2164 m

	<u>Lithology:</u> basalt <u>Description:</u> vesicles (1 mm); phenocrysts: Ol (1 mm), Plg (5 mm); Mn-crust (2 mm)
	<u>Lithology:</u> basalt <u>Description:</u> phenocrysts: Ol, Plg; Mn-crust
	<u>Lithology:</u> basalt <u>Description:</u> phenocrysts: Ol, Plg; Mn-crust
	<u>Descripti Lithology:</u> basalt <u>Description:</u> phenocrysts: Ol, Plg; Mn-crust

	Lithology: basalt Description: phenocrysts: Ol, Plg; Mn-crust
	Lithology: basalt Description: phenocrysts: Ol, Plg; Mn-crust
	Lithology: basalt Description: phenocrysts: Ol, Plg; Mn-crust
	Lithology: chalk Description: very fine grain size

M170-DR015

Locality: Oceanographer Transform Fault, Eastern Fracture Zone, Older plate
Date: 24th January 2021
Coordinates on bottom: 34°54,206' N 34°36,428' W Depth: 2673 m
Coordinates off bottom: 34°53,986' N 34°36,743' W Depth: 2400 m

	Lithology: chalk Description: white; black alteration; very fine grainsize; Mn-crust (6 mm)

<table>
<tr><td>
</td><td><u>Lithology:</u> black serpentinite</td></tr>
<tr><td>
</td><td><u>Lithology:</u> black serpentinite</td></tr>
<tr><td>
</td><td><u>Lithology:</u> talc

<u>Description:</u> orange-greenish; very fine grained; Mn-crust</td></tr>
<tr><td>
</td><td><u>Lithology:</u> serpentinite

<u>Description:</u> black-greenish;
harnish (slickenslide) → frictional movement</td></tr>
<tr><td>
</td><td><u>Lithology:</u> black serpentinite

<u>Description:</u> Mn-crust</td></tr>
<tr><td>
</td><td><u>Lithology:</u> talc

<u>Description:</u> very fine grained; Mn-crust</td></tr>
</table>

M170-DR016

Locality: Oceanographer Transform Fault, Eastern Fracture Zone, Abyssal Hill on Older Plate

Date: 24th January 2021

Coordinates on bottom: 34°53,819' N 34°39,863' W Depth: 1970 m

Coordinates off bottom: 34°53,844' N 34°39,951' W Depth: 2123 m

Lithology: basalt

Description: pillow fragments; altered glass; Mn-crust

Lithology: basalt

Description: pillow fragments; palagonite; very altered; Mn-crust

Lithology: basalt

Description: pillow fragments; altered palagonite; Mn-crust (12 mm)

Lithology: basalt

Description: very altered pillow fragments; Mn-crust (6 mm)

Lithology: serpentinite

Description: Mn-crust (2 mm)

M170-DR019

Locality: Hayes Transform Fault, Western RTI, “Rooster Comb”
Date: 29th January 2021
Coordinates on bottom: 33°45,027' N 39°00,651' W Depth: 3636 m
Coordinates off bottom: 33°45,024' N 39°01,169' W Depth: 3384m

Lithology: basalt

Description: black alteration; glass rim (3 mm)

Lithology: basalt

Description: pillow segment; Mn-crust; glass rim (5 mm)

Lithology: basalt

Description: big vesicles; zeolites; glass rim (6 mm)

Lithology: basalt

Description: pillow segment; small vesicles in the core; Mn-crust

Lithology: basalt

Description: pillow segment; Mn-crust; glass rim (2 mm)

M170-DR020

<u>Locality:</u> Hayes Transform Fault, Western RTI, Abyssal Hill on Older Plate
<u>Date:</u> 29th January 2021
<u>Coordinates on bottom:</u> 33°46,372' N 39°02,469' W <u>Depth:</u> 3226 m
<u>Coordinates off bottom:</u> 33°46,372' N 36°02,786' W <u>Depth:</u> 3004 m

	<u>Lithology:</u> basalt <u>Description:</u> black alteration; brown-grey inside
	<u>Lithology:</u> basalt <u>Description:</u> dark grey; phenocrysts: Ol (~4 mm), Plg (1 mm)and Px; Mn-crust