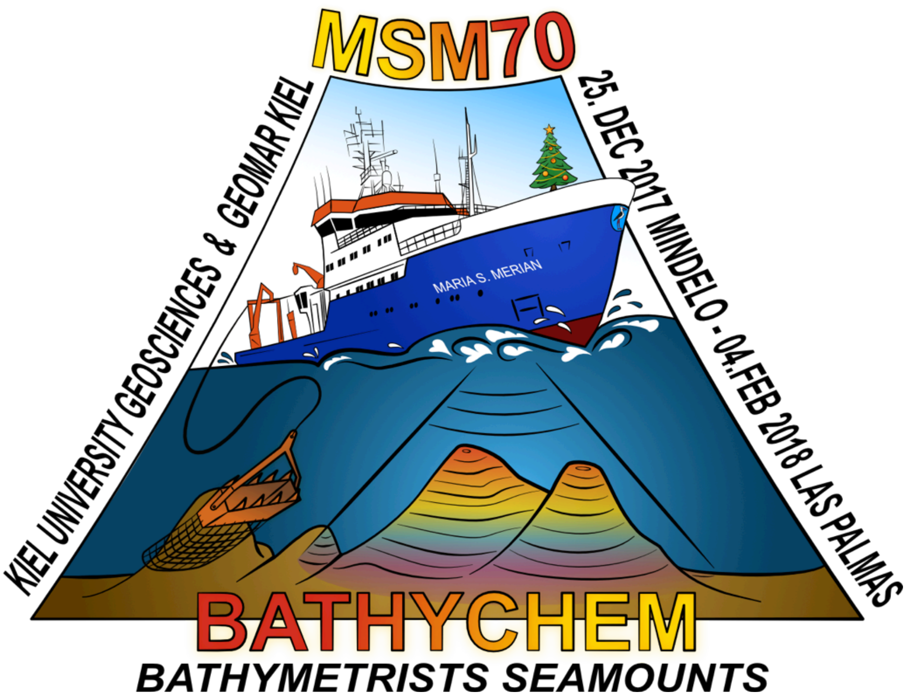
MERIAN S. MERIAN-Berichte

# BATHYCHEM
# The Effect of Intraplate Volcanism on the Geochemical Evolution of Oceanic Lithosphere:

## Detailed Mapping and Sampling of the Bathymetrists Seamounts and Adjacent Fracture Zones

Cruise No. MSM70

December 26, 2017 – February 01, 2018
Mindelo (Cape Verde) – Las Palmas de Gran Canaria, Canaries (Spain)

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**& C.- Dieter Garbe-Schönberg**

2018

**Table of Contents**

# 1 Summary

(F.M. van der Zwan)

Intraplate volcanism, in contrast to mid-ocean-ridge (MOR) oceanic crustal basalts, is formed by low degrees of deep mantle melting and has a unique and distinct major and trace element and isotopic composition. Intraplate magmatism can therefore significantly alter the composition of the lithosphere, but may also trigger local structural changes and fluid flow causing large-scale hydrothermal activity, which would also modify the original composition of the lithosphere. The BATHYCHEM (MSM70, Dec 2017-Febr 2018) cruise aimed to study the effect of the magmatism of the, so far poorly researched, *Bathymetrists and Grimaldi Seamounts* intraplate volcanic province on the Atlantic oceanic plate. The *Bathymetrists Seamounts* were formed on oceanic crust that has a wide range of ages from 30 to >100 Ma and thus has been exposed to variable degrees of seafloor alteration. This project aims at characterizing the structure, age and composition of the *Bathymetrists Seamounts* and adjacent areas to understand their origin and formation mechanism, which will allow a better assessment of how intraplate volcanism modifies the structure and composition of oceanic lithosphere through time. To achieve these aims the MSM70 expedition undertook high-resolution mapping and dense rock sampling of the intraplate *Bathymetrists Seamount Chain* and its corresponding N-bounding fracture zones; *Cape Verde Ridge* and *Kane Gap*. Hydro-acoustic models could be greatly improved to a resolution of 50 m and the position of 40 named and unnamed seamounts could be refined. The bathymetric maps reveal a complicated pattern of emplacement and indicate that most of the seamounts (62%) resemble guyots capped by carbonated platforms. A total of 65 dredge-tows recovered volcanic samples, carbonates, phosphorites, mudstones and manganese crusts and nodules. Volcanic samples from 27 seamounts revealed dense basaltic samples and vesicular volcanoclastic material of mafic origin containing pyroxenes, amphiboles and biotite.

Die Haupt-, Spurenelement und Isotopengeochemie von Intraplattenvulkanismus unterscheidet sich wegen der tiefen und geringeren Aufschmelzgrade stark von Mittelozeanischer Rücken. Dabei beeinflusst Platznahme und Magmatismus von Intraplattenvulkanen die ozeanische Kruste nicht nur lokal sondern führt auch weiträumig zu chemischen und mineralogischen Veränderung der Kruste z.B. durch hydrothermale Zirkulation. Ziel der BATHYCHEM-Expedition (MSM70, Dec 2017-Febr 2018) ist es herauszufinden wie die Entstehung der kaum untersuchten *Bathymetrists* und *Grimaldi Seamounts* die chemische Zusammensetzung der ozeanischen Kruste im Atlantik in unterschiedlichen Stadien der Krustenentwicklung (Krustenalter von 30 bis >100 Ma) beeinflusst hat. In diesem Projekt soll die Struktur, das Alter und die Zusammensetzung der *Bathymetrists Seamount Chain* und angrenzender Gebieten charakterisiert werden um deren Ursprung und Entstehung zu verstehen und die, durch Intraplattenvulkanismus hervorgerufenen, Veränderungen in der Struktur und Zusammensetzung ozeanischer Kruste besser abschätzen zu können. Um diese Ziele zu erreichen wurde während der MSM70 Expedition ein hochauflösendes Kartierprogramm sowie eine detaillierte geologische Beprobung der *Bathymetrists Seamounts* und der nördlich angrenzenden Transformstörungen (*Cape Verde Ridge* und *Kane Gap*) durchgeführt. Die neuen hydroakustischen Modelle verbessern die Auflösung um ein Vielfaches und erreichen eine Pixelgröße von 50 m. Die Position von 40 der *Bathymetrists Seamounts* konnte damit genauer bestimmt werden. Die bathymetrischen Karten zeichnen ein kompliziertes Entstehungsmuster der Vulkane und die meisten der Seamounts (62%) haben eine deutliche Guyot-morphologie, bedeckt mit Karbonatplattformen. Insgesamt 65 Dredgezüge haben vulkanische Gesteine, Karbonate, Phosphorite, Mudstones sowie Mangankrusten und -knollen geborgen. Die Vulkanite von 27 der Seamounts bestehen aus Basalt und vesikulärem, vulkanoklastischen Material mafischer Herkunft, das u.a. Pyroxene, Amphibole und Biotit enthält.

## 2 Participants

Fig. 2.1 Participants of the MSM70 expedition. From left to right: Jakub Miluch, Janto Schönberg, Xiaojung Long, Richard Antonio, Anne-Cathrin Wölfl, Louisa Krach, Morgane Le Saout, Nico Augustin, Froukje van der Zwan, Martin Schade, Jörg Follmann, Mehmet Köse, Verena Heinath.

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| 3. Xiaojun Long | Petrology | GEOMAR |
| 4. Richard J. M. Antonio | (Alteration)Petrology | GeoB |
| 5. Verena Heinath | Petrology | CAU |
| 6. Jörg Follmann | Petrology | CAU |
| 7. Louisa Krach | Petrology | CAU |
| 8. Mehmet C. Köse | Petrology | CAU |
| 9. Dr. Anne-Cathrin Wölfl | Bathymetry | GEOMAR |
| 10. Dr. Morgane Le Saout | Bathymetry | GEOMAR |
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# 3 Research Programme

(F.M. van der Zwan, N. Augustin, C.-D. Garbe-Schönberg)

## 3.1 Scientific Questions and Goals

Main goal of the BATHYCHEM project was to gain more in-depth insights into the origins and ages of the 900 km long, intraplate volcanic province of the Bathymetrists Seamounts Chain, including the Grimaldi Seamounts and their corresponding fault zones to the North, the Cape Verde Ridge and Kane Gap (western Guinea FZ; Fig. 3.1).

Intraplate volcanism, in contrast to mid-ocean-ridge (MOR) oceanic crustal basalts, is formed by low degrees of mantle melting under thick lithosphere and thus has a unique and distinct major element, trace element and isotopic composition. Magmatism associated with the emplacement of this seamount province did not only directly alter the composition of the underlying lithosphere, but the magmatism may have triggered local structural changes and fluid flow causing large-scale hydrothermal activity, which would have modified the original composition of the lithosphere additionally. The formation of the *Bathymetrists Seamounts* may have affected the Atlantic oceanic crust ranging from 30 to >100 Ma in age (Müller et al., 2008), which was thus exposed to variable degrees of seafloor alteration during the evolution of the seafloor. With information on the structure, age and composition of the *Bathymetrists Seamounts* and adjacent areas, we aim to understand their origin and formation mechanism, which will allow a better constrains on how intraplate volcanism modifies the structure, morphology and composition of the oceanic lithosphere through time. Addressing this is important for our understanding of how ocean basins evolve and alter, and for determining the global composition of the oceanic lithosphere (mass budget).

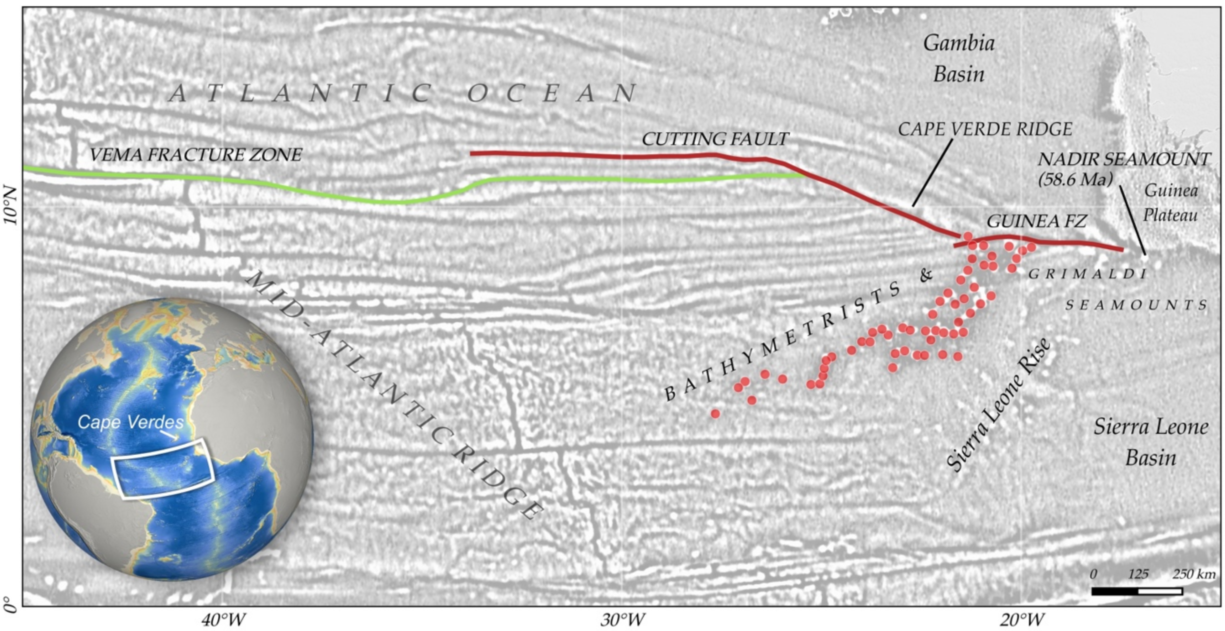


Fig. 3.1 The working area is situated in the eastern central Atlantic, where the Bathymetrists and Grimaldi Seamounts are bordered to the North by the Cape Verde Ridge and Guinea (Kane Gap) Fracture Zones.

The seafloor between the Sierra Leone Basin and the Gambia Basin is dominated by the Sierra Leone Rise and the SW-NE striking Bathymetrists Seamounts (Fig. 3.1). Vertical gravity gradient data (Sandwell et al., 2014) show that the northern parts of the Bathymetrists and Grimaldi Seamounts formed along several E-W striking lineaments, south of the Cape Verde

Ridge and Kane Gap. The junction between Cape Verde Ridge, Bathymetrists Seamounts and Kane Gap has been formed by at least three neotectonic movements between the Oligocene and Holocene together with the formation of the Cape Verde Ridge, second order ridges and some upwelling in the Cape Verde Basin (Skolotnev et al., 2009). Apart from its complicated tectonic setting, little is known about the origin, age and nature of the Bathymetrists Seamounts and their mantle source. Only a few volcanic samples, mostly from the northern seamounts, have been chemically and mineralogically analysed and dated: (a) from Annan and Carter Seamounts, close to the Cape Verde Ridge (Kharin, 1988; Petrova et al., 2010; Skolotnev et al., 2012), and (b) from the Grimaldi Seamounts (Krause Seamount; Peyve and Skolotnev, 2009; Peyve, 2011). Only rare samples from the southern Bathymetrists Seamounts have been analysed (Kharin, 1988; Skolotnev et al., 2017). There are very few geochronological age determinations from this region, ranging from 36-59 Ma, but determined from partially altered rocks and without clear systematics (Kharin, 1988; Jones et al., 1991; Skolotnev et al., 2010). In contrast, transit data from Meteor expedition M116 (Visbeck, 2016) over the Bathymetrists Seamounts revealed indications of potentially younger volcanism (high multibeam backscatter reflectivity and undisturbed volcano morphology) and tectonic influence in the surrounding areas of the seamounts – tectonic influences were also observed in the older parts of the Vema FZ (Sonne SO237; Devey, 2015), indicating that the Bathymetrists Seamounts may potentially still be volcanically and tectonically active.

Two hypotheses have been proposed for the origin and formation of the Bathymetrists and Grimaldi Seamounts: (a) the rising of a deep mantle plume, possibly by bending or a detached offshoot of the Sierra Leone plume (Schilling et al., 1994; Peyve and Skolotnev, 2009), where the spatial positioning of the two seamount chains was determined by local plate tectonics (e.g., Peyve, 2011; Skolotnev et al., 2017), or (b) decompression melting of asthenosphere mafic rocks due to extension along the Cape Verde Ridge and Kane Gap transform faults (Jones et al., 1991; Skolotnev et al., 2012), each having their own effect on the oceanic lithosphere.

To study the Bathymetrists Seamounts we planned an extensive mapping program to generate high-resolution bathymetric maps and a dredge program to sample these seafloor structures. This will be followed by petrological, geochemical and geochronological analyses aiming at deciphering the origin of this sparsely studied volcanic province, and to distinguish between the different formation hypothesis for the Bathymetrists and Grimaldi Seamounts, i.e. if they were formed from a deep plume source or shallower asthenosphere melting. Furthermore, the role of local transform faults intersecting the seamount province will be studied.

Bathymetric maps will help to understand the tectonic interplay at the junction of the Cape Verde Ridge FZ, Kane Gap FZ with the northern part of the Bathymetrists Seamounts and the Grimaldi Seamounts and to answer questions regarding seafloor characteristics and possibly identify areas with younger (Holocene) volcanism. Morphological and tectonic studies on bathymetric data will improve the knowledge of emplacement of intraplate volcanoes and their effects on the surrounding plate, especially in this complicated tectonic environment.

Petrology, mineralogy, major and trace element and isotope (Sr-Nd-Pb-Hf-O) geochemistry together with $^{40}Ar/^{39}Ar$ dating of preserved multi-phase K-rich minerals (to avoid alteration) will be carried out on the recovered rock samples after the expedition. These data will be used to address the following scientific questions and hypotheses:

1) The source and origin of the Grimaldi and Bathymetrists Seamount chain
2) The age of the Seamounts and their formation mechanism. Is there any young volcanism?
3) How is large-scale intraplate volcanism affecting the geochemical budget of oceanic lithosphere of different ages?
4) Is there evidence for systematic, long-term (over the life span of the Atlantic Ocean basin) changes in the spreading rate of the plate or temperature and composition of the upper mantle source, e.g., was more continental or plume material present in the MORB source during the early stages of ocean basin formation just after continental?
5) How do these parameters relate to crustal thickness and younger volcanism?

## 3.2 Scientific Operations

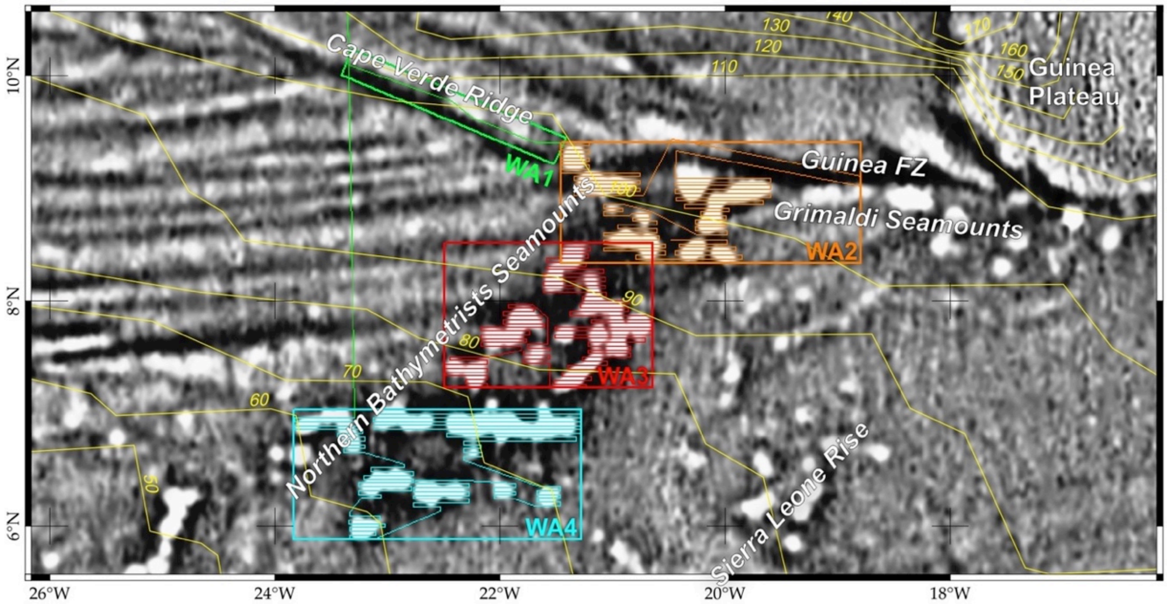


Fig. 3.2 Illustration of the four working areas (WA1-4) on a vertical gravity gradient (VVG) map after Sandwell et al., 2014. Sediment covered fracture zones crossing the northern part of the Bathymetrists Seamounts are well visible in the VVG data.

To achieve the scientific aims described above we planned to combine hydro-acoustic mapping with hard rock sampling by dredges. High-resolution multibeam surveys were used to defining dredge targets and to obtain a bathymetric map for tectonic and structural analysis of the area. The multibeam mapping was carried out with the hull mounted EM122 deep water multibeam echo sounder system provided by Kongsberg Maritime AS and additionally with the shallow-water system EM712 at water depths <<1000 m deep. With this system, we could effectively map the working areas and, due to the so-called dual-ping mode and the good weather and sea conditions during expedition MSM70, we could map with relatively high speeds of 10-11 knots with still very good results. Swath mapping of seafloor morphology and seafloor properties was done in real-time enabling a very good identification of dredge targets within shortest time (<15 min). This enabled us to alternate quickly between mapping and dredging, whenever a good target was indicated and avoided long transit times from and to dredge positions. The hard rock sampling was carried out using heavy chain bag dredges, a highly successful and efficient (low cost and little time-consuming) method for sampling igneous rocks from the seafloor of various depths and age.

Sampling and mapping was planned to be conducted mainly along the Cape Verde Ridge, in the Kane Gap (western Guinea FZ) as well as at the Bathymetrists and Grimaldi Seamounts. We planned to sample these features with up to 65 dredge stations: 15 dredge stations along the Cape Verde Ridge and the corresponding fault (Working Area 1); 20 dredges in Working Area 2, consisting of Kane Gap, the Grimaldi Seamounts and the northernmost Bathymetrists Seamounts. For Working Areas 3 and 4 (central and southern Bathymetrists seamount chain), we planned 15 dredges each (Fig. 3.2).

Due to less available working days compared to the original proposal, we decided to focus mostly on the Bathymetrists Seamounts, i.e. working areas 2-4. Along the Cape Verde Ridge we reduced mapping to one transect profile. This quickly showed that the transform fault is strongly sedimented and that there were little good dredge targets. Therefore, and due to the time constrains, we reduced the dredges in WA1 to 4 dredges, which returned the necessary samples for comparison to samples of the Bathymetrists Seamounts and gave more time at WA2-4.

Contrary to the original working plan we did not systematically finish the working areas one-by-one. Instead, after completing the most western and eastern targets of WA2, we continued southwards along the eastern side of the central and southern Bathymetrists Seamounts (WA3&4), to return along the western side of these areas before finishing WA2. This saved considerable transit time and ensured a good sampling coverage of all working areas early on in the cruise and the opportunity to focus on more difficult target areas. We completed 4 dredges in WA1, 22 dredges in WA2, also 22 dredges in WA3 and 17 dredges in WA4. Two sound velocity profiles were taken, one with XSV at the beginning of WA1 and a deeper profile with SVP central in the Bathymetrists Seamounts area. As both profiles gave similar results, no more profiles were required. One PARASOUND profile was acquired during the crossing of an east-west striking transform fault, visible in vertical gravity gradient data, to see possible structures in the sediment. The overall rough terrain of the working areas inhibited the acquisition of more or longer PARASOUND profiles.

## 3.3 Measures of Responsible Conduct of Marine Research

The scientific work performed during Expedition MSM70 strictly adhered to the "Maßnahmen im Hinblick auf die Erklärung zu einer verantwortungsvollen Meeresforschung" and the *Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas* of the OSPAR Maritime Area.

Sampling and acoustic measurements were restricted solely to methods and areas being essential to conduct the research outlined above, and the number of sampling stations has been reduced to the necessary minimum. Careful selection of sites for hard rock sampling by dredging allowed us to carry out short dredge tracks (<800 m in length), with resulting high success rates (79%), to minimize the number of dredges and the impact of dredging to the marine habitat.

Acoustic measurements were performed in a way to minimize the impact on marine mammals by activating the mammal protection system of the Kongsberg multibeam echo-sounder. There was no duplication of previous studies, since little samples exist from the vast majority of the proposed study areas thus far and the locations of known samples were verified before dredging.

Our close cooperation with international scientists, organizations, and authorities as well as public domain data bases and web sites will ensure that our activities do not disturb experiments of other scientists. That also ensures the fullest possible use of all samples and data as well as comprehensive data-sharing.

# 4 Narrative of the Cruise

(F.M. van der Zwan)

On the 24th of December three of the thirteen scientific participants boarded MARIA S. MERIAN for the MSM70 cruise in the harbour of Mindelo, Cape Verdes. The other participants were planned to join as well, but were stranded in Lisbon due to cancelled flights due to a sandstorm above the Cape Verdes. An extra flight on the 26th of December finally brought the remaining participants, together with a large part of the crew to Sao Vicente and we could leave port with only a small delay compared to the scheduled program at 20:00 the same day, sailing southwards in the direction of the Bathymetrists Seamounts (Fig. 4.1).

The next morning, when we left the EEZ of the Cape Verdes, we started recording hydro-acoustic data during our transit to collect data in the framework of the EU-Project AtlantOS. The petrologists prepared the laboratories and the dredge equipment until we arrived in our first working area in the morning of the 27th of December, where we started our scientific work with an XSV profile to obtain the sound velocity of the water column for the bathymetric measurements (Fig. 4.2). This was followed on this and the next day by hydro-acoustic mapping of the Cape Verde Ridge. The mapping was interrupted for four dredge hauls along the Ridge, that we could plan on the almost instantly available bathymetric models of the mapped area and from which one returned ~100 Ma old basalts.

The work on the Bathymetrists Seamounts themselves started midday of the 29th with the northwestern-most *Annan Seamount*. This seamount was mapped with the multibeam system together with the first (of many) unnamed seamount in the area. These unnamed seamounts we labelled throughout the expedition with working names BSM (Bathymetrists SeaMount) and succeeding Roman Nr. (e.g. BSM I). After the mapping three dredge positions were selected based on the bathymetric model of the seamount. These dredge hauls were performed the next day and brought back volcanoclastic and phosphorite-crust samples. Sampling of *Annan Seamount* was directly followed on the 30th and 31th by the mapping and sampling of the west part of *Carter Seamount*, where manganese crusts were recovered. On the last day of 2017 and the first day of 2018 we had a longer mapping program, finishing the seafloor mapping of

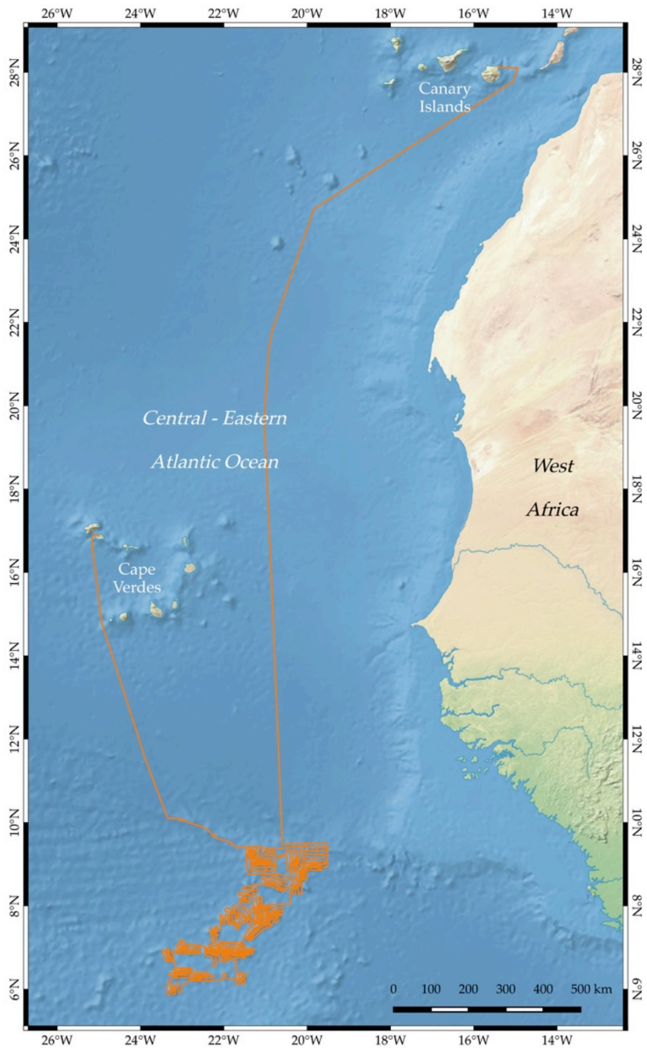


Fig. 4.1 Cruise track of Expedition MSM70, from Mindelo to the working area of the Bathymetrists Seamounts and ending in Las Palmas de Gran Canaria.

*Carter Seamount* and the first of the Grimaldi Seamounts: *Hirondelle Seamount*, located in the northeastern part of our area. After three dredge hauls the next day at *Hirondelle Seamount*, bringing up volcanoclastic material, we mapped and sampled on the 3rd of January the Kane Gap (including BSM II), which borders the Bathymetrists Seamounts to the North. Here we recovered a full dredge with manganese nodules. The 4th till the 6th of January we finalized the work at the northeast corner by hydro acoustic mapping and six dredge hauls at the remaining Grimaldi Seamounts: *Prince Albert*, BSM III and *Princesse Alice*, and their neighbour *Whitney Seamount*. We recovered basalts and volcanoclastics, all strongly coated by manganese crusts.

During a short transit on the 7th of January to the central Bathymetrists Seamounts, we crossed a deeper transform fault indicated from gravity data. Therefore we recorded here in addition to multibeam data, a PARASOUND profile. In the evening we reached the Central Seamounts, where we started with studying the two middle seamounts *Murchison* and *Cindy Seamounts*. Also here, the seamounts were mapped followed by four dredge tracks. While we could recover some relatively fresh basalts from *Murchison Seamount*, *Cindy Seamount* was more challenging to obtain samples from and only Mn-crusts could be recovered. As *Cindy Seamount* represents also the most central part of our working area, we performed here a sound-velocity profile up to 3,700 m depth, to obtain the sound-velocity over the full water column,

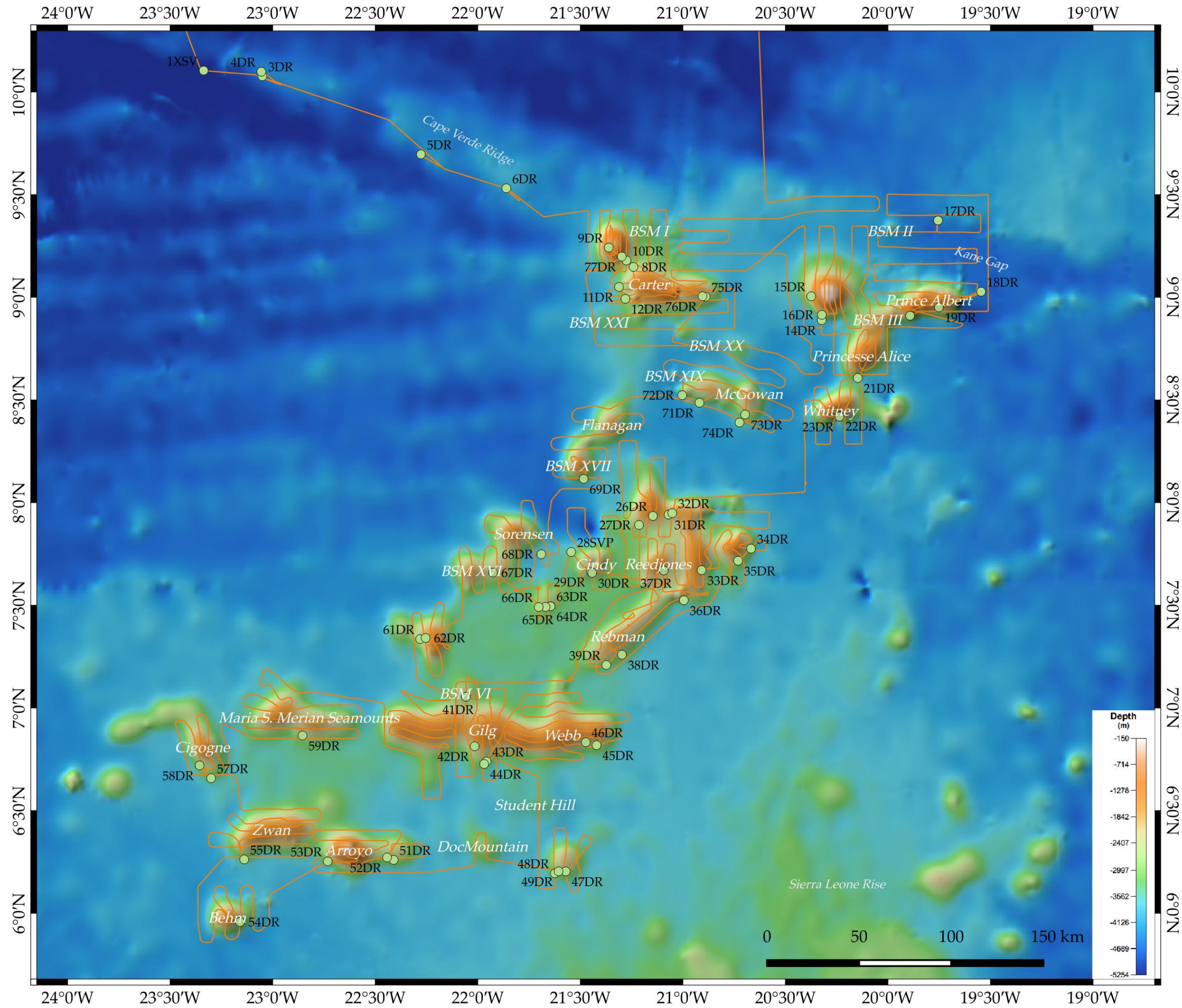


Fig. 4.2 Overview of the working area with the cruise track, seamount names and station locations.

required for accurate multibeam modelling. On the 8th in the evening we continued with the eastern group of the central seamounts, consisting of *Reedjones*, BSM IV and V, *Snodgrass* and *Rebmann Seamounts*. In four days we mapped these Seamounts and performed nine dredge-tows, which successfully recovered basalts, volcanoclastics and Mn-crusts.

In the morning of 12th of January we began our work in the southern study area of the Bathymetrists seamounts. This area consists of one very large composite-Seamount: *Webb & Gilg Seamount* and multiple smaller solitaire seamounts. Due to the large size of *Webb & Gilg Seamount* (≈140x50 km) it took us three days to map and sample the central and eastern part of the seamount. Six dredge hauls recovered volcanoclastic breccias and carbonates. For planning purposes, we afterwards first continued south to the solitaire seamounts BSM VIII, *Arroyo Seamount*, BSM X, BSM XI, BSM XII and BSM XIII-XV. On the 15th till the 20th of January we mapped and sampled these seamounts, which took a day for each of those. At both BSM VIII and *Arroyo Seamount* we dredged three times; from BSM VIII we collected basalt and volcanoclastics, from *Arroyo Seamount* we recovered in addition also carbonates. One dredge haul at BSM X returned volcanoclastics, while we found basalt at BSM XI. BSM XII was dredged two times returning basalt and volcanoclastic material. At the seamount group BSM XIII-XV we performed one dredged and collected volcanoclastics. The southern group was finished in the morning of the 21rst of January with the mapping of the western end of *Webb & Gilg Seamount*.

After finishing the southern seamounts, we worked our way back northwards along the western side of the central Bathymetrists Seamounts. *Marchant Seamount* was mapped and basalts and volcanoclastics were sampled by two dredge hauls in the afternoon and night of the 21rst of January. *Carron Seamount* we mapped on the 22nd followed by four dredge hauls. Nevertheless, we could only recover Mn-crusts, similar as at Cindy seamounts, which is just North of it. *Sorensen Seamount* and BSM XVI were mapped on the 23rd and *Flanagan Seamount* and BSM XVII the day after. At both Sorensen and BSM XVI seamounts dredging recovered volcanoclastics, while basalts were collected at *Flanagan Seamount*.

The 25th of January we worked on the last unmapped Bathymetrists Seamount group – *McGowan Seamount* and BSM XVIII. After mapping we performed three dredge hauls, recovering volcanoclastics, basalts and Mn-crusts. To obtain a good sampling coverage, we finished the dredge program on the 26th of January with three more dredges at *Carter* and *Annan Seamounts*, were recovery of volcanic samples in the beginning of the cruise was poor. This time we could recover volcanoclastics, basalts and carbonates with the last successful dredges. We finished our overall working program on the 27th of January with mapping of the Kane Gap transform fault north of the Bathymetrists Seamounts. At 16:00 left the working area and started the four days transit towards the port of Las Palmas de Gran Canaria.

# 5 Preliminary Results

## 5.1 Hydroacoustic Measurements

(N. Augustin, M. Le Saout, A.-C. Wölfl, M. Schade, J.M. Miluch, J.J. Schönberg)

### *5.1.1 Multibeam Operations*

Multibeam bathymetry data were acquired over 40 guyots and seamounts of the Grimaldi and Bathymetrists Seamounts and the transform faults at Cape Verde Ridge and Kane Gap that have been surveyed systematically and in detail during cruise MSM70 for the very first time (Fig. 5.1 and Tables 5.1 and 5.2). The surveyed area of MSM70 covers a total area of 67,580 km$^2$, an area comparable to the area of the Benelux countries Belgium, Netherlands and Luxembourg together.

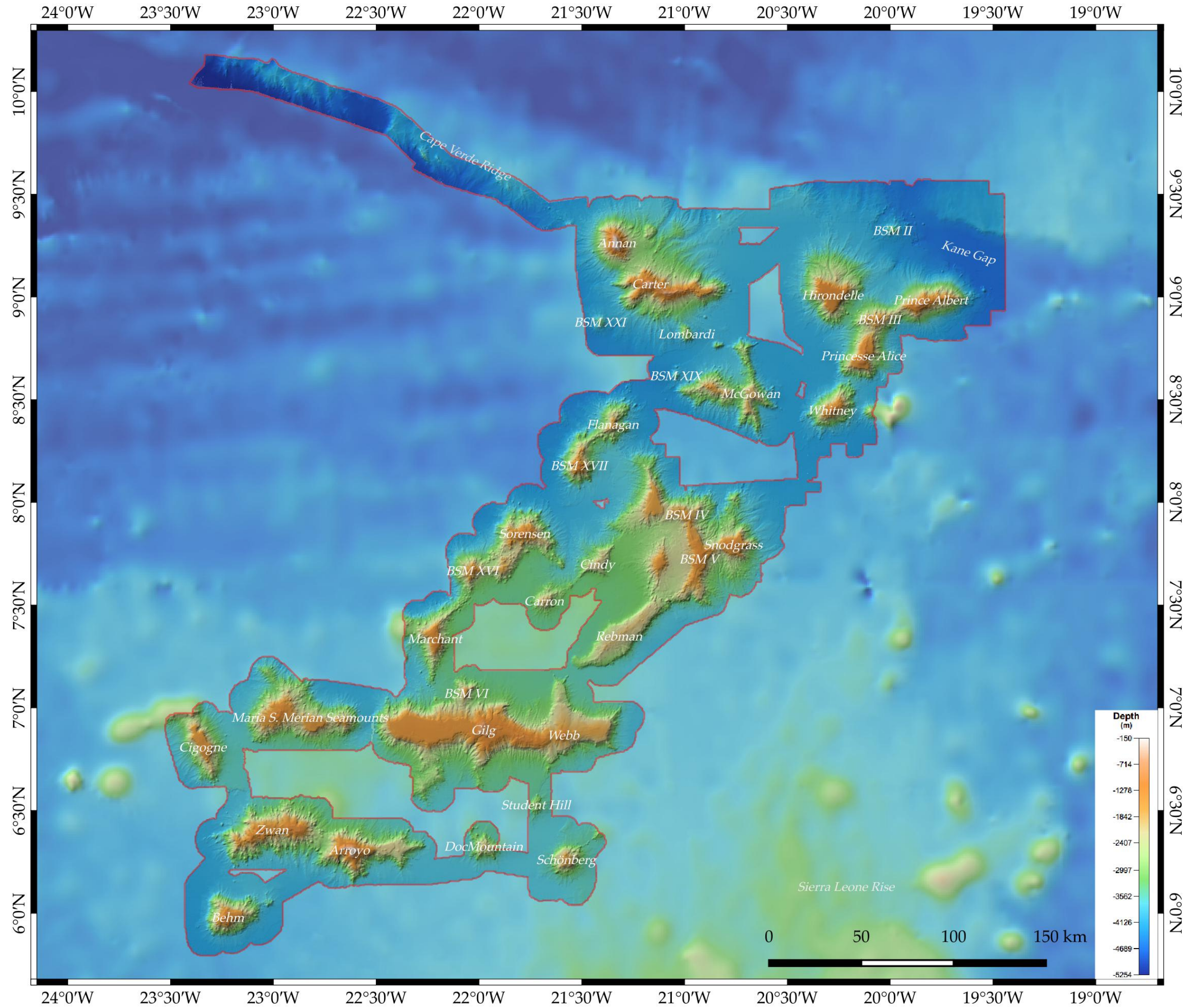


Fig 5.1 Overview of the mapped area during expedition MSM70. Feature names are given after GEBCO/SCUFN, NGA and MSM70 numbering/naming. The significant gain in resolution compared to the low-resolution Sandwell & Smith (2009), version 2014, background data is clearly visible.

Multibeam and backscatter data were acquired using the hull-mounted Kongsberg EM122 12 kHz echo-sounder. Data were collected at variable ping rates depending on water depth with a ship speed of 10-11 kn. The survey speed was relatively high for mapping but required to cover the large survey area in the available working days. Nevertheless, the good weather conditions and enabled double-swath mode at ping rates never below 0.07-0.08 Hz (4-5 pings per minute) yielded in an along track resolution of 30-40 m. Thus, bathymetric data were gridded at a spatial resolution of 50 m. Backscatter mosaics yielded a resolution of 30 m. Only transit data (along track records) to and from the working area were achieved at a lower resolution. These data were recorded at >12 knots and greater water depths (>4,000 m) and result in grids with a resolution of 100 m per cell (Backscatter 50 m). Beam widths were normally kept between 60° and 65° in typical water depths of 3,500 – 1,000 m, but occasionally increased to 70° in shallower water.

In the shallowest areas of some of the seamounts (<500 m) the Kongsberg EM712 75kHz echo-sounder was additionally used to collect bathymetric data. Although the EM712 can obtain higher resolution for the shallower areas, the quality of the EM122 was very good over the whole range of water depths and this expedition was not focusing on high-resolution bathymetry of the carbonate platforms that cover the tops of many of the seamounts. Therefore, the EM712 data have just been incorporated in the 50 m grids to increase sounding density rather than being processed for higher resolution maps. Only during the survey of the shallowest (≈200 m depth) parts of Annan Seamount (07MB) we discovered graben-like artefacts in the EM122 data that were thus replaced with EM712 data. At Arroyo Seamount, which is comparably shallow as Annan SM, these artefacts did not appear. To reduce the Kongsberg typical near-nadir artefacts known as "Eric's horn", that appear on deep pelagic sediments, we consequently set the swath auto tilt on 4° and turned the penetration filter off during the surveys.

Sound velocity profiles (SVP) were taken from with XSV and SVP at the beginning of station work at position 10°12.35'N, 23°22.96'W (Station 01XSV) up to 2,000 m water depth and in the centre of the working area at 7°45.58'N 21° 32.71'W (Station 28SVP) up to 3,750 m water depth, northwest of Cindy Seamount. Station 28SVP shows a few more variations in sound velocity in the upper water column and gives slightly slower sound velocities than the XSV profiles (Fig. 5.2). The differences between the XSV and SVP sound velocity profiles are not significantly and we decided to use the higher resolution and deeper reaching SVP data for the depth correction of soundings in post-processing.

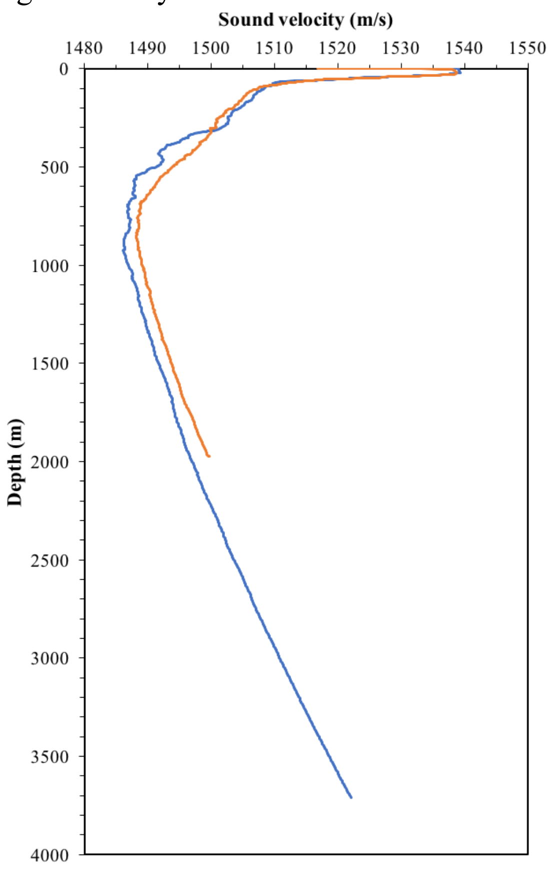


Fig 5.2 Sound velocity profiles obtained during MSM70. XVS profile (MSM70-1XSV, orange) and deeper sound velocity probe (MSM70-28SVP, blue).

Multibeam data were post-processed, cleaned and gridded using the QPS Qimera and Fledermaus Pro packages. Qimera was used to host the project/survey data and for post-processing, Fledermaus for multibeam data gridding and FMGT for backscatter. GMT was used to close minor gaps in the data by creating interpolated grids with a combination of high- and low-resolution grids of the same data. The result was stored at a resolution of 50 m. Also data gaps over the shallowest summit areas of Annan and Arroyo seamounts, that were inaccessible due to fishery activities, have been successfully interpolated with GMT with low-resolution grids.

A 3σ filter was applied in FMGT to the backscatter data to emphasize the difference between higher and lower backscattering areas. All the collected data has received a full post-processing and do not require further editing on shore. Thus, the bathymetric data are fully available for research directly after the cruise.

### 5.1.2 Statistics & Preliminary Results

During MSM70 over 67,580 $km^2$ of the seafloor were surveyed in the working area using the multibeam echo-sounder. The bathymetry and backscatter data were gridded with a resolution of 50 m and 30 m, respectively (Fig. 5.3).

The majority of the data covers the Bathymetrists and Grimaldi Seamounts, more data was collected along the fracture zones (Cape Verde Ridge, Kane Gap) and during transits between the different survey areas (Fig 6.1). A few targets (smaller volcanoes outside the main group) that have been planned earlier were skipped due to the significant reduction of working days (31.5 instead of the 37.5 requested in the original proposal).

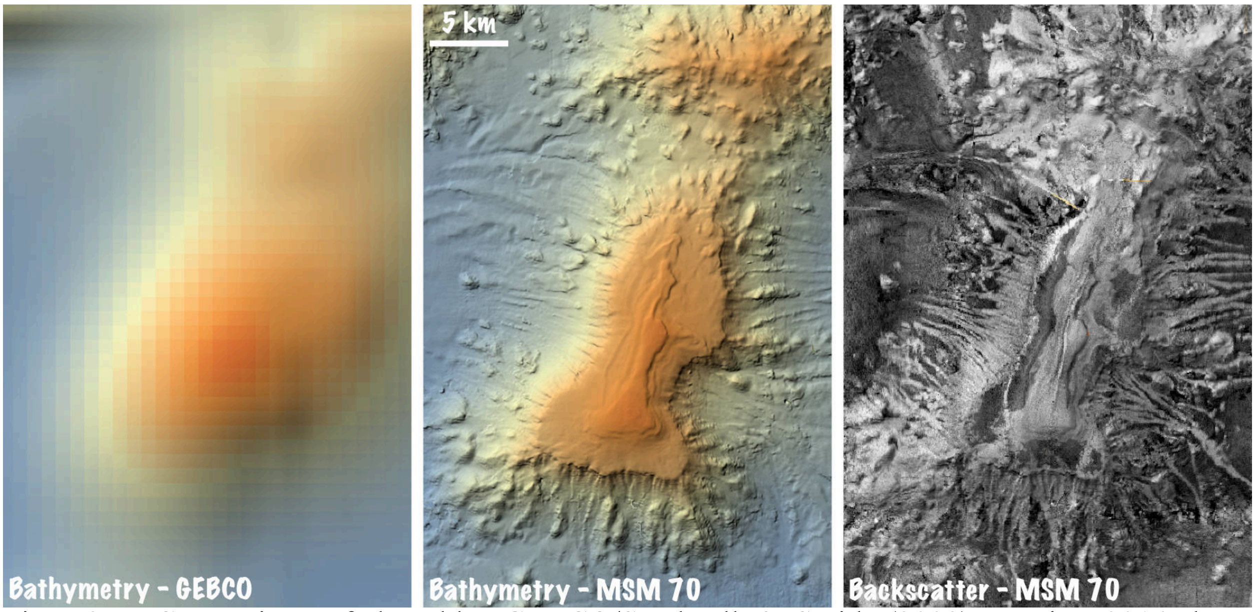


Fig. 5.3 Comparison of the older GEBCO/Sandwell & Smith (2009), version 2014, low-resolution grid to the 50 m bathymetry and 30 m backscatter data of Princesse Alice Seamount (Grimaldi Seamount group, see also Figure 5.1 and Table 5.1.). Where no detail was available in earlier km-scale data, now a huge amount of geomorphological structures, such as the guyot shape, reef/carbonate platforms, steep volcano flanks and land-slides are visible in the bathymetry.

The Cape Verde Ridge was surveyed between 23.3°W and 21.5°W by a single transect along the fracture zone over a distance of 225 km with a width of ~16 km. A second section of the fracture zone (Kane Gap) was surveyed between 19.9°W and 19.5°W (~ 52 km) while imaging a field of manganese nodule evidenced by a high reflectivity in the backscatter data and ground truthed with a dredge (station 17DR). The area of the Bathymetrists and Grimaldi Seamounts that extend from 23.5° N to 19.4°N and 5.7°W to 10.2°W were mapped for 87 %, with a total of 40 seamounts. The position of named seamounts could be refined (Table 5.1). In addition, many seamounts were unnamed and have been numbered with BSM (Bathymetrists SeaMounts) combined with a roman numbering (BSM I – BSM XXI, see Fig 5.1 and Table 5.2). The bathymetry team aboard MARIA S. MERIAN named some of the larger, newly charted seamounts. They will apply for the official registration of the names *Schönberg Seamount*, *Behm Seamount*, *Zwan Seamount*, *Cigogne Seamount* and *Maria S. Merian Seamounts* (for details see Table 5.2) at the IHO-IOC GEBCO Sub-Committee on Underwater Feature Names (SCUFN)

Table 5.1 List of named undersea features in the Grimaldi and Bathymetrists Seamounts area.

| | | | GEBCO/SCUFN coordinates[B] | | NGA coordinates[C] | | MSM70 position | | |
|---|---|---|---|---|---|---|---|---|---|
| No.[A] | Seamount Name | a.k.a. | Lat | Long | Lat | Long | Lat | Long | Named after |
| 1 | Hirondelle Seamount | | 9°04' | -20°20' | 9°04' | -20°20' | 9°00' | -20°17' | research ship belonging to Prince Albert I of Monaco |
| 2 | Prince Albert Seamount | Krause[1] | 8°58' | -19°52' | 8°58' | -19°52' | 8°58' | -19°50' | Prince Albert I of Monaco |
| 3 | Princesse Alice Seamount | | 8°41' | -20°07' | 8°41' | -20°07' | 8°42' | -20°08' | research ship belonging to Prince Albert I of Monaco |
| 4 | Annan Seamount[2] | - | n.l. | n.l. | n.l. | n.l. | 9°16' | -21°20' | Lord Noel Annan, Vice-Chancellor University College, London |
| 5 | Arroyo Seamount[3] | Nephrite[3] | n.l. | n.l. | 6°15' | -22°40' | 6°18' | -22°37' | Rafael Arroyo, Defense Mapping Agency |
| 6 | Carron Seamount[4] | - | 8°45' | -20°06' | 7°32' | -21°41' | 7°31' | -21°41' | Dr. Michael Carron, former sci. head USNOO |
| 7 | Carter Seamount | Annan[2] | 9°03' | -21°14' | 8°58' | -21°10 | 9°04' | -21°10' | Terence Carter, Defense Mapping Agency |
| 8 | Cindy Seamount | - | 7°43' | -21°27' | 7°40' | -21°25 | 7°42' | -21°25' | Cynthia Titus Murchison, Defense Mapping Agency |
| 9 | Flanagan Seamount | - | 8°22' | -21°18' | 8°22' | -21°22' | 8°22' | -21°21' | Joseph Flanagan, Defense Mapping Agency |
| 10 | Gilg Seamount[5] | - | n.l. | n.l. | 6°52' | -21°54' | 6°53' | -21°59' | Joseph Gilg, Defense Mapping Agency |
| 11 | Lombardi Seamount[4] | - | 8°45' | -20°05' | 8°50' | -21°00' | 8°49' | -21°00' | Leo Lombardi, Defense Mapping Agency |
| 12 | Marchant Seamount | - | n.l. | n.l. | 7°15' | -22°15' | 7°20' | -22°13 | Francis Marchant, Defense Mapping Agency |
| 13 | McGowan Seamount | - | 8°30' | -20°43' | 8°24' | -20°40' | 8°32' | -20°41 | Katherine McGowan, Defense Mapping Agency |
| 14 | Murchison Seamount | - | 7°58' | -21°07' | 7°54' | -21°00' | 8°00' | -21°09' | Richard Murchison, Defense Mapping Agency |
| 15 | Rebman Seamount | - | 7°22' | -21°16' | 7°17' | -21°24' | 7°21' | -21°19' | Jack Rebman, Defense Mapping Agency |
| 16 | Reedjones Seamount[6] | - | 7°40' | -21°07' | 7°34' | -21°05' | 7°42' | -21°07 | Charles Reed Jones, Defense Mapping Agency |
| 17 | Snodgrass Seamount | - | 7°54' | -20°48' | 7°50' | -20°44' | 7°47' | -20°46 | Laverne Snodgrass, Defense Mapping Agency |
| 18 | Sorensen Seamount | - | n.l. | n.l. | 7°50' | -21°50' | 7°51' | -21°47' | Frederick Sorensen, Defense Mapping Agency |
| 19 | Webb Seamount[5] | - | 7°00' | -21°39' | 7°00' | -21°33' | 6°52' | -21°35' | Stephen Webb, Defense Mapping Agency |
| 20 | Whitney Seamount[7] | - | 9°00' | -21°10' | 8°29' | -20°15' | 8°27' | -20°17' | Joseph Whitney, Defense Mapping Agency |

[A]No. 1-3 belong to the Grimaldi Seamount group. No. 4-20 are the Bathymetrists Seamounts, all (except No 4) were named after a group of US Naval Oceanographic Office (USNOO) employees in the Bathymetry Division who have been working in this area [B]GEBCO (General Bathymetric Chart of the Oceans) Sub-Committee on Undersea Feature Names [C]US BGN Advisory Committee on Undersea Features (ACUF), secondary source for MSM70 feature names [1]Krause Seamount as name for the group in many low resolution maps e.g. Jones et al. (1991), Skolotnev et al. (2012, 2017); Emelyanov et al. (1990) name the group Three Peaked [2]Annan seamount was the former name of Carter and Annan seamounts as they appeared as one structure on older low-resolution maps, a new position of Annan was introduced by Jones et al. (2002) refined after mapping [3]Nephrite seamount is described in Kharin (1988) and Emelyanov et al. (1990) at the position of NGA named Arroyo Seamount; a position given by Skolotnev et al. (2017) is misplaced and collides with the position of NGA named Sorensen Seamount [4]position of Carron as given by GEBCO shows no feature, thus NGA position was used and refined after mapping [5]SCUFN position of Webb seamount points to the eastern part of NGA named Gilg seamount. Since Gilg is a very big structure with two summits we named the eastern summit Webb and the central summit Gilg. The whole structure will be referred as Webb & Gilg Seamount [6]position of NGA is in-between two features and it is not clear which feature is meant, GEBCO position clearly points to a seamount and thus this position was used and refined after mapping [7]position of Whitney seamount given by SCUFN collides with Carter seamount, thus NGA position was used and refined after mapping.

The seamounts mapped are 5 to 139 km in length and 710 to 3930 m in height. The shallowest seamounts (Annan and Arroyo seamounts) reach a minimum depth of about 210 m below sea level and are found on the northern and southern end of the seamount chain. The seamounts flanks have slopes that vary from <10° to >35°. Lower slope angles most likely result from landslides that modified most of the seamount flanks, except for Rebmann Seamount that does not reveal any major landslides and is surrounded by steep flanks.

Most of the seamounts (62%) resemble flat-topped seamounts or guyots (Hess, 1946) capped by carbonated platforms, manganese-iron or phosphorite crusts as has been observed in the Pacific (Schlanger et al., 1987; Jenkyns and Wilson, 1999; Flood, 1999; 2001). Their shape and geological composition indicates that some of the seamounts must have been exposed above the water level for some time, being subject to erosion processes, as well as to shallow water processes at some time since their formation. A gradual subsidence linked to sea level variation in combination with thermal subsidence of the oceanic lithosphere with increasing distance to the mid-ocean ridge could have led to the development of reef structures on their top (Jenkyns and Wilson, 1999). Bathymetric evidence for recent tectonic activity (as observed in the western end of the Vema Fracture Zone during expedition SO237, Devey et al. 2015), could not be found in the study area. Also, high backscatter values are not associated with recent volcanic activity, but instead indicate the occurrence of hard, unsedimented ground, such as manganese and (Mn-coated) phosphorite crusts, that extensively cover all of the sampled (and thus ground-truthed) seamounts.

The bathymetric data reveal a complicated pattern of volcano emplacement and erosion and thus, will be subject of post-cruise geomorphological studies in Kiel. Therefore, a detailed discussion is subject of further studies that will be published in appropriate international journals. The geomorphological analyses will, together with petrological and geochemical results, resolve answers regarding questions about the tectonic interplay between the oceanic crust and volcano growth, the timing on volcano emplacement and the relationship of the Bathymetrists Seamounts to the Sierra Leone rise.

Table 5.2 List of numbered/named seafloor features in the Grimaldi and Bathymetrists Seamounts area that were newly mapped during expedition MSM70.

| MSM70 number | Seamount Name proposed at SCUFN | | Lat | Long | Named after |
|---|---|---|---|---|---|
| BSM I | | E of Annan | 9°19' | -21°10' | |
| BSM II | | NE of Hirondelle at Kane Gap | 9°19' | -19°59' | |
| BSM III | | between Pr. Albert and Pr. Alice | 8°53' | -20°04' | |
| BSM IV | | E of Murchison | 7°57' | -21°00' | |
| BSM V | | between Reedjones and Snodgrass | 7°45' | -20°56' | |
| BSM VI | | close N of Webb & Gilg Seamount | 7°04' | -22°04' | |
| BSM VII | | S of Webb & Gilg Seamount | 6°32' | -21°43' | |
| BSM VIII | Schönberg Seamount | S of Webb & Gilg Seamount | 6°15' | -21°35' | Dr. Dieter Garbe-Schönberg; marine reseacher and principle investigator of expedition MSM70 |
| BSM IX | | S of Webb & Gilg Seamount | 6°19' | -21°58' | |
| BSM X | Behm Seamount | SW of Arroyo Seamount | 5°59' | -23°14' | Alexander Behm (1880-1952), German inventor that was granted the German patent No. 282009 for the invention of echo sounding in 1913 |
| BSM XI | Zwan Seamount | W of Arroyo Seamount | 6°49' | -23°20' | Dr. Froukje M. van der Zwan; marine reseacher, PI and Chief Scientist MSM70 |
| BSM XII | Cigogne Seamount | NW of BSM XI (Zwan Seamount) | 6°50' | -23°21' | french Stork, heraldic animal in the coat-of-arms of the German research vessel Maria S. Merian that mapped the Bathymetrists Seamounts during expedition MSM70 |
| BSM XIII | Maria S. Merian Seamounts | one of a group of 3 mounts E of Webb & Gilg seamount | 6°58' | -22°58' | German research vessel that firstly charted the majority of the Bathymetrists Seamounts in high resolution |
| BSM XIV | | one of a group of 3 mounts E of Webb & Gilg seamount | 6°55' | -22°48' | |
| BSM XV | | one of a group of 3 mounts E of Webb & Gilg seamount | 6°56' | -22°40' | |
| BSM XVI | | SW of Sorensen Seamount | 7°40' | -22°02' | |
| BSM XVII | | SW of Flanagan Seamount | 8°11' | -21°31' | |
| BSM XVIII | | W of McGowan | 8°33' | -20°41' | |
| BSM XVIX | | W of McGowan | 8°37' | -21°02' | |
| BSM XX | | Between Lombardi and McGowan Seamount | 8°46' | -20°50' | |
| BSM XXI | | SW of Carter Seamount | 8°53' | -21°25' | |

### *5.1.3 PARASOUND*

PARASOUND data was acquired using an ATLAS PARASOUND P70 Deep-Sea Parametric Sub-Bottom Profiler. This equipment allows to penetrate sediments up to 200 m deep, using 0.5 - 0.6 kHz wave frequency. One survey was performed on a transit between Whitney and Murchison Seamounts (Fig. 5.4). Its target was to collect data on a short transect crossing a Fracture Zone south of Whitney SM that is visible in vertical gravity gradient data (Sandwell et al., 2014) to obtain insights into the sedimentary structures. The PARASOUND profile was 13 nautical miles long, mapped at the speed of 12 knots. The collected data (SEGY, PS3) will be processed and interpreted after the MSM70 cruise and thus no detailed discussion can be given here.

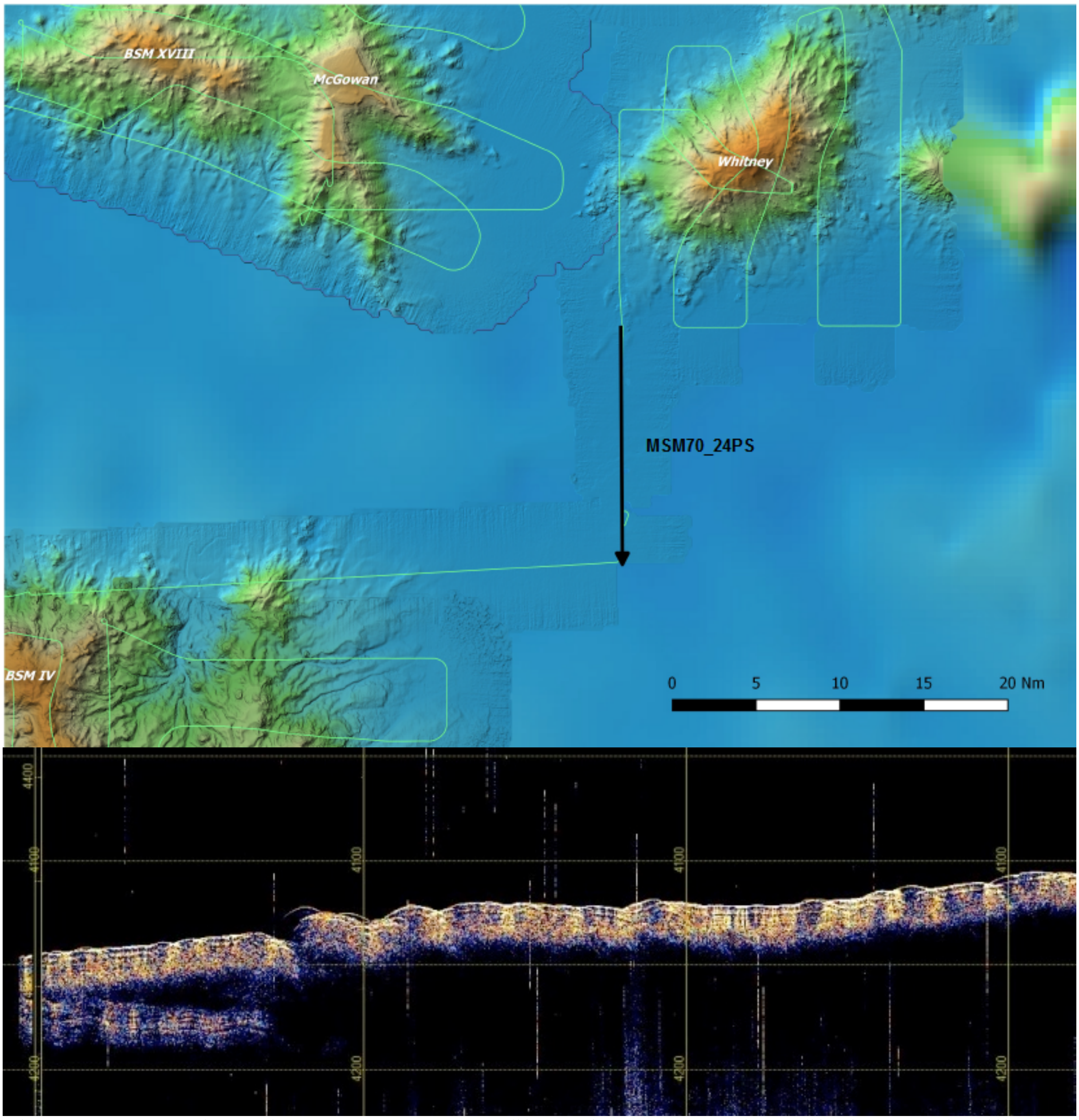


Fig 5.4 Location of MSM70_24PS profile and unprocessed profile image (for illustration purpose).

## 5.2 Seafloor Sampling

(X. Long, R.J.M. Antonio, V. Heinath, J. Follmann, L. Krach, M.C. Köse, J.J. Schönberg, F.M. van der Zwan)

### *5.2.1 Previous sample situation*

The sampling situation of the Bathymetrists Seamounts research area is poor and little extensive data is available. Dredging operations and grabs are limited in quantity and were carried out only in the northern and southern parts of the area (Fig. 5.5) during expeditions by the *R.S.S. Shackleton* and *Darwin* (Jones et al. 1991, Jones et al. 2002), the 7$^{th}$ cruise of the *R/V Professor Shtokman* (Emelyanov et al. 1990), the 23$^{rd}$ cruise of the *R/V Akademik Nikolaj Strakhov* (Petrova et al. 2010) and the 43$^{rd}$ cruise of the *R/V Academik Ioffe* (Skolotnev et al. 2017).

In the North, Carter Seamount was sampled most thoroughly by four one-tonne clam grabs and by one dredge haul, all located on the central part of the mount. The collected samples consist of phosphorites in varying states of alteration, mostly formed by the modification of reef limestones, and are generally covered in ferromanganese crusts (Jones et al. 2002). Volcanic samples from Carter Seamount give U-Pb zircon ages of 57-58 Ma (Skolotnev et al., 2010). Further dredges were pulled along the south-east flank of the neighbouring Annan Seamount that recovered variously sized samples of volcanites, tuff breccias, tuffs, limestones and breccias, all of which are covered with Fe-Mn crusts of up to 5 cm thick (Petrova et al. 2010). K-Ar rock dating of samples from Annan Seamount gives ages of 36 – 43 Ma old, however, samples are considerably altered (Kharin, 1988).

Further to the east, grabs from the western part of the plateau of Hirondelle Seamount recovered phosphorites similar to the ones from Carter Seamount (Jones et al. 2002). A dredge from the southeastern flank of Prince Albert Seamount, which lies east of Hirondelle, recovered mostly igneous material and pieces of breccia. The igneous rocks contain phenocrysts of Ca-rich pyroxene, Ti-rich amphibole and mica and have a lack of feldspar and olivine (Jones et al. 1991). A representative whole rock analysis (e.g. Sample S-1224-4) give lamprophyric compositions containing 37% $SiO_2$, 14% $Al_2O_3$, 14% FeO*, 6% MgO and 15% CaO (rounded oxide proportions). Whole rock dating (K-Ar) of samples from Prince Albert Seamount give ages between 5.4 ± 0.3 and 14.5 ± 0.5 Ma, but whole rock dating quality is poor due to advanced alteration of the material (Jones et al. 1991). Mineral dating from lamprophyre breccia give Miocene ages (53.3 ± 1.5 Ma for Biotite, 55.4 ± 1.2 Ma for Amphibole and 54.5 ± 1.8 Ma for Pyroxene).

In the southern part of the working area, sample locations are concentrated on the central plateau and the western flank of Webb & Gilg Seamount. Additionally, a single dredge was pulled along the southeastern flank of Cigogne Seamount and two dredges along the Northern and southern flanks of Arroyo Seamount. Grabs from the plateau of Webb & Gilg Seamount hauled phosphorites similar in composition to the samples from the Northern Seamounts (Jones et al. 2002). Carbonates on top of these volcanoes have an age of 40-46 Ma (Skolotnev et al., 2017). From the slopes of Cigogne Seamount, dredges collected material consisting of volcanic breccia, limestone and Fe-Mn crusts (Skolotnev et al. 2017). The whole rock compositions of the igneous samples are comparable to the samples of Jones et al. (1991). The hauls from Arroyo (Nephrite) Seamount recovered phosphorites, crusts, tuffs and basalts (Kharin, 1988; Emelyanov et al. 1991). Whole rock analyses of the igneous rocks are of trachytic composition containing significant higher $SiO_2$ contents. K-Ar ages of these samples indicate ages of 36-43 million years old (Kharin, 1988).

### *5.2.2 Dredge Operations*

With a total of 65 deployed dredges, all of the bigger volcanoes of the Bathymetrists Seamounts were sampled during the MSM70 expedition as well as some smaller structures (Fig. 5.5). Since some early, shallow (<2000 m depth) dredges retrieved mostly carbonates and phosphorites, the latter dredges were deployed to depths around 3000 m onto slopes of 25 to 35 degrees for an average distance of 750-800 m. A total of 38 dredges collected mainly basalts or volcanoclastics; other recovered lithologies are carbonates, phosphorites, mudstones, as well as manganese crusts and nodules (Table 5.3, Fig. 5.6). Detailed sample descriptions can be found in the Appendix.

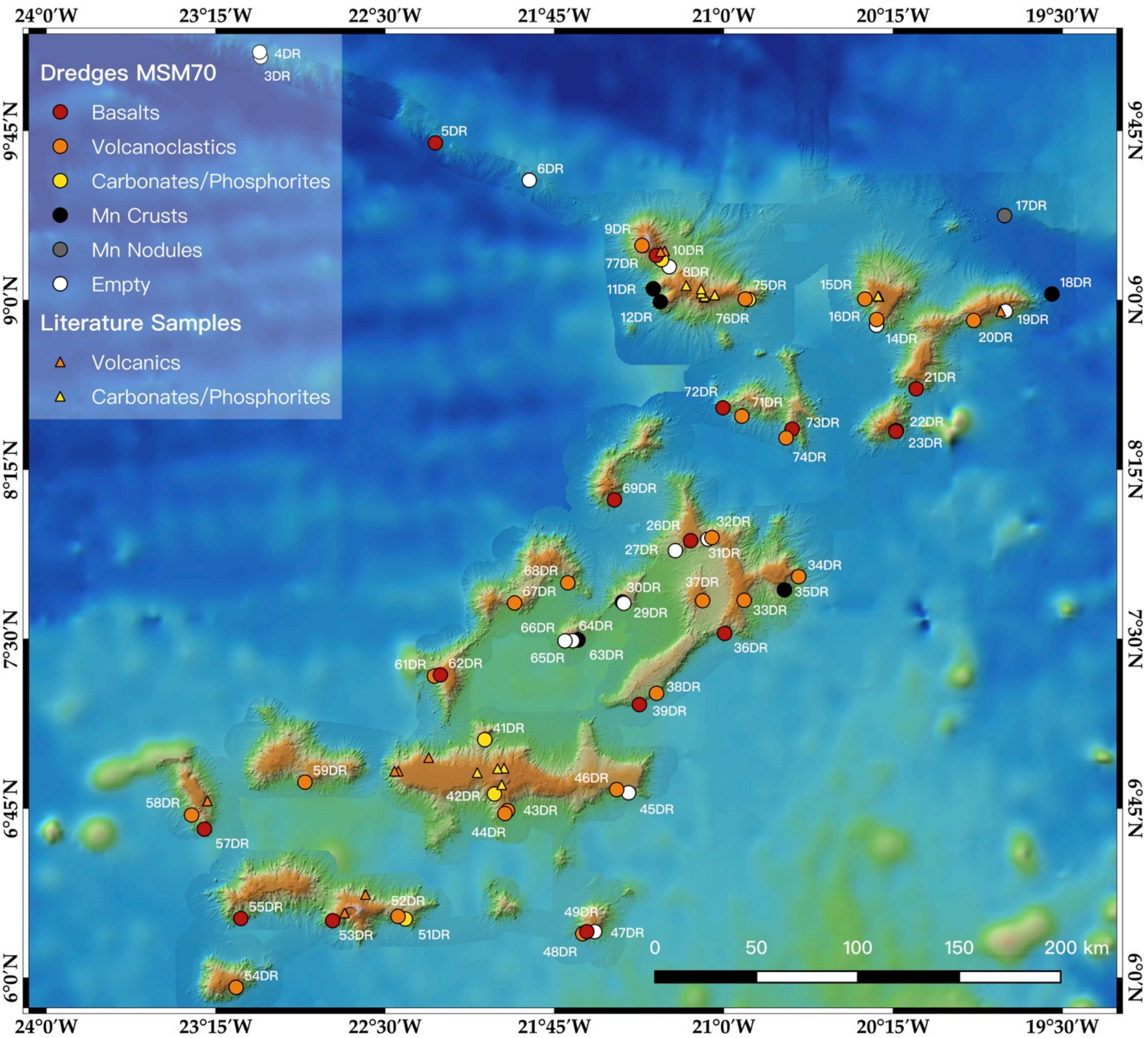


Fig. 5.5 Overview of dredge stations and the main lithology dredged together with the locations of previous samples from the Bathymetrists Seamounts.

Table 5.3 Dredge statistics.

| | | | |
|---|---|---|---|
| Total dredge time | 181 hours 49 minutes (approx. 7 days 14 hours) | | |
| Average dredge time | 2 hours 47 minutes | | |
| Overall success rate dredges (samples recovered) | 78,5% | | |
| Dredges which included volcanic samples (volcanoclastics or basalts) | 65% | | |
| Average depth dredges | Approximately 2780 m | | |
| Main lithologies dredged | | **Absolute** | **%** |
| | Basalt | 15 | 23.1 |
| | Volcanoclastics | 23 | 35.4 |
| | Carbonate-Phosphorite | 5 | 7.7 |
| | Manganese crusts | 7 | 10.8 |
| | Nodules | 1 | 1.5 |
| | Empty (sediments in traps) | 14 | 21.5 |
| Preservation of volcanic samples | Excellent* | 9 | 21.4 |
| | Good | 13 | 31.0 |
| | Moderate | 12 | 28.6 |
| | Poor | 8 | 19.1 |

* Excellent preservation means only little alteration (<10%); poor means completely altered.

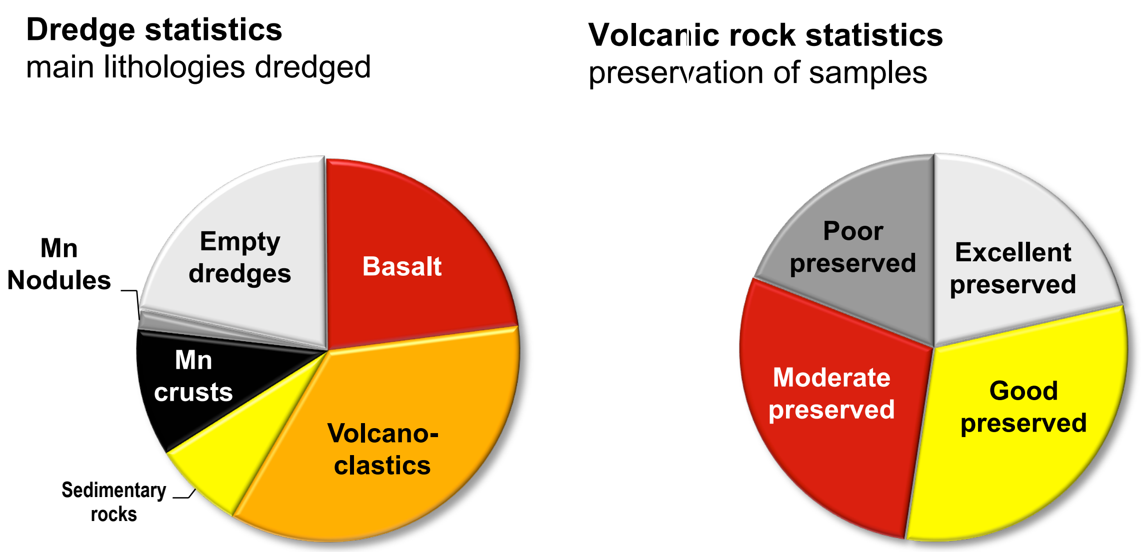


Fig. 5.6 Dredge statistics showing the amounts of the main lithologies dredged and the preservation of the volcanic samples.

### *5.2.3 Volcanic Rock Samples*

The volcanic samples recovered during MSM70 have various macroscopic appearances, ranging from dense phyric basalts (e.g. 21DR from Princess Alice; 39DR from Rebmann Fig. 5.7a,b) to vesicular samples (e.g. 69DR from BSM XVII, Fig. 5.7c) or amygdaloidal (e.g. 15DR from Hirondelle seamount; Fig. 5.7d) and aphyric basalt fragments (e.g. 32DR from Murchison seamount) to volcanoclastic breccias (e.g. 9DR from Annan seamount; Fig. 5.7e,f), though mixed appearances occur as well in single dredges (e.g. 62DR from Marchant seamount). Therefore, the types of samples recovered seem not directly related to the location of the samples. Most of the volcanic samples show manganese encrustations varying from 1 mm up to 8 cm in thickness (Fig. 5.7b,e). The overall degree of alteration varies from (almost) fresh basalts (<10 % of alteration) with a grey to dark-grey matrix colour to heavily altered basalts (maximum up to 80 % of alteration) where the matrix colour ranges from beige (light brown) to brown (e.g. 15DR Hirondelle seamount, fig. 5.7d). Volcanic samples from BSM XVII (69DR; Fig. 5.7c) appear different and display a grey matrix colour with elongated vesicles as flow textures, at which some of them are filled with white minerals (zeolite or phosphorite?). A higher silica content is inferred from the lighter grey colour of the groundmass compared to the basalts.

Most basaltic samples show little vesicularity with maxima of 50-60 % (e.g. 77DR from Annan seamount), but mostly less than 5 %. Primary minerals are largely pyroxene, amphibole and plagioclase, olivines are merely observed in basaltic samples from several dredges, including samples from 26DR at Murchison seamount and 62DR at Marchant seamount (Fig. 5.7g,h), and possibly from 5DR at the Cape Verde Ridge. In addition, rusted pseudomorphs are observed in many of the basaltic samples (e.g. 21DR from Princess Alice, see Fig. 5.7a), indicating former ferromagnesian minerals such as olivines and clinopyroxenes. As secondary minerals zeolites, Fe-oxyhydroxides and manganese were observed.

The samples recovered during MSM70 can be subdivided in different categories of volcanic rocks: in the denser basalt blocks/lavas and in the volcanoclastics breccias with pebbles (usually <10 cm and rounded) of mafic composition (Fig. 5.5). Although all samples show some degree of alteration, there are variations in the amounts and the samples can be further subdivided (Fig. 5.8). The freshness of the rocks ranges from relatively fresh basalts (excellent in Fig. 5.8; *e.g. 21DR from Princess Alice (Fig. 5.7a), 23DR from Whitney, 26DR from Murchison, 36DR from BSM V, 39DR from Rebmann (Fig. 5.7b), 62DR from Marchant (Fig. 5.7g), 69DR from BSM XVII (Fig. 5.7c), 73DR from McGowan*) and fresh volcanoclasts (*e.g. 46DR from Webb and Gilg*), to basalts (*e.g. 5DR from Guinea Fracture Zone, 53DR from Arroyo, 55DR from Zwan, 57DR from Cigogne*) and volcanoclasts with moderate to good freshness (good in Fig. 5.8 *e.g. 16D from Hirondelle, 32DR from Murchison, 38DR from Rebmann, 48DR from Schoenberg, 54DR from Behm, 61DR from Marchant, 67DR from BSM XVI, 76DR from Carter E branch*), to moderately altered basalts (*e.g. 49DR from Schoenberg, 77DR from Annan, 72DR from Carter*) and moderately altered volcanoclasts (moderate in Fig. 5.8; *e.g. 9DR from Annan, 20DR from Prince Albert, 37DR from Reedjones, 43DR from Gilg, 52DR from Arroyo, 59DR from Maria S. Merian, 68DR from Sorensen*) to very altered volcanic samples (poor in Fig. 5.8). In conclusion, we could recover volcanic samples of most of Bathymetrists Seamounts, and 19 out of 25 sampled seamounts from the Bathymetrists seamount group resulted in appropriate (good or excellent in Fig. 5.8) volcanic rock samples for post-cruise geochemical analyses. From other seamounts including Prince Albert, Reedjones, Maria S. Merian, BSM XVIII and Sorensen we could only recover moderately altered volcanic rocks, while from Snodgrass, Cindy and Carron Seamounts very altered or no volcanic samples were collected.


Fig. 5.7 Typical examples of dredged volcanic samples. a) and b) dense plagioclase and/or pyroxene phyric basalt coated by manganese crust. c) trachytic vesicular sample. d) amygdaloidal basalt sample. e) and f) volcanoclastic breccia with mafic rock

fragments and amphibole, pyroxene and biotite, coated by manganese crust. g) and h) olivine phyric basalt samples.

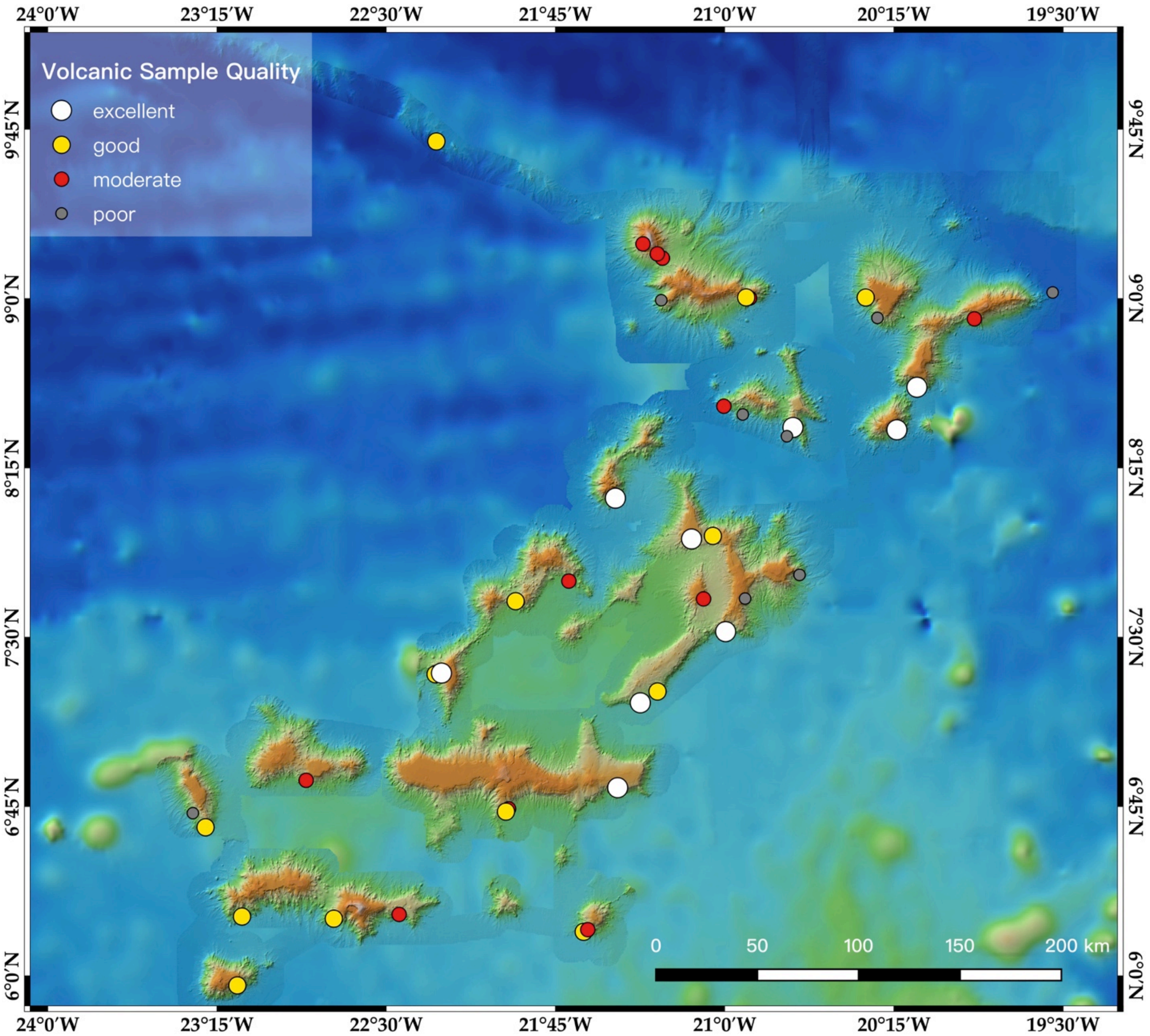


Fig. 5.8 Overview map showing the quality of the dredged volcanic samples. From 19 of the 25 sampled seamounts samples of good to excellent quality were recovered.

### *5.2.4 Sedimentary Rock Samples*

Sedimentary rocks are ubiquitous in the study area and are typically biogenic, ranging from phosphorites to limestones with varying degrees of alteration with some rare occurrence of clastic rocks such as claystones and mudstones. Large quantities of cobble-sized manganese nodules (Fig. 5.9a) were also recovered along the Kane Gap north of Hirondelle and Prince Albert seamounts.

Manganese formation and encrustation is pervasive over all samples. Manganese crusts vary in thickness from partial encrustation with less than 1 mm thickness to 10 cm thickness for older boulders (Fig. 5.9b). Manganese accumulation in the sedimentary matrix is much more pronounced at the rims and pore spaces such as burrows due to the available space and greater exposure to seawater.

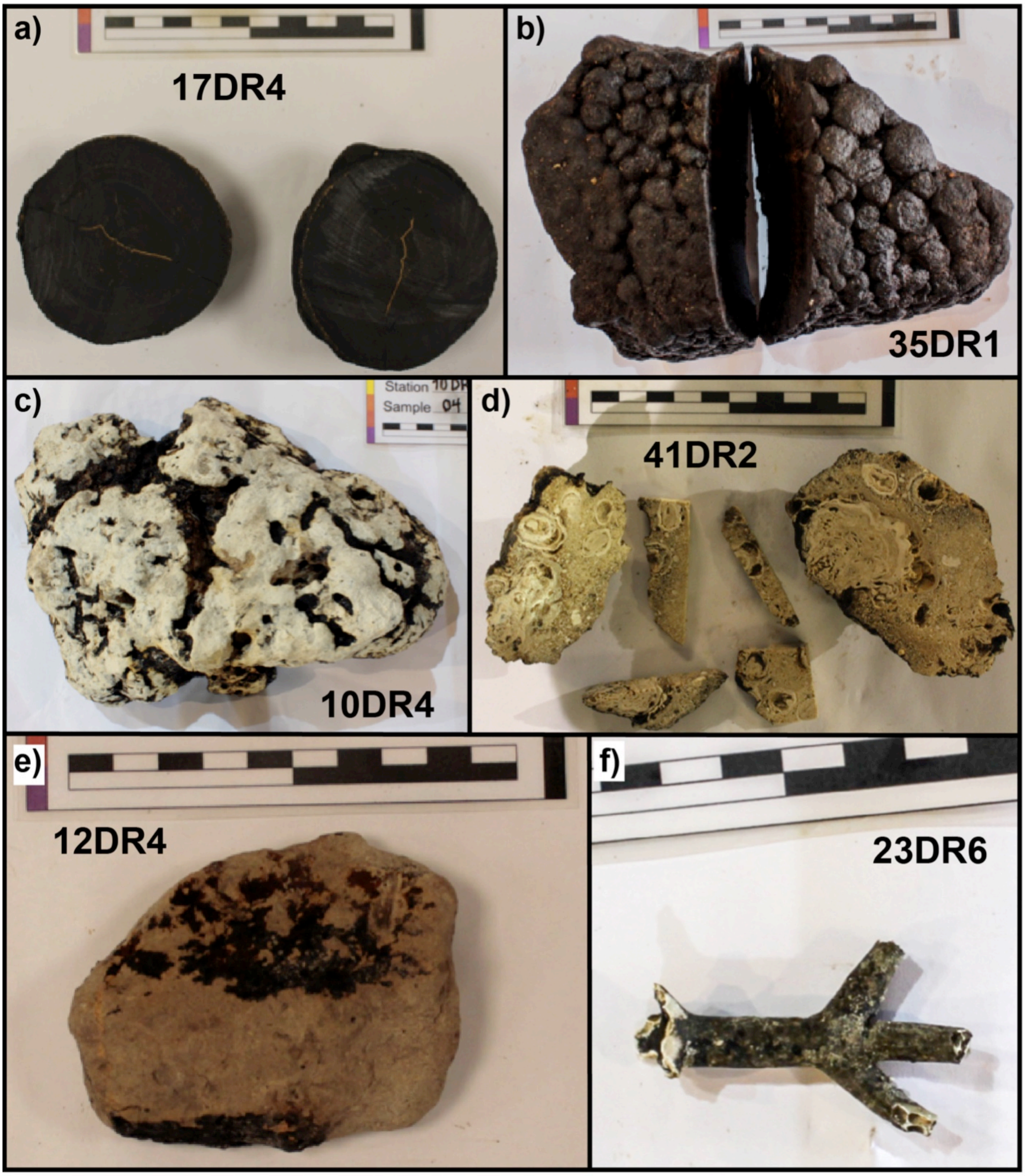


Fig. 5.9 Examples of dredged sedimentary rocks. a) 8 cm manganese nodule split in half to expose the core and growth rings. b) Manganese crust, 8 cm thick with nodular surface and layered interior. c) Coral fully replaced by phosphorites. d) Limestone classified as a grainstone according to the Dunham classification. Coral and shell fragments as well as foraminifera are present. Lime-mud is absent in the pore spaces. e) Brown mudstone with no manganese alteration and limited encrustation. f) younger coral fragment.

Phosphorites are the main matrix and/or cement component for the sedimentary rocks. The colour ranges from white, yellow, yellow-green and brown depending on the degree of alteration. Small black grains of manganese can also occur throughout the entire sample especially near the rim and open pore spaces. The matrix is usually soft but some larger samples with less-altered inner cores tend to be more indurated. Phosphorites can occur as a secondary mineral replacing carbonates such as coral fragments and lime mud (Fig. 5.9c) as proposed by Jones et al., 2002.

Limestones are mainly limited to the shallower dredges (<2200m depth) and occur as fine-grained mudstones, matrix supported wackestones, and grain supported packstones and grainstones (Fig. 5.9d). They are typically white to beige and are comprised of foraminifera, coral and shell fragments, with lime mud as matrix. Some carbonate-bearing phosphorites and clastic breccias can occur at deeper depths where larger grains of carbonate fragments and foraminifera are present and phosphorite-replacement and/or carbonate dissolution is incomplete.

Clastic sedimentary rocks are represented by light brown to brown soft claystones and mudstones which are recovered along with phosphorites during some dredges (Fig. 5.9e). They behave similarly to the phosphorites in terms of manganese alteration where greater exposure to seawater circulation exacerbates secondary manganese formation. Isolated occurrences of younger coral branch fragments and sponges were sometimes recovered by dredges up to depths of 3000 m (Fig. 5.9f).

# 6 Station List

(X. Long, R.J.M. Antonio, V. Heinath, J. Follmann, L. Krach, M.C. Köse, F.M. van der Zwan)

Total: 78

Station abbreviations: DR = Chainbag dredge (Kettensack Dredge); MB = Multibeam survey; XSV = Expandable Sound Velocimeter; PS = Parasound; SVP = Sound Velocity Profiler

| **Station** | **Station Area** | **Gear** | **Latitude (°N)/ Longitude (°W)** | **Date/ Time (UTC) Start/End** | **Depth (m)** | **Comments** |
|---|---|---|---|---|---|---|
| MSM70_1 | Cape Verde Ridge | XSV | 10°12.35'/023°22.96' To 10°11.49'/023°22.96' | 28.12.2017 07:25 07:32 | 4827 | Sound velocity profile till 2000 m depth |
| MSM70_2 | | MB | | 28.12.2017 08:05 29.12.2017 14:23 | | Multibeam survey of a single profile along the Cape Verde Ridge in eastern direction |
| MSM70_3 | Guinea Fracture Zone | DR | 10°04.44'/23°03.19' To 10°04.73'/23°02.92' | 28.12.2017 11:33 14:45 | 4442-4333 | Empty (sediments in traps) |
| MSM70_4 | Guinea Fracture Zone | DR | 10°05.78'/23°03.51' To 10°06.05'/23°03.18' | 28.12.2017 15:11 18:24 | 4348-4215 | Empty (sediments in traps) |
| MSM70_5 | Guinea Fracture Zone | DR | 09°41.60'/022°16.74' To 09°41.94'/022°16.58' | 29.12.2017 01:17 04:29 | 3880-3546 | 17 samples taken fine and coarse-grained Basalt; volcanic Breccia and biogenic sedimentary rock |
| MSM70_6 | Guinea Fracture Zone | DR | 09°31.68'/021°51.79' To 09°32.03'/021°51.55' | 29.12.2017 08:34 11:40 | 3942-3653 | Empty (sediments in traps) |
| MSM70_7 | | MB | | 29.12.2017 14:37 01.01.2018 04:39 | | Multibeam survey of Seamounts Annan, Carter, Lombardi |
| MSM70_8 | Annan Seamount; Carter Seamount | DR | 09°08.79'/021°14.60' To 09°08.94'/021°14.35' | 30.12.2017 13:07 15:28 | 2745-2468 | Empty (sediments in traps) |
| MSM70_9 | Annan Seamount | DR | 09°14.53'/021°21.73' To 09°14.54'/021°21.71' | 30.12.2017 16:28 18:31 | 1221-1205 | 6 samples taken Breccia, Mn crust, one piece of aphyric basalt |
| MSM70_10 | Annan Seamount | DR | 09°10.61'/021°16.67' To 09°10.90'/021°16.44' | 30.12.2017 19:35 22:09 | 2619-2297 | 7 samples taken + reserve Breccia, Mn crust, sedimentary rock, 1 piece of basalt |
| MSM70_11 | Carter Seamount; Western Branch | DR | 09°02.84'/021°18.83' To 09°03.22'/021°18.61' | 31.12.2017 07:20 10:25 | 3379-2963 | 4 samples taken Breccia, Phosphorites |
| MSM70_12 | Carter Seamount; southwestern Branch | DR | 08°59.38'/021°16.93' To 08°59.76'/021°16.80' | 31.12.2017 11:16 14:14 | 2751-2449 | 6 samples taken Mn crust with light-coloured soft sediments (mudstones) |
| MSM70_13 | | MB | | 01.01.2018 11:26 06.01.2018 07:51 | | Multibeam survey of Grimaldi Seamounts (Prince Albert, Hirondelle, Princesse Alice), Whitney Seamounts and east side of Kane Gap |
| MSM70_14 | Hirondelle Seamount | DR | 08°53.13'/020°19.45' To 08°53.53'/020°19.38' | 02.01.2018 00:38 03:30 | 3389-2999 | Empty (sediment in traps) |
| MSM70_15 | Hirondelle Seamount | DR | 09°00.10'/020°22.54' To 09°00.49'/020°22.45' | 02.01.2018 04:15 06:38 | 2508 2098 | 9 samples taken Large manganese crusts, amygdaloidal basalt, breccia, limestone |
| MSM70_16 | Hirondelle Seamount | DR | 08°54.68'/020°19.39' To 08°55.07/020°19.37' | 02.01.2018 07:34 10:09 | 2930 2592 | 5 samples taken Breccia |
| MSM70_17 | Guinea Fracture Zone | DR | 09°22.16'/019°45.55' To 09°22.77'/019°45.19' | 03.01.2018 12:32 16:24 | 4464-4329 | 6 samples taken Mn crust and Manganese nodules |
| MSM70_18 | Single cone east of Prince Albert | DR | 09°01.43'/019°32.83' To 09°01.85'/019°32.75' | 04.01.2018 11:38 15:11 | 4432-4023 | 5 samples taken + reserve Manganese crust, breccia |
| MSM70_19 | Prince Albert Seamount | DR | 08°56.88'/019°45.19' To 08°57.29'/019°45.08' | 04.01.2018 16:42 19:21 | 2560-2125 | Empty (sediment in traps) |

| Station | Station Area | Gear | Latitude (°N)/ Longitude (°W) | Date/ Time (UTC) Start/End | Depth (m) | Comments |
|---|---|---|---|---|---|---|
| MSM70_20 | Prince Albert Seamount | DR | 08°54.43'/019°53.65' To 08°54.82'/019°53.55' | 04.01.2018 21:57 05.01.2018 00:20 | 2474-2078 | 16 samples taken + reserve Volcanoclastic breccia, encrusted sedimentary rock |
| MSM70_21 | Princess Alice Seamount | DR | 08°36.48'/020°08.90' To 08°36.92'/020°08.85' | 05.01.2018 19:22 23:23 | 3401-3409 | 6 samples taken Phyric basalt, breccia, Mn crust Dredge stuck at 08°36.91'/020°08.85'; vessel moved backwards; Dredging aborted |
| MSM70_22 | Whitney Seamount | DR | 08°25.17'/020°14.21' To 08°25.58'/020°14.13' | 06.01.2018 10:18 12:59 | 2804-2364 | Empty (sediment in traps) |
| MSM70_23 | Whitney Seamount | DR | 08°25.17'/020°14.21' To 08°25.58'/020°14.22' | 06.01.2018 13:17 16:27 | 2775-2844 | 6 samples taken Pyric basalt, breccia, Mn crust, coral Dredge stuck at 08°25.11'/020°14.22'; vessel moved backwards; Dredging aborted |
| MSM70_24 | | PS | 08°17.36'/020°24.32' To 08°03.44/020°24.48' | 06.01.2018 19:07 20:55 | | PARASOUND profile from Whitney Seamount southwards |
| MSM70_25 | | MB | | 07.01.2018 00:11 12.01.2018 06:58 | | Multibeam survey of the central area of the Bathymetrists Seamounts including Murchison, Snodgrass, Reedjones, Rebmann and Cindy Seamounts |
| MSM70_26 | Murchison Seamount | DR | 07°55,91'/021°08.80' To 07°56.33'/021°08.80' | 07.01.2018 14:45 17:01 | 2029-1688 | 6 samples taken Phyric basalt, sedimentary rock |
| MSM70_27 | Murchison Seamount | DR | 07°53.32'/021°12.86' To 07°53.64'/021°12.86' | 07.01.2018 17:48 20:00 | 2749-2555 | Empty (sediment in traps) |
| MSM70_28 | W of Cindy Seamount | SVP | 07°45.58'/021°32.71' | 08.01.2018 10:34 12:18 | 3806 | Sound velocity profile till 3750 m depth |
| MSM70_29 | Cindy Seamount | DR | 07°39.64'/021°26.96 To 07°40.02'/021°26.88' | 08.01.2018 14:15 16:03 | 3041-2623 | 2 samples taken + reserve Mn crust |
| MSM70_30 | Cindy Seamount | DR | 07°39.28'/021°26.60' To 07°39.70'/021°26.52' | 08.01.2018 16:44 19:31 | 3095-2684 | Empty (sediment in traps) |
| MSM70_31 | Murchison Seamount | DR | 07°56.35'/021°04.25' To 07°56.69'/021°04.19' | 09.01.2018 05:31 07:26 | 1890-1689 | Empty (sediment in traps) |
| MSM70_32 | Murchison Seamount | DR | 07°56.74'/021°03.18' To 07°57.15'/021°03.11' | 09.01.2018 07:44 09:45 | 1808-1577 | 7 samples taken Aphyric basalt, breccia, Mn crust with breccia |
| MSM70_33 | BSM VI | DR | 07°40.14'/020°54.51' To 07°40.44'/020°54.64' | 09.01.2018 21:35 10.01.2018 00:02 | 1997-1640 | 9 samples taken Phosphorites, Mn-crust |
| MSM70_34 | Snodgrass Seamount | DR | 07°46.36'/020°40.07' To 07°46.80'/020°40.11 | 10.01.2018 08:28 11:26 | 3083-2630 | 3 samples taken Mn encrusted breccia, breccia |
| MSM70_35 | Snodgrass Seamount | DR | 07°42.83'/020°43.86' To 07°43.27'/020°43.89' | 10.01.2018 12:22 15:04 | 2704-2317 | 2 samples taken Mn crust |
| MSM70_36 | BSM VI | DR | 07°31.28'/020°59.73' To 07°31.72'/020°59.77' | 11.01.2018 02:11 05:14 | 3211-2682 | 5 samples taken + reserve Aphyric basalt, breccia, Mn crust |
| MSM70_37 | Reedjones Seamount | DR | 07°40.01'/021°05.60' To 07°40.37'/021°05.63' | 11.01.2018 07:01 09:14 | 2152-1849 | 2 samples taken + reserve Basalt, breccia |
| MSM70_38 | Rebmann Seamount | DR | 07°15.38'/021°17.84' To 07°15.79'/021°17.88' | 11.01.2018 14:37 17:26 | 3401-2957 | 7 samples taken Phyric basalt, breccia |
| MSM70_39 | Rebmann Seamount | DR | 07°12.53'/021°22.43' To 07°12.91'/021°22.46' | 11.01.2018 18:23 21:37 | 3556-3444 | 1 sample taken Phyric basalt Dredge stuck at 07°12.63'/021°22.43'; vessel moved backwards; Dredging aborted |

| Station | Station Area | Gear | Latitude (°N)/ Longitude (°W) | Date/ Time (UTC) Start/End | Depth (m) | Comments |
|---|---|---|---|---|---|---|
| MSM70_40 | | MB | | 12.01.2018 07:02 14.01.2018 01:01 | | Multibeam survey of the central and eastern part of the largest volcanic structure: Webb & Gilg Seamount and BSM VII and VIII (Schönberg) |
| MSM70_41 | Northern Part of Gilg Seamount | DR | 07°03.09'/022°03.55' To 07°03.44'/022°03.51' | 12.01.2018 17:59 20:06 | 2168-1762 | 6 samples taken Sedimentary rock, Mn crust |
| MSM70_42 | Gilg Seamount | DR | 06°48.69'/022°01.00' To 06°48.99'/022°00.89' | 12.01.2018 22:28 13.01.2018 00:31 | 2162-1856 | 5 samples taken Carbonate rich sedimentary rocks |
| MSM70_43 | Gilg Seamount | DR | 06°44.19'/021°57.47' To 06°44.60'/021°57.47' | 13.01.2018 09:53 12:34 | 2986-2575 | 2 samples taken Volcanoclastic breccia |
| MSM70_44 | Gilg Seamount | DR | 06°43.45'/021°58.15' To 06°43.86'/021°58.16' | 13.01.2018 13:02 15:38 | 3033-2495 | 6 samples taken + reserve Aphyric basalt, Volcanoclastic breccia, sedimentary rock, Mn crust |
| MSM70_45 | Webb Seamount | DR | 06°49.05'/021°25.27' To 06°49.26'/021°25.31' | 14.01.2018 11:51 15:43 | 3073-2927 | Empty (sediment in traps) |
| MSM70_46 | Between Webb Seamount and Gilg Seamount | DR | 06°49.81'/021°28.42' To 06°50.22'/021°28.49' | 14.01.2018 16:13 18:56 | 2969-2617 | 13 samples taken Phyric and aphyric basalt, volcanoclastic breccia, sedimentary rock, Mn crust, coral |
| MSM70_47 | BSM VII | DR | 06°12.07'/021°34.28' To 06°12.48'/021°34.31' | 15.01.2018 15:08 17:47 | 2928-2531 | Empty (sediment in traps) |
| MSM70_48 | BSM VII | DR | 06°11.51'/021°37.49' To 06°11.92'/021°37.49' | 15.01.2018 18:17 21:01 | 3301-2874 | 8 samples taken Amygdaloidal basalt, encrusted breccia, sedimentary rock |
| MSM70_49 | BSM VII | DR | 06°12.08'/021°36.40' To 06°12.50'/021°36.40' | 15.01.2018 21:32 16.01.2018 00:14 | 2960-2594 | 6 samples taken Amygdaloidal basalt, Mn crust |
| MSM70_50 | | MB | | 16.01.2018 00:23 17.01.2018 06:01 | | Multibeam survey of SW Bathymetrists Seamounts: Arroyo Seamount, BSM IX, BSM X (Behm), BSM XI (Zwan) |
| MSM70_51 | Arroyo Seamount eastern edge | DR | 06°15.43'/022°24.64' To 06°15.84'/022°24.65' | 16.01.2018 13:56 16:46 | 3162-2758 | 1 sample taken Sedimentary rock; sediment traps also sampled |
| MSM70_52 | Arroyo Seamount eastern edge | DR | 06°16.27'/022°26.56' To 06°16.68'/022°26.56' | 16.01.2018 17:18 20:21 | 3087-2985 | 2 samples taken Encrusted volcanoclastic breccia, Mn crust Dredge stuck at 06°16.48'/022°26.56', vessel moved backwards; dredging aborted |
| MSM70_53 | Arroyo Seamount | DR | 06°15.15'/022°43.93' To 06°15.56'/022°43.93' | 17.01.2018 06:23 09:29 | 2851-2785 | 4 samples taken Aphyric basalt, Mn crust Dredge stuck at 06°15.56'/022°43.93', vessel moved backwards; dredging aborted |
| MSM70_54 | BSM X | DR | 05°57.29'/023°09.66' To 05°57.68'/023°09.52' | 17.01.2018 18:49 21:15 | 2632-2204 | 6 samples taken Aphyric Basalt, Mn crust, volcanoclastic breccia, corals |
| MSM70_55 | BSM XI | DR | 06°15.97'/023°08.41' To 06°15.46'/023°08.28' | 18.01.2018 08:22 11:15 | 3248-2750 | 8 samples taken + reserve Aphyric Basalts, Mn-crust, altered basalt rims |
| MSM70_56 | | MB | | 19.01.2018 03:00 21.01.2018 08:22 | | Multibeam survey of SW Bathymetrists Seamounts: BSM XII (Cigogne), BSM XIII-XV (Maria S. Merian) and western Webb & Gilg Seamount |
| MSM70_57 | BSM XII | DR | 06°39.29'/023°18.12' To 06°39.71'/023°17.96' | 19.01.2018 03:10 06:21 | 3200-2717 | 39 samples taken + reserve Aphyric Basalt, Mn-crust, Manganese boulder |
| MSM70_58 | BSM XII | DR | 06°43.03'/023°21.49' To 06°43.46'/023°21.34' | 19.01.2018 07:28 10:29 | 3145-2742 | 5 samples taken Mn-crust, volcanoclastic Breccia |
| MSM70_59 | BSM XII | DR | 06°51.76'/022°51.32' To 06°52.20'/022°51.25' | 19.01.2018 21:17 23:54 | 2749-2353 | 3 samples taken Phyric Basalt, altered Scoria, Mn-crust |

| Station | Station Area | Gear | Latitude (°N)/ Longitude (°W) | Date/ Time (UTC) Start/End | Depth (m) | Comments |
|---|---|---|---|---|---|---|
| MSM70_60 | | MB | | 21.01.2018 08:24 24.01.2018 15:02 | | Multibeam survey of western central Bathymetrists Seamounts: Marchant, BSM XVI, Carron, Sorensen, BSM XVII and Flanagan Seamount |
| MSM70_61 | Marchant Seamount | DR | 07°19.94'/022°16.91' To 07°20.37'/022°16.91' | 21.01.2018 16:38 19:24 | 2974-2472 | 5 samples taken Phyric Basalt, encrusted Breccia, volcanoclastic Breccia |
| MSM70_62 | Marchant Seamount | DR | 07°20.42'/022°15.31' To 07°20.85'/022°15.26' | 21.01.2018 19:58 22:46 | 2297-2177 | 11 samples taken + reserve Phyric Basalt, volcanoclastic Breccia, coral, sedimentary rock Dredge stuck at 2293m, 07°20.52'/022°20.52', vessel backwards |
| MSM70_63 | Carron Seamount | DR | 07°29.58'/021°38.77' To 07°30.00'/021°38.67' | 22.01.2018 11:23 14:36 | 2962-2962 | 1 sample taken Mn crust Dredge stuck at 3069 m, 07°30.00'/021°38.69', vessel moved backwards to start point |
| MSM70_64 | Carron Seamount | DR | 07°29.58'/021°38.77' To 07°30.00'/021°38.69' | 22.01.2018 14:54 18:15 | 2985-2568 | 1 sample taken Mn crust Dredge stuck at 2902 m, 07°30.00'/021°38.69', vessel backwards |
| MSM70_65 | Carron Seamount | DR | 07°29.65'/021°40.20' To 07°30.08'/021°40.20' | 22.01.2018 18:39 21:56 | 2475-2688 | Empty Dredge stuck at 2641m, 07°29.36'/021°40.20', vessel backwards |
| MSM70_66 | Carron Seamount | DR | 07°29.31'/021°42.24' To 07°29.70'/021°42.17' | 22.01.2018 22:34 23.01.2018 00:46 | 2741-2489 | Empty |
| MSM70_67 | BSM XVI | DR | 07°39.38'/021°55.61' To 07°39.78'/021°55.58' | 23.01.2018 02:21 04:55 | 2502-2164 | 10 samples taken Phyric Basalt, Breccia, Mn crust, Phosphorites |
| MSM70_68 | Sorensen Seamount | DR | 07°44.72'/021°41.44' To 07°45.15'/021°41.44' | 23.01.2018 15:10 17:51 | 3144-2667 | 10 samples taken + reserve Breccia, Mn crust |
| MSM79_69 | BSM XVII | DR | 08°06.91'/021°29.06' To 08°07.01'/021°29.05' | 24.01.2018 00:24 03:37 | 3185-3105 | 6 samples taken + reserve Vesicular, aphyric, Basalt, volcanoclastic Breccia |
| MSM70_70 | | MB | | 24.01.2018 15:06 26.01.2018 03:03 | | Multibeam survey of BSM XVIII, BSM XIX and McGowan Seamount |
| MSM70_71 | BSM XVIII | DR | 08°29.03'/020°55.16' To 08°29.39'/020°55.22' | 24.01.2018 21:00 25.01.2018 00:00 | 3583-3222 | 3 samples taken Volcanoclastic Breccia, Mn crust |
| MSM70_72 | BSM XVIII | DR | 08°31.19'/021°00.25' To 08°31.60'/021°00.20' | 25.01.2018 00:48 03:54 | 3640-3196 | 1 sample taken Vesicular volcanic rock |
| MSM70_73 | McGowan Seamount | DR | 08°25.55'/020°41.81' To 08°25.96'/020°41.88' | 25.01.2018 06:52 09:51 | 2742-2504 | 8 samples taken + reserve Dense Basalt, Phosphorites, Mn crust, biogenic material Dredge stuck at 2396m, 08°25.96'/020°41.88', vessel moved backwards |
| MSM70_74 | McGowan Seamount | DR | 08°23.22'/020°43.41' To 08°23.64'/020°43.49' | 25.01.2018 10:29 13:17 | 3372-2954 | 1 samples taken Volcanoclastic Breccia |
| MSM70_75 | Carter Seamount | DR | 08°59.95'/020°53.36' To 09°00.36'/020°53.40' | 26.01.2018 03:08 05:41 | 2668-2271 | 4 samples taken Volcanoclastic Breccia, Phosphorites |
| MSM70_76 | Carter Seamount | DR | 09°00.11'/020°54.28' To 09°00.53'/020°54.28' | 26.01.2018 06:02 08:32 | 2307-2185 | 20 samples taken Basalt, volcanoclastic Breccia |
| MSM70_77 | Annan Seamount | DR | 09°11.69'/021°17.88' To 09°12.10'/021°17.95' | 26.01.2018 11:00 13:47 | 1897-1468 | 8 samples taken Dense Basalt, vesicular Basalt, encrusted Breccia, Mn crust |
| MSM70_78 | | MB | | 26.01.2017 14:09 27.01.2018 17:01 | | Bathymetric survey of BSM XX and XXI, the flanks of Hirondelle, Carter and Annan and Kane Gap |

# 7 Data and Sample Storage and Availability

## 7.1 Geological Samples

All dredged rock samples will be placed in the sample and core repositories of GEOMAR, Kiel. Access to samples in these repositories is protected initially by a moratorium period until February 2020 for cruise participants and proponents. After post-cruise research and publication, applications for the use of the rock samples, can be made to the University of Kiel and the data management team at Geomar (responsible Dr. van der Zwan). Initial analyses of the volcanic samples (e.g. XRF, XRD, ICP-MS, radiogenic isotopes) will be performed by X. Long under supervision of F.M. van der Zwan, J. Geldmacher, K. Hoernle and C.D. Garbe-Schönberg.

## 7.2 Hydroacoustic Data

The hydroacoustic (multibeam bathymetry, PARASOUND) data of the working area will be placed in the GEOMAR data management system to ensure safe archiving (responsible Dr. Augustin). Following interpretation and publication of the data, it will be transferred to a World Data Centre archive linked to the GeoMapApp project via EMODNet. After a moratorium period until February 2020, it will be available from the data management team on request. The transit data (multibeam bathymetry) will be provided to the AtlantOS Project and made public available shortly after the cruise.

# 8 Acknowledgements

We like to thank Captain Ralf Schmidt and the professional crew of the MARIA S. MERIAN for their enthusiastic support during the MSM70 expedition that enabled us to successfully complete our working program in a good atmosphere on board. The ship time of R/V MARIA S. MERIAN was provided by the Deutsche Forschungsgemeinschaft DFG. We gratefully acknowledge the support. F.M.Z gratefully acknowledges support of the University of Kiel.

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# 10 Appendix

(X. Long, R.J.M. Antonio, V. Heinath, J. Follmann, L. Krach, M.C. Köse, F.M. van der Zwan)

## 10.1 Sample Descriptions

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **5DR** | **1** | Phyric basalt | 28x15x15 | subangular | Mn (1 mm) | NA | 0 | brown | Ol (?), px, pl | NA | TS | some green alteration (epidote?), coarse-grained matrix |
| **5DR** | **2** | Phyric basalt | 40x20x20 | subangular | Mn (1 mm) | NA | 0 | brown | Ol (?), px, pl | NA | - | coarse-grained matrix |
| **5DR** | **3** | Phyric basalt | 15x10x10 | subangular | Mn | NA | 0 | bluish white | large px(?) | NA | - | some green/orange alteration, coarse-grained matrix |
| **5DR** | **4** | Serpentinised basalt | 10x9x4 | subangular | serpentine (?) | 50 | 0 | black | NA | NA | TS, 2x XRD | |
| **5DR** | **5** | Phyric basalt | 20x14x7 | subrounded | Mn | 50 | 0 | grey | px, pl | NA | GC, TS | brown alteration |
| **5DR** | **6** | Phyric basalt | 20x12x10 | subangular | Mn | NA | 0 | grey | large red minerals, pl, px | black minerals | - | looks like veins -> serpentine (?) |
| **5DR** | **7** | Phyric basalt | 10x8x7 | subangular | absent | 10 | 0 | grey | white mine-rals: pl(?) | NA | GC, TS | light brown alterations |
| **5DR** | **8** | Phyric basalt | 12x9x8 | subrounded | Mn | NA | 0 | dark grey | pl, px, il (?) | NA | GC, TS | brown alteration |
| **5DR** | **9** | Phyric basalt | 10x6x3 | subrounded | Mn | NA | 0 | dark grey | pl, px, il (?) | NA | - | green alteration (chloride) |
| **5DR** | **10** | Phyric basalt | 14x13x6 | subangular | absent | 60 | 0 | grey | px (?) | NA | TS, XRD | green/orange alteration |
| **5DR** | **11** | Phyric basalt | 14x8x6 | subangular | Mn | 10 | 0 | dark grey | px (?) | black minerals | TS | light brown alterations, brown veins cut through clasts |
| **5DR** | **12** | Phyric basalt | 17x8x7 | subrounded | absent | 60 | 0 | dark grey | NA | NA | TS | green/ brown alteration, altered greenish minerals |
| **5DR** | **13** | Phyric basalt | 9x8x2 | subangular | absent | 60 | 0 | dark grey | NA | NA | - | green/ brown alteration, altered greenish minerals |
| **5DR** | **14** | Manganese crust | 26x14x6 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **5DR** | **15** | Manganese crust | 25x20x11 | subangular | absent | NA | 0 | black | NA | NA | XRD | |
| **5DR** | **16** | Biogenic sedi-mentary rock | 19x13x10 | subrounded | absent | NA | 0 | beige | NA | NA | - | burrows inside, light rock (not dense) |
| **5DR** | **17** | Volcanoclastic breccia | 14x10x5 | subangular | Mn | NA | 0 | black | red and white minerals | NA | TS, XRD | orange alteration, brown alteration (clasts) |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **9DR** | **1** | Volcanoclastic breccia | 39x30x11 | subrounded | Mn (<2 cm) | 20-30 | <10 | light brown | NA | NA | - | Angular to rounded basalt clasts, the size ranges from 5 cm to <1 mm, vesicularity <2%, colours from green to brown depending on the alteration degree, mostly aphyric except for pyroxenes(1-2mm) in some of the clasts |
| **9DR** | **2** | Dense, phyric basalt | 10x7x4.5 | angular | nearly absent | <5 | 0 | dark grey | px | NA | TS, GC | fine-grained, almost aphyric except for scattered pyroxene phenocrysts as large as 5 mm. There are reddish brown altered parts surrounding the less altered part |
| **9DR** | **3** | Volcanoclastic breccia | 10x7.5x2.5 | subrounded | Mn (<2 cm) | 15-20 | 0 | brown | NA | NA | - | fine-grained, with some white veins |
| **9DR** | **4** | Manganese crust | 5.5x3.5x2.5 | angular | absent | NA | 0 | black | brownish red minerals | NA | - | |
| **9DR** | **5** | Manganese crust | 6x4x2 | angular | absent | NA | 0 | black | NA | NA | - | |
| **9DR** | **6** | Manganese crust | 6x4.5x2 | angular | absent | NA | 0 | black | NA | NA | - | |
| **10DR** | **1** | Phyric basalt | 18x17x11 | subrounded | Mn (1.5 cm) | 5-20 | <5 | grey to brown | px (<1cm), amp, mica (1%) | zeolites | TS, GC | white veins |
| **10DR** | **2** | Volcanoclastic breccia | 23x12x9 | subrounded | Mn (1.5 cm) | 10-20 | <5 | Yellowish-white | NA | NA | - | Clasts are supported by white/yellowish matrix. Clast description: primary minerals pyroxenes (3%,up to 1cm), amphibole (several), biotite (around 1%). white secondary minerals in well-rounded vesicles. |
| **10DR** | **3** | Manganese crust | 9x7x4 | subrounded | absent | NA | 0 | black | NA | NA | - | 2.5x2.3x0.6 cm pebble. Clast colour: brown-grey; alteration: around 30%; Vesicularity: moderate, some filled with crystal secondary minerals. |
| **10DR** | **4** | White sediments | 25x18x10 | rounded | Mn (3 mm) | NA | 0 | white | NA | NA | - | White main body with lots of channels covered by Manganese crust. Soft and light rock |
| **10DR** | **5** | White sediments | 14.5x10x6 | rounded | Mn (3 mm) | NA | 0 | white | NA | NA | TS | White main body with lots of channels covered by Manganese crust. Soft and light rock |
| **10DR** | **6** | White sediments | 16x12x7 | rounded | Mn (1 mm) | NA | 0 | white | NA | NA | - | White main body with lots of channels covered by Manganese crust. Soft and light rock |
| **10DR** | **7** | White sediments | 8.5x7x4 | rounded | absent | NA | 0 | white | NA | NA | - | White main body with lots of channels covered by Manganese crust. Soft and light rock |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **11DR** | **1** | Volcanoclastic breccia | 13x11x7 | subrounded | Mn | 70 | 0 | white | NA | NA | - | Manganese crust with a portion of grain supported subrounded to angular volcanic clasts embeddedin brown sedimentary matrix (phosphorite?) |
| **11DR** | **2** | Volcanoclastic breccia | 11x7x14 | subrounded | Mn | 80 | 0 | brown | NA | NA | - | Grain supported subrounded to angular basalt clasts (brown to black) embedded in a brown sedimentary matrix (phosphorite?). |
| **11DR** | **3** | Volcanoclastic breccia | 10x6x5 | subrounded | Mn | 70 | 0 | white | NA | NA | - | Manganese crust with a portion of grain supported subrounded to angular volcanic clasts (brown) embedded in a brown sedimentary matrix (phosphorite?). |
| **11DR** | **4** | Phosphorite | 16x12x4 | angular | Mn | NA | 0 | white | NA | Mn | - | Manganese crust with a portion of white sediment (phosphorite?) |
| **12DR** | **1** | Sedimentary rock | 25x19x8 | angular | Mn | NA | 0 | light brown | NA | Mn | - | Manganese crust with light brown soft sediments attached. |
| **12DR** | **2** | Sedimentary rock | 7x6x2 (slabs) | angular | Mn | 40 | 0 | white | NA | Mn | TS | White mudstone encrusted in manganese. Black dendrites present |
| **12DR** | **3** | Volcanoclastic breccia | 14x8x5 | angular | Mn | NA | 0 | light brown | NA | NA | TS | Manganese crust with light brown sediments andlithic fragments up to 3cm (volcanic?) |
| **12DR** | **4** | Sedimentary rock | 9x6x2 | rounded | Mn | NA | 0 | light brown | NA | Mn | - | Light brown mudstone with minor Manganese crust |
| **12DR** | **5** | Sedimentary rock | 21x20x7 | angular | Mn | NA | 0 | light brown to orange | NA | Mn | - | Manganese crust with light brown sediments attached. |
| **12DR** | **6** | Sedimentary rock | 22x20x11 | angular | Mn | NA | 0 | brown | NA | Mn | - | Manganese crust with light brown sediments attached. |
| **15DR** | **1** | Amygdaloidal basalt | 30x20x18 | rounded | Mn (<1 mm) | 70 | 30 | brown | px? | zeolites | TS,GC | Brown-grey amygdaloidal basalt. Vesicles are filled by white minerals (zeolite?) |
| **15DR** | **2** | Amygdaloidal basalt clast | 15x10x8 | subrounded | sediment (1 cm) | 70 | 20 | brown | NA | zeolites | TS,GC | Brown-grey amygdaloidal basalt clast from a breccia. Vesicles are filled by white minerals (zeolite?) |
| **15DR** | **3** | Volcanoclastic breccia | 11x11x6 | subangular | Mn (1 mm) | 80 | 0 | light brown | NA | NA | - | Breccia with clasts up to 2 cm in size (brown to grey volcanics). Grain supported. |
| **15DR** | **4** | Volcanoclastic breccia | 14x10x7 | subrounded | Mn (5 mm) | 80 | 40 | beige | NA | NA | TS,GC | Breccia with vesicular basalt clasts up to 5cm (dark brown). Grain supported. |
| **15DR** | **5** | Volcanoclastic breccia | 16x13x10 | angular | NA | 20 | 0 | beige | NA | NA | - | Breccia with clasts up to 5 cm in size of greyamygdaloidal basalt and brown volcanics. Grain supported. |
| **15DR** | **6** | Volcanoclastic breccia | 13x8x6 | angular | Mn (6 cm) | NA | 0 | black | NA | NA | - | Manganese crust with small amounts of breccia and amygdaloidal basalt clasts (8 cm, dark brown). |
| **15DR** | **7** | Manganese crust | 18x14x6 | angular | Mn (5 cm | NA | 0 | black | NA | NA | TS, XRD | |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15DR** | **8** | Amygdaloidal basalt | 2x3x5 | subrounded | sediment (1 mm) | 80 | 40 | brown | NA | zeolites | TS, GC | Brown-grey amygdaloidal basalt. Vesicles are filled by white minerals (zeolite?) |
| **15DR** | **9** | Coral/ limestone | 1.5x1.5x14 | elongated | NA | NA | 0 | white | calcite | NA | - | 2 Pieces of stick-shaped coral. |
| **16DR** | **1** | Volcanoclastic breccia | 10x10x6 | subrounded | Mn (1 cm) | 30 | 0 | brown | NA | NA | - | Breccia with clasts of light grey rock fragments up to 8 cm in size. Grain supported. |
| **16DR** | **2** | Volcanoclastic breccia | 20x13x5 | angular | Mn (1 cm) | 30 | 0 | brown | NA | NA | TS, XRD | Breccia with clasts of light grey rock fragments up to 3 cm in size. Grain supported. |
| **16DR** | **3** | Volcanoclastic breccia | 27x15x9 | subangular | Mn (5 cm) | 40 | 0 | brown | NA | NA | - | Breccia layer fully encrusted by manganese. |
| **16DR** | **4** | Volcanoclastic breccia | 8x6x2 | angular | Mn (1 cm) | 50 | 0 | redbrown | NA | NA | TS | Manganese crust with fragment of breccia attached |
| **16DR** | **5** | Volcanoclastic breccia | 16x8x4 | angular | Mn (1.5 cm) | 30 | 0 | brown | NA | NA | - | Breccia with clasts of brown rock fragments up to 5 mm in size. Matrix supported. |
| **17DR** | **1** | Fe-Mn-nodule | 10x9.5x9.5 | rounded | Mn (<5 cm) | NA | 0 | black | NA | NA | - | |
| **17DR** | **2** | Fe-Mn-nodule | 12x9x8.5 | subrounded | Mn | NA | 0 | black | NA | NA | - | |
| **17DR** | **3** | Fe-Mn-nodule | 10x8x8 | rounded | Mn | NA | 0 | black | NA | NA | - | |
| **17DR** | **4** | Fe-Mn-nodule | 7x6.5x6 | rounded | Mn | NA | 0 | black | NA | NA | - | |
| **17DR** | **5** | Fe-Mn-nodule | 7.5x5.5x5 | rounded | Mn | NA | 0 | black | NA | NA | - | |
| **17DR** | **6** | Manganese crust | 8.5x6x1.5 | subrounded | Mn | NA | 0 | black | NA | NA | - | Sediment (yellowish, about 0.5cm thick) encrusted with Mn |
| **18DR** | **1** | Encrusted manganese nodules | 30x21x18 | subrounded | Mn (7 mm) | NA | 0 | black | NA | NA | TS, XRD | Aggregate of manganese nodules |
| **18DR** | **2** | Manganese nodule | 14x14x13 | rounded | Mn (7 mm) | NA | 0 | black | NA | NA | - | |
| **18DR** | **3** | Volcanoclastic breccia | 20x14x14 | angular | Mn (5 cm) | NA | 0 | white | NA | NA | TS | Manganese crust with attached breccia with brown rock fragments up to 1-5 cm in size suspended in a white matrix. Matrix supported. |
| **18DR** | **4** | Manganese crust | 25x17x6 | angular | Mn (6 cm) | NA | 0 | black | NA | NA | - | |
| **18DR** | **5** | Manganese crust | 13x11x6 | angular | Mn (6 cm) | NA | 0 | black | NA | NA | - | |
| **20DR** | **1** | Volcanoclastic breccia | 10.5x8x4 | subrounded | Mn (1 mm) | 30-40 | <20 | white to grey | px, amp, ol (?) | NA | - | Breccia with brown to grey volcanic clasts up to 2 cm in size. Matrix supported. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **20DR** | **2** | Volcanoclastic breccia | 9x7x5 | very angular | nearly absent | 30-40 | 5 | white to grey | px, mica, amp, altered pl(?) | NA | - | Breccia with brown volcanic clasts up to 5 cm. Grain supported. |
| **20DR** | **3** | Volcanoclastic breccia | 18x14x9 | subangular | Mn (<3 cm) | 30-40 | <60 | white | px, amp, pl(?) | NA | TS, GC | Breccia with brown to grey volcanic clasts up to 2.5 mm in size. Grain supported but a layer of white fine-grained material is present in between 2 possibly different breccia layers. |
| **20DR** | **4** | Volcanoclastic breccia | 22x20x14 | angular | Mn (1 mm) | 35-45 | <30 | yellowish -white | px, amp | NA | 2xTS, 3xGC, 2xXRD (TS1= GC1, TS2= GC3) | Breccia with brown to grey volcanic clasts up to 5 cm in size. Grain supported. 1 cm size minerals present. (TS1 extracted from same clast as GC1, TS2 from same clast as GC3). |
| **20DR** | **5** | Volcanoclastic breccia | 24x21x15 | subrounded | Mn (1 mm) | 35-45 | <15 | white | amp | NA | 2xTS, GC, XRD | Breccia with brown to grey volcanic clasts up to 7 cm. Grain supported. 0.7 cm minerals present. (TS2=GC1) |
| **20DR** | **6** | Volcanic lithic fragment | 8x6x4 | angular | Fe-Mn (1 mm) | 25 | <40 | white to grey | px, amp | NA | - | Breccia with grey volcanic clast (5 cm, possiblyvesicular basalt). |
| **20DR** | **7** | Volcanoclastic breccia | 14x13x9 | subangular | Fe-Mn (1 mm) | 40 | <40 | white to grey | amp | zeolites (?) | - | Breccia with brown volcanic clasts (vesicular basalt?) up to 3 cm, Grain supported. |
| **20DR** | **8** | Encrusted breccia | 8x7x6 | subrounded | Mn (2.5 cm) | 30 | <5 | white to grey | NA | NA | - | Manganese crust with a breccia core. |
| **20DR** | **9** | Volcanoclastic breccia | 8x7x5 | angular | nearly absent | 40 | <25 | white to grey | amp | zeolites (?) | - | Breccia with brown to grey volcanic clasts up to 3 cm. Grain supported. 1 cm minerals present. |
| **20DR** | **10** | Volcanoclastic breccia | 8.5x5.5x5 | angular | absent | 30 | <15 | white to grey | amp | zeolites (?) | - | Vesicular basalt clast |
| **20DR** | **11** | Volcanoclastic breccia | 28x20x16 | angular | Fe-Mn (5 cm) | 45 | <30 | brownish -white | amp | NA | - | Breccia with brown to grey volcanic clasts up to 3 cm in size. Grain supported. |
| **20DR** | **12** | Volcanoclastic breccia | 28x20x14 | subrounded | Fe-Mn (4 cm) | <20 | <50 | beige to grey | amp | NA | GC | Breccia with brown to grey volcanic clasts up to 5 cm in size. Grain supported. |
| **20DR** | **13** | Encrusted breccia | 28x15x7 | rounded | Mn (2.5 cm) | 30 | <15 | brownish -white | amp | NA | - | Manganese crust with a breccia core. |
| **20DR** | **14** | Encrustedsedimentary rock | 11x6x6 | angular | Mn (3 cm) | <40 | <5 | yellowish-white | amp | NA | - | Breccia with brown clasts up to 3 cm in size. Grainsupported |
| **20DR** | **15** | Volcanoclastic breccia | 5.5x4x3.5 | subangular | Mn (1 cm) | >40 | <50 | yellowish -white | NA | zeolites | - | Breccia with black volcanic clast (2 cm, possibly vesicular basalt). |
| **20DR** | **16** | Volcanoclastic breccia | 14x11x9 | angular | Mn (1 mm) | 30-40 | 0 | grey | NA | NA | TS, XRD | Breccia with brown volcanic clasts up to 2 cm in size. Grain supported. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **21DR** | **1** | Phyric, amygdaloidal basalt | 42x34x15 | subrounded | Mn (5 mm) | <10 | <15 | dark grey | px | zeolites | TS (2x), GC (4x), XRD | reddish-brown altered/weathered minerals in vesicular volcanic rock throughout all the rock, in the outer parts vesiculars filled with zeolites, also glasslike shining colourless minerals. Half of rock packed separately. |
| **21DR** | **2** | Phyric, amygdaloidal basalt | 54x22x16 | angular | Mn (4 cm) | 25-30 | <30 | dark grey | amp, px (?) | zeolites | TS, GC (4x), XRD | fine matrix, secondary filled vesicular parts up to 3 mm, some not filled at all. Some vesicular fillings are greenish, glasslike minerals, also reddish-brown weathered/altered minerals. |
| **21DR** | **3** | Volcanoclastic breccia | 15x12x9 | subrounded | Fe-Mn (3 cm) | <40 | <15 | Yellow to white | px | zeolites | - | very weathered, grain supported (?), clasts size1.5-3 cm |
| **21DR** | **4** | Volcanoclastic breccia | 11x8x7 | angular | Mn (4 cm) | 15-40 | 15-20 | yellow to orange | NA | zeolites | TS | grain supported, clasts have dark grey matrix, in there reddish-brown altered/weathered mineral remnants, no other minerals visible -> fine matrix, clasts size hardly distinguishable because of weathering |
| **21DR** | **5** | Manganese Crust | 25x14x8 | rounded | absent | NA | 0 | black | NA | NA | - | |
| **21DR** | **6** | Phyric, amygdaloidal basalt | 53x42x16 | angular | Mn (1 cm) | 10 | 15 | dark grey | px | zeolites | TS, GC (2x), XRD | some vesicular parts partly filled with glasslike, shiny, elongated, colourless minerals, reddish-brown altered/weathered mineral remnants HALF OF ROCK NOT PROCESSED but packed separately |
| **23DR** | **1** | Dense, phyric basalt | 11x7x2.5 | subangular | Fe-Mn (< 1 mm) | <5 | 0 | greenish grey | px, pl | NA | TS, GC | extraordinary fresh, fine matrix, very dense, few minerals reddish weathered |
| **23DR** | **2** | Manganese crust | 14x9x2 | angular | absent | NA | 0 | black | NA | NA | - | |
| **23DR** | **3** | Sedimentary rock | 11x6x6 | angular | Mn (<1 mm) | NA | 5 | white | NA | NA | - | harder than recent sedimentary rocks |
| **23DR** | **4** | Sedimentary rock | 13x11x9 | angular | Mn (<1 mm) | NA | 5 | white | NA | NA | TS, XRD | harder than recent sedimentary rocks |
| **23DR** | **5** | Manganese crust | 13x11x4.5 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **23DR** | **6** | Coral | 5x3x1 | elongated | - | NA | 0 | - | - | - | - | |
| **26DR** | **1** | Dense, phyric basalt | 16x11x6 | subangular | Fe-Mn (< 1 mm) | around 5% | 0 | Interme-diate grey; particularly dark grey in the center | ol, px | NA | TS, GC | relatively fresh, fine matrix, very dense, minerals at the center are mostly reddish weathered (rusted), some black minerals (most of them are pyroxenes) are observed at rims |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **26DR** | **2** | Dense, phyric basalt | 10x10x6.5 | subrounded | nearly absent | less than 5% | 0 | Interme-diate grey | ol, px | NA | 3TS, GC | Fresher than 26DR-1, around half minerals are reddish weathered and rusted, but some fresh olivines are observed at the center, and some unaltered pyroxenes exist at rims |
| **26DR** | **3** | Sedimentary rock | 12.5x9x5 | subrounded | Mn (1 cm) | NA | 5 | white | NA | NA | - | a small cobble of volcanic rock attached |
| **26DR** | **4** | Sedimentary rock | 16x7.5x5 | angular | Mn (5 mm) | NA | 5 | white | NA | NA | TS | more altered than 26DR-3 and also different from 26DR-3 |
| **26DR** | **5** | Sedimentary rock | 7.5x6x4 | angular | Mn (1 cm) | NA | 0 | greenish white | NA | NA | - | |
| **26DR** | **6** | Sedimentary rock | 8x6x5 | subrounded | Fe-Mn (< 1 mm) | NA | 5 | yellow | NA | NA | - | |
| **29DR** | **1** | Manganese crust | 16x15x6 | angular | absent | NA | 0 | black | NA | NA | - | |
| **29DR** | **2** | Manganese crust | 14x12x8 | angular | absent | NA | 0 | black | NA | NA | - | |
| **32DR** | **1** | Volcanoclastic breccia | 12x11x8 | subangular | Mn (1 cm) | NA | 0 | white | NA | NA | TS, GC | Breccia with a large brown basalt clast (8 cm, altered) and carbonates(?). Grain supported and poorly sorted. Manganese crust removed. |
| **32DR** | **2** | Aphyric basalt | 8x6x5 | subangular | Mn (5 mm) | 40 | 15 | grey to brown | px? <1mm | zeolites? | TS, GC | 6cm basalt rock fragment encrusted in manganese. Manganese crust removed and separated. |
| **32DR** | **3** | Aphyric basalt | 8x7x7 | rounded | Mn (1 cm) | 30 | 15 | brown to grey | pl 1mm, px 1mm | zeolites? | TS, GC | Mn nodule with 6cm basalt core. Vesicles are elongated. Manganese crust removed and separated |
| **32DR** | **4** | Aphyric basalt | 6x5x3 | subrounded | Mn (1.5 cm) | 50 | 15 | grey to brown | px? <1mm | zeolites? | TS, GC | 4 cm basalt rock fragment encrusted in Mn. Somevesicles exhibit deformation/ elongation. Manganese crust removed and separated |
| **32DR** | **5** | Volcanoclastic breccia | 11x10x8 | angular | Mn (2 cm) | NA | 0 | white | NA | NA | TS, XRD | Breccia with up to 3 cm clasts of volcanics (basalt?) and carbonate grains. Grain supported and poorly sorted. |
| **32DR** | **6** | Manganese crust with breccia | 14x13x7 | subangular | Mn (4 cm) | NA | 0 | black | NA | NA | - | Manganese crust with breccia attached. Breccia has up to 2 cm clasts of brown and greenish white rock fragments. Grain supported and poorly sorted. |
| **32DR** | **7** | Manganese crust with breccia | 21x18x13 | subrounded | Mn (2 cm) | NA | 0 | white to yellow green | NA | NA | - | Manganese crust with breccia attached. Breccia has up to 3 cm clasts of brown to grey and greenish white rock fragments. Grain supported and poorly sorted. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **33DR** | **1** | Breccia | 7x6x3 | subrounded | Fe-Mn (1 mm) | 40 | 0 | dark grey | px | NA | TS | Various clasts in fine grey matrix, grain supported, clasts include sedimentary rocks, basalts of different colours and alteration degrees. Clast sizes from <1 mm up to 3 cm |
| **33DR** | **2** | Breccia | 7x5x2 | subangular | Fe-Mn (1 mm) | 40 | 0 | brownish | amp | NA | TS | Grain supported, clasts vary, some single weathered minerals up to 1 cm, some clasts are completely altered, some partially. Clast size varies from <1 mm up to 1.3 cm. Clast colours: dark grey, brownish red, light brown, black |
| **33DR** | **3** | Breccia | 16x13x3 | subrounded | Fe-Mn (1 mm) | <15 | 0 | greenish white | px, amp | NA | TS | Grain supported, Fe-Mg oxides, clasts vary, some fresh looking, dense basalts, some clasts include non-altered minerals up to 4 mm in size |
| **33DR** | **4** | Manganese crust with breccia | 15x6x5 | angular | Mn (2 cm) | 60-70 | 0 | beige | NA | NA | - | Very altered, reddish colour, no hard parts left, everything is scratchable with fingernails (except for manganese crust) |
| **33DR** | **5** | Sedimentary rock | 29x26x10 | rounded | Mn (1 mm) | NA | 0 | white | NA | NA | TS | Soft, scratchable with fingernail. Black spots,holes in rock, on the insides encrusted with Mn |
| **33DR** | **6** | Sedimentary rock | 22x21x8 | rounded | Mn (1 mm) | NA | 0 | white | NA | NA | - | Soft, scratchable with fingernail. Black spots, holes in rock, on the insides encrusted with Mn, marks in one direction on rock surface next to holes |
| **33DR** | **7** | Sedimentary rock | 14x12x8 | rounded | absent | NA | 0 | white | NA | NA | - | Soft, scratchable with fingernail. Black spots, holes in rock, on the insides encrusted with Mn |
| **33DR** | **8** | Sedimentary rock | 15x10x3 | rounded | absent | NA | 0 | white | NA | NA | - | Soft, scratchable with fingernail. Black spots, holes in rock, on the insides encrusted with Mn |
| **33DR** | **9** | Sedimentary rock | 5x4x3 | rounded | absent | NA | 0 | white | NA | NA | - | Soft, scratchable with fingernail. Black spots, some minerals <2 mm included (e.g. amphibole) |
| **34DR** | **1** | Mn encrusted breccia | 24x22x4 | subangular | Mn (3.5 cm) | 40 | <5 | white | amp (?) | zeolites | TS, GC | Fe oxide as alteration product, clasts altered scoria, sizes range from <1mm to 2.5cm, grain supported; Rock fragments picked out and packed |
| **34DR** | **2** | Volcanoclastic breccia | 7x7x3 | subangular | Mn (3 mm) | 50-60 | 5 | white | NA | NA | TS | Lots of rusted parts as DR34-1, altered scoriae, grain supported |
| **34DR** | **3** | Encrusted breccia | 4x3x2 | subangular | Mn (1.5 cm) | 50-60 | 5 | white | NA | NA | - | Lots of rusted parts, altered scoriae, grain supported |
| **35DR** | **1** | Manganese crust | 17x12x8 | rounded | absent | NA | 0 | black | NA | NA | - | few small grey/yellow fragments included |
| **35DR** | **2** | Manganese crust | 29x15x7 | rounded | absent | NA | 0 | black | NA | NA | - | |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **36DR** | **1** | Aphyric basalt | 15x7x5 (slabs) | subrounded | Mn (1 cm) | 25 | 0 | grey | px <1mm, pl <1mm | NA | TS, GC | Basalt with Mn encrustation. Small crystals exhibit parallel orientation suggesting a trachytic or flow texture. Sample was cut into slabs with Manganese crust removed. |
| **36DR** | **2** | Aphyric basalt | 16x11x6 | subangular | Mn (1 mm) | 15 | 0 | dark grey | px 1mm, pl 1mm | zeolites | TS, GC | Basalt with Mn encrustation. |
| **36DR** | **3** | Volcanoclastic breccia | 13x9x5 | subangular | Mn (1 cm) | NA | 0 | white | px 1mm, pl 1mm | zeolites | TS | 7 cm brown basalt clast in a breccia encrusted in Mn. Clasts are matrix supported (white) and poorly sorted. |
| **36DR** | **4** | Aphyric basalt | 16x14x11 | subrounded | Mn (1 cm) | 35 | 15 | grey | px 1mm, pl 1mm | zeolites | TS, GC | Basalt with Mn encrustation. |
| **36DR** | **5** | Manganese crust | 7x7x5 | subrounded | absent | NA | 0 | black | NA | NA | - | |
| **37DR** | **1** | EncrustedVolcanoclastic breccia | 41x24x10 | angular | Mn (5 cm) | NA | 0 | yellowishwhite | NA | NA | TS | Manganese crust with a layer of breccia as nucleuswith brown basalt clasts up to 2 cm. Grain supported and poorly sorted. |
| **37DR** | **2** | Dense, phyric basalt | 8x5x4 | rounded | Mn (1 mm) | 30 | 5 | dark grey | px 1mm, pl 1mm | zeolites, epidote? | TS, GC | Basalt fragment with some white inclusions. Reddish outer appearance. |
| **38DR** | **1** | Dense, phyric basalt clast | 22x14x11 | subrounded | absent | 15 | <5 | dark grey | pl, px, yellow minerals | zeolites (?) | TS, GC | Basalts are part of Breccia, basalts extracted. Breccia is grain supported, white matrix, poorly sorted. Two different Basalts in breccia included, one further weathered than the other. Described is the less altered one. |
| **38DR** | **2** | Dense, phyric basalt clast | 12x11x8 | angular | absent | 25-30 | <5 | brown | pl, px | NA | TS, GC | Basalt clast taken from a breccia. Breccia is grain supported, white matrix, poorly sorted. Basalt makes up most of the rocks mass, which is why description belongs to basalt. |
| **38DR** | **3** | Dense, phyricbasalt clast | 10x8x7 | subangular | Mn (1 mm) | 25-30 | 0 | brown | pl, px | NA | - | Basalt clast taken from a breccia. Breccia is grainsupported, white matrix, poorly sorted. Basalt makes up most of the rocks mass. |
| **38DR** | **4** | Dense, phyric basalt clast | 9x7x5 | rounded | absent | 25 | 0 | brown to grey | pl, px | NA | - | Basalt clast taken from a breccia. Breccia is grain supported, white matrix, poorly sorted. Basalt makes up most of the rocks mass. |
| **38DR** | **5** | Dense, phyric basalt clast | 8x6x5.5 | rounded | Mn (1 mm) | 15 | 0 | grey | pl, px | zeolites (?) | TS, GC | Basalt clast taken from a breccia. Breccia is grain supported, white matrix, poorly sorted. Basalt makes up most of the rocks mass. |
| **38DR** | **6** | Volcanoclastic breccia | 7x6x5 | subangular | Mn (1 mm) | <50 | 5 | reddish brown | NA | NA | GC | GC probe is a piece of basalt (as clast in rock) broken out. Breccia includes clasts of different weathering states, is poorly sorted, grain supported, white to brown matrix. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **38DR** | **7** | Dense, phyric basalt clast | 7x6x5.5 | angular | Mn (1 mm) | <30 | 0 | green to reddish brown | pl, px | NA | TS | Basalt alteration in colourful rings, very strong differences in colour throughout the rock |
| **39DR** | **1** | Dense, phyric basalt clast | 18x15.5x8 | subrounded | Mn (3 mm) | 15 (?) | 0 | grey | px | NA | TS, GC | Basalt includes lots of small (around 1mm) whitish parts, looks like mineral accumulations. Some oxidised iron |
| **41DR** | **1** | Carbonated sedimentary rock | 29x28x16 | subrounded | Mn (1 mm) | NA | <15 | brownish grey | NA | NA | - | Carbonate fragments (e.g. of shells) in different sizes accumulated in muddy environment |
| **41DR** | **2** | Carbonate rock | 8.5x7x6 | angular | Mn (1 mm) | NA | <20 | beige-white | NA | NA | TS | Shell and coral fragments, sizes up to 7cm, almost no matrix, grainstone (DUNHAM) |
| **41DR** | **3** | Sedimentary rock | 9x5x4.5 | subangular | Mn (1 cm) | NA | 5 | brown to orange | NA | NA | - | carbonate bearing, brittle sedimentary rock, fine, muddy matrix, origin can not be further defined. |
| **41DR** | **4** | Carbonate rock | 17x11x8 | subangular | Mn (1 mm) | NA | <5 | beige-white | NA | NA | - | accumulated coral and shell fragments, poorly cemented, grain supported (nearly no matrix), grainstone (DUNHAM), fragments up to 3cm |
| **41DR** | **5** | Sedimentary rock | 13x11x7 | subrounded | Mn (1 mm) | NA | <5 | beige-white | NA | NA | - | accumulated coral and shell fragments, grain supported, packstone (DUNHAM), fragments up to 1cm |
| **41DR** | **6** | Manganese crust | 19x16x4 | rounded | absent | NA | <15 | black | NA | NA | TS | very dense on one side, reddish-brown weathered layer on the other side, less dense |
| **42DR** | **1** | Sedimentary rock | 19x14x9.5 | wellrounded | absent | NA | 0 | light brown | NA | NA | - | small carbonate and rock fragments (<1 mm) included in clay matrix, mudstone (DUNHAM) |
| **42DR** | **2** | Sedimentary rock | 15x11x7 | subangular | Mn (1 mm) | NA | 20 | beige to orange | NA | NA | - | similar overall structure as phosphorites (holes in rock covered with Mn), clay matrix, shell (<5 mm) and rock (<1 mm) fragments, wackestone (DUNHAM) |
| **42DR** | **3** | Sedimentary rock | 21x12x10 | subangular | Mn (1 mm) | NA | 40 | beige | NA | NA | - | clay matrix, few shell fragments (<5 mm), overall structure as phosphorites (holes in rock covered in Mn), mudstone (DUNHAM) |
| **42DR** | **4** | Sedimentary rock | 13x11x6.5 | subrounded | Mn (1 mm) | NA | 40 | beige | NA | NA | - | clay matrix, few shell fragments (<5 mm), overall structure as phosphorites (holes in rock covered in Mn), mudstone (DUNHAM) |
| **42DR** | **5** | Sedimentary rock | 10x7x5.5 | subangular | Mn (1 mm) | NA | <5 | yellow to brown | NA | NA | - | densely packed, grain supported, shell and coral fragments (<1.5 cm), rock fragments (<2 mm), packstone (DUNHAM) |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **43DR** | **1** | Volcanoclastic breccia | 16x11x9 | angular | Mn (1 mm) | NA | 0 | brownto white | NA | NA | TS, 2x GC | Breccia which basalt clasts, grain supported, poorly sorted, clast size up to 4 cm. Two types of basalt clasts (2x GC), one brown, phyric (pl), the other dark grey and vesicular |
| **43DR** | **2** | Manganese crust | - | subrounded | absent | NA | 0 | black | NA | NA | - | found in sediment traps |
| **44DR** | **1** | Sediment | 22x13x4 | well rounded | absent | NA | 0 | light brown | NA | NA | - | only slightly consolidated mud, organic dark parts included, clay matrix |
| **44DR** | **2** | Volcanoclastic breccia | 23x10x9 | subangular | Mn (2 cm) | 30 | 0 | reddish brown | NA | NA | TS, GC | Breccia with brown aphyric basalt clasts, grain supported, poorly sorted, clasts up to 6 cm |
| **44DR** | **3** | Volcanoclastic breccia | 9x6x5 | angular | Mn (2 cm) | 40 | 0 | brown to white | NA | NA | - | clasts <1.5 cm, dense basalts? |
| **44DR** | **4** | Dense, aphyric basalt | 11x7x5 | subangular | Fe-Mn (<1 cm) | 15 | 0 | dark grey | NA | NA | TS, GC | |
| **44DR** | **5** | Manganese crust | 9x7x3 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **44DR** | **6** | Sedimentary rock | 6x6x3 | subangular | Mn (1mm) | NA | 5 | yellow | NA | NA | - | probably carbonate rock, <5 mm shell fragments and dark grains in matrix included |
| **46DR** | **1** | Dense, phyric basalt | 28x25x21 | angular | Sediment (<1 mm) | 20 | 0 | dark grey | pl (10%),px (<5%) | NA | TS, GC | fresh looking, only few Fe-oxidised parts. Minerals up to 1 cm long, mica-like shine |
| **46DR** | **2** | Dense, aphyric basalt | 30x18x12.5 | angular | Sediment (<1 mm) | 15 | 0 | grey to brown | NA | NA | TS, GC | mica-like shine in one direction (two sides of cut cube), some cracks with brownish weathering marks around, very homogeneous except shine |
| **46DR** | **3** | Dense, phyric basalt | 17.5x16x9 | subangular | absent | 20 | <5 | dark grey | pl (10%), px (<3%) | NA | TS, GC | fresh looking, only few Fe-oxidised parts. Minerals up to 1 cm long |
| **46DR** | **4** | Dense, phyric basalt | 14x11.5x10 | subangular | Sediment (<1 mm) | 25 | 0 | dark grey | pl (10%), px (<5%) | NA | - | fresh looking, only few Fe-oxidised parts. |
| **46DR** | **5** | Dense, aphyric basalt | 15x11x9.5 | angular | Sediment (<1 mm) | 30 | 0 | grey | NA | NA | - | Some cracks in rock, brownish weathering marks around cracks, mica-like shine |
| **46DR** | **6** | Dense, phyric basalt | 14x10x8 | rounded | Sediment (<1 mm) | 25 | <5 | dark grey | pl (10%), px | NA | TS, GC | fresh looking, only few Fe-oxidised parts, mica-like shine |
| **46DR** | **7** | Phyric basalt | 10x6x4 | subangular | absent | 25 | 15-20 | brown-grey | px | NA | TS, GC | bright spots in less weathered parts |
| **46DR** | **8** | Volcanoclastic breccia | 37x26x25 | subangular | absent | NA | 0 | yellow to white | NA | NA | - | poorly sorted, grains up to 8 cm, grain supported breccia. Clasts: phyric, dense basalts, mica-like shine. Similar to 46DR1 |
| **46DR** | **9** | Volcanoclastic breccia | 24x17x12 | subangular | absent | NA | 0 | yellowto white | NA | NA | - | Basalt clasts phyric, dense, up to 6cm wide. Breccia poorly sorted, grain supported |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **46DR** | **10** | Volcanoclastic breccia | 19x17x13 | subangular | absent | NA | 0 | yellow to white | NA | NA | - | Basalt clasts phyric, dense, up to 7 cm wide. Breccia poorly sorted, grain supported |
| **46DR** | **11** | Sedimentary rock | 9x8x5 | subangular | absent | NA | 15 | beige | NA | NA | - | clay matrix, soft, small holes and channels throughout the rock |
| **46DR** | **12** | Manganese crust | 8x5.5x2 | subangular | absent | NA | 0 | black | NA | NA | - | some reddish weathered parts |
| **46DR** | **13** | Coral | 8x5x1.5 | rounded | - | - | - | - | - | | - | |
| **48DR** | **1** | Amygdaloidal basalt | 31x34x20 | subrounded | Mn (2 cm) | 25 | <15 | dark grey | px | zeolites | GC (3x), TS (3x) | Breccia is of poorly sorted clasts; Clast size up to 10 cm; grain supported breccia; brittle; Clasts were very different, three samples (GC and TS) taken |
| **48DR** | **2** | Encrusted breccia | 40x30x10 | subangular | Mn (3 cm) | 70 | <5 | greenish yellow | NA | NA | - | Breccia is of poorly sorted, red clasts; bright veins going through matrix and clasts; matrix supported rock; close to the Mn rim white clasts accumulate |
| **48DR** | **3** | Encrusted breccia | 27x25x12 | subrounded | Mn (4.5 cm) | 70 | <5 | bright yellow | NA | NA | - | Breccia is of poorly sorted clasts, partly basaltic others red or pale green. Matrix is soft and dense. Red clasts are fully altered. |
| **48DR** | **4** | Encrusted basalt | 5.5x5x5 | well rounded | Mn (1.5 cm) | 30 | <15 | dark grey | NA | NA | GC, TS | spherical basalt; increase of vesicularity to the core; vesicles are very spherical too; some of the big ones are filled with red-brown alteration products (Fe-hydroxides) |
| **48DR** | **5** | Amygdaloidal basalt | 6x5x4.5 | well rounded | absent | 40 | 25 | dark grey | NA | zeolites | GC, TS | spherical basalt; vesicles are very spherical too; some of the big ones are filled with red-brown alteration products (Fe-hydroxides); no pattern in the zeolite distribution |
| **48DR** | **6** | Amygdaloidal basalt | 5x5x4 | well rounded | Mn (1 mm) | 40 | 25 | brownish grey | NA | zeolites | TS | weathered minerals (Fe-red) cannot be named due to alteration but phyric structure is clearly visible |
| **48DR** | **7** | Sedimentary rock | 7.5x6x4 | subrounded | Mn (1 cm) | NA | <5 | white | NA | NA | - | dark spots in fine matrix |
| **48DR** | **8** | Amygdaloidal basalt | 22x16x12 | subrounded | Mn (3 cm) | 40 | <30 | brownish grey | amp | zeolites | TS, GC | basalt as clast in breccia, breccia poorly sorted, grain supported, greenish matrix. Clasts up to 10 cm. Basalt varies in vesicularity and alteration rate, some Fe-weathered minerals |
| **49DR** | **1** | Amygdaloidal basalt | 40x39x22 | angular | Mn (8 cm) | 45 | 30 | brownish grey | NA | zeolites, green fillings | TS, GC | vesicles (<4 mm) evenly spread throughout rock, not oriented, round, some filled with zeolites or green alteration products. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **49DR** | **2** | Amygdaloidal basalt | 21x14x7 | subrounded | Mn (2.5 cm) | 45 | 25 | grey | amp | zeolites | TS, GC | different fillings of vesicles, some greenish, some white, some whites include black parts which seem to come from also black cracks. Fillings not evenly distributed, vesicles evenly distributed. Vesicle size <3 mm |
| **49DR** | **3** | Amygdaloidal basalt | 12x9x8 | subrounded | Mn (2 cm) | 45 | 30 | grey | px(?) | zeolites, green fillings | TS, GC | matrix coarser (in comparison to other basalts from 49DR), vesicles evenly spread, no direction visible |
| **49DR** | **4** | Amygdaloidal basalt | 9x6x2 | angular | absent | 45 | 25 | brownish grey | mafic minerals | zeolites | - | small minerals (<0.5 mm), vesicles <1 mm, round and evenly distributed |
| **49DR** | **5** | Manganese crust | 13x10x8 | angular | Mn (5 cm) | NA | 0 | black | NA | NA | - | crust makes up ca. 65% of rock, sedimentary rock attached, vesicles 40%, matrix colour white |
| **49DR** | **6** | Manganese crust | 13x13x6 | angular | absent | NA | 0 | black | NA | NA | - | some reddish weathered parts, sedimentary rock parts attached |
| **51DR** | **1** | Sedimentary rock | 12x7x6 | subangular | Mn (1 mm) | NA | 0 | white | NA | NA | - | holes in rock (burrows?), encrusted with manganese |
| **52DR** | **1** | Volcanoclastic breccia | 10x7.5x4 | angular | Mn (1 cm) | NA | 0 | white | NA | NA | TS, GC | Manganese crust with breccia attached, including a small cobble of basalt, taken for TS and GC. |
| **52DR** | **2** | Manganese crust | 11.5x5x3.5 | angular | Mn (3.5 cm) | NA | 0 | black | NA | NA | - | some reddish weathered parts |
| **53DR** | **1** | Aphyric basalt | 7x3x3 | angular | absent | 60 | <5 | brown | NA | zeolites | TS, GC | brown altered basalt |
| **53DR** | **2** | Aphyric basalt | 8x7x6 | angular | Mn (<1 mm) | 40 | 0 | grey | NA | NA | TS, GC | brown altered basalt |
| **53DR** | **3** | Manganese crust | 8x8x4 | subangular | Mn (4 cm) | NA | 0 | black | NA | NA | - | |
| **53DR** | **4** | Manganese crust | 12x10x3 | subangular | Mn (3 cm) | NA | 0 | black | NA | NA | - | |
| **54DR** | **1** | Volcanoclastic breccia | 36x20x13 | subangular | Mn (3 cm) | NA | 0 | yellow to white | NA | NA | 5x TS,6x GC | Breccia poorly sorted; grain supported; clasts reddish brown to grey; clast size up to 6cm. Six clasts hammered out and sampled separately as GC and TS, clasts show varying vesicularity, alteration and secondary fillings. |
| **54DR** | **2** | Dense, phyric basalt | 10x7x2 | angular | absent | 25 | <5 | grey | px (5%, <3mm), pl (<0.5mm) | NA | TS, GC | Fe-weathered minerals, greenish alteration products in some vesicles |
| **54DR** | **3** | Volcanoclastic breccia | 9x6.5x5 | subangular | Mn (1 cm) | NA | <5 | greenish white | NA | NA | - | breccia poorly sorted; grain supported; clasts up to 3 cm |
| **54DR** | **4** | Volcanoclastic breccia | 8.5x8x3.5 | angular | Mn (5 mm) | NA | 0 | white | NA | NA | - | breccia poorly sorted; grain supported; clasts up to 2 cm. Clasts partly aphyric and vesicular |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **54DR** | **5** | Manganese crust | 17x11x6 | angular | absent | NA | 0 | black | NA | NA | - | |
| **54DR** | **6** | Coral | - | | - | NA | 0 | - | - | - | - | |
| **55DR** | **1** | Dense, phyric basalt | 38x21x14 | rounded | Mn (3 mm) | 60 | 0 | brown | NA | clay? | XRD | altered basalt. Secondary black minerals (Mn?) pervasive. |
| **55DR** | **2** | Dense, phyric basalt | 30x20x18 | rounded | Mn (<1 mm) | 60 | 0 | brown | NA | clay? | TS, GC, XRD | altered basalt. Secondary black minerals (Mn?) pervasive. |
| **55DR** | **3-1** | Dense, phyric basalt | 30x22x18 | subrounded | Mn (<1 mm) | 55 | 0 | grey | NA | clay? | TS, 2xGC, XRD | altered basalt. Secondary black minerals (Mn?) pervasive. |
| **55DR** | **3-2** | Aphyric basalt | 30x22x18 | subrounded | Mn (<1 mm) | 15 | 15 | grey | NA | clay? | TS, GC, XRD | basalt pebble attached to 3-1 |
| **55DR** | **4** | Aphyric basalt | 30x10x8 | subangular | absent | 50 | 0 | brown-grey | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. |
| **55DR** | **5** | Aphyric basalt | 18x13x14 | rounded | Mn (2 mm) | 65 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. |
| **55DR** | **6** | Aphyric basalt | 13x13x9 | rounded | Mn (<1 mm) | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. |
| **55DR** | **7** | Manganese crust | 28x20x6 | subrounded | Mn (6 cm) | NA | 0 | black | NA | NA | TS, XRD | |
| **55DR** | **8** | altered basalt rim | 4.5x3x2 | angular | Mn (<1 mm) | 80 | 0 | white | NA | clay? | - | Outer rim of a highly altered basalt with pervasive secondary black minerals (Mn?) present. |
| **57DR** | **1** | Manganese boulder | 55x48x20 | subrounded | Mn (9 cm) | NA | 0 | black | NA | NA | - | pebble to cobble sized rock fragments cemented by Mn. Subsamples 1-9 are brown altered basalts. Subsample 10 is a limestone fragments with lots of round foraminifera |
| **57DR** | **1-1** | Aphyric basalt fragment | 13x9x5 | subangular | absent | 60 | 0 | brown | NA | clay? | TS, GC | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-2** | Aphyric basalt fragment | 13x6x5 | subangular | absent | 60 | 0 | brown | NA | clay? | TS, GC | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-3** | Aphyric basalt fragment | 7x6x5 | subangular | absent | 60 | 0 | brown | NA | clay? | TS, GC, XRD | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-4** | Aphyric basalt fragment | 26x17x6 | subrounded | absent | 60 | 0 | brown | NA | clay? | TS, GC | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-5** | Aphyric basalt fragment | - | subrounded | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-6** | Aphyric basalt fragment | - | subrounded | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-7** | Aphyric basalt fragment | - | subrounded | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **57DR** | **1-8** | Aphyric basalt fragment | - | subrounded | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-9** | Aphyric basalt fragment | - | subrounded | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **1-10** | Aphyric basalt fragment | - | subrounded | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 1. |
| **57DR** | **2** | Manganese boulder | 36x26x20 | subrounded | Mn (10 cm) | NA | 0 | black | NA | NA | - | pebble to cobble sized rock fragments cemented by Mn. |
| **57DR** | **2-1** | Aphyric basalt fragment | 9x8x7 | subangular | absent | 60 | 0 | brown | NA | clay? | TS, GC, XRD | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-2** | Aphyric basalt fragment | 13x10x5 | subrounded | absent | 55 | 0 | brown to grey | NA | clay? | TS, GC, XRD | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-3** | Aphyric basalt fragment | 6x5x5 | subangular | absent | 60 | 0 | brown | NA | clay? | TS, GC | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-4** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-5** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-6** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-7** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-8** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-9** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-10** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-11** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-12** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-13** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **2-14** | Aphyric basalt fragment | - | subangular | absent | 60 | 0 | brown | NA | clay? | - | altered basalt. Secondary black minerals (Mn?) pervasive. Subsample of 2 |
| **57DR** | **3** | Manganese crust | 22x16x9 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **57DR** | **4** | Manganese crust | 10x8x4 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **57DR** | **5** | Manganese crust | 8x5x4 | subangular | absent | NA | 0 | black | NA | NA | - | |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **58DR** | **1** | Manganese crust | 30x22x10 | subangular | absent | NA | 0 | black | NA | NA | GC | Manganese crust with small pebble of brown amygdaloidal basalt |
| **58DR** | **2** | Volcanoclastic Breccia | 26x18x9 | subangular | Mn (1 cm) | NA | 0 | white | NA | NA | TS, XRD | Breccia with dark brown volcanic lithic fragments. Grain supported and poorly sorted. |
| **58DR** | **3** | Volcanoclastic Breccia | 25x16x6 | subangular | Mn (5 mm) | NA | 0 | white | NA | NA | TS, XRD | Breccia with grey to brown vesicular basalt fragments. Grain supported and poorly sorted. |
| **58DR** | **4** | Volcanoclastic Breccia | 11x10x4 | subrounded | Mn (<1 mm) | NA | 0 | white | NA | NA | - | Breccia with brown vesicular basalt fragments. Matrix supported and poorly sorted. |
| **58DR** | **5** | Manganese crust | 12x8x6 | subangular | Mn (6 cm) | NA | 0 | black | NA | NA | - | |
| **59DR** | **1** | Manganese boulder | 60x42x22 | subrounded | Mn (<6 cm) | NA | <5 | beige-white | NA | | XRD, TS | Gain supported, poorly sorted; Clast size up to 13 cm; clasts vesicular, Phyric basalt: some party include reddish clay or mud lenses. 8 clasts sampled separately. |
| **59DR** | **1-1** | Phyric basalt fragment | 13.5x8x4 | subangular | absent | <50 | <15 | brown | amph, px | zeolites | TS, GC | Moderately altered basalts, shiny tiny spots are observed on the vesicles, most likely owing to zeolites, pervasive, subsample of 1 |
| **59DR** | **1-2** | Aphyric basalt fragment | 3.5x3.5x2 | angular | absent | 30 | <15 | grey to brown | NA | zeolites | TS, GC | on one side red weathering mark, vesicles show inhomogeneous sizes, up to 2 mm; possibly primary direction of the vesicles |
| **59DR** | **1-3** | Phyric basalt fragment | 5x3x3 | subangular | absent | <60 | 10 | reddish brown | amph(?) | zeolites | - | Pervasive altered basalt. Subsample of 1 |
| **59DR** | **1-4** | Phyric basalt fragment | 8.5x6x5 | subrounded | absent | <30 | 5-15 | grey to brown | px | zeolites | GC | on one side red weathering marks; inhomogeneous distribution and sizes (up to 4 mm) |
| **59DR** | **1-5** | Phyric basalt fragment | 6x4x3 | subangular | absent | <50 | 5-10 | brown | amph | zeolites | GC | Pervasive altered basalt. Subsample of 1 |
| **59DR** | **1-6** | altered scoria | 6x3.5x3 | subrounded | absent | <80 | 40-50 | brown | NA | NA | - | Pervasive altered basalt. Subsample of 1 |
| **59DR** | **1-7** | Phyric basalt fragment | 10x7x5 | subangular | absent | <50 | 5 | brownish grey | amph | zeolites | TS, GC, XRD | Pervasive altered basalt. Subsample of 1 |
| **59DR** | **1-8** | Phyric basalt fragment | 7x5.5x5 | angular | absent | <30 | 5-20 | grey to brown | amph | zeolites | - | Inhomogeneous distribution of vesicle sizes (up to 4 mm); some vesicles have white, glasslike minerals growing at the rims |
| **59DR** | **2** | Manganese crust | 20x17x10 | rounded | absent | NA | 0 | greyish white | NA | NA | - | Grain supported, poorly sorted, clasts phyric, vesicles in volcanic rocks; clast sizes up to 7 cm |
| **59DR** | **3** | Manganese crust | 10x8x6 | subangular | absent | NA | 0 | black | NA | NA | - | |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **59DR** | **4** | Manganese crust | 11x7x5 | subrounded | absent | NA | 0 | black | NA | NA | - | some Fe-weathering at one side; some white sedimentary Matrix included as well as red clay |
| **59DR** | **5** | Manganese crust | 9x8x3.5 | subrounded | absent | NA | 0 | black | NA | NA | - | some Fe-weathering |
| **61DR** | **1** | Phyric vesicular basalt | 9x6.5x6 | rounded | Mn (1 mm) | <50 | 10 | brownish grey | amph, px(?) | NA | TS, GC | The alteration changes from rims to the center, the dark minerals do not show high degree of alteration. |
| **61DR** | **2** | Encrusted breccia | 29x15x10 | subrounded | Mn (1 mm) | <40 | 10 | brownish grey | amph, px | zeolites (?) | TS, GC | Similar to 61DR1, but its center shows lower degree of alteration than that of 61DR1, white secondary minerals with black spots exist in some vesicles. |
| **61DR** | **3** | Volcanoclastic breccia | 16x8.5x5 | angular | Mn (1 mm) | NA | 0 | yellow-white | NA | NA | TS, XRD | Breccia with dark brown volcanic lithic fragments. Grain supported and poorly sorted. |
| **61DR** | **4** | Volcanoclastic breccia | 14x7x4 | angular | Mn (1 mm) | NA | 0 | yellow-white | NA | NA | - | similar to 61DR3, but the breccia is more altered. |
| **61DR** | **5** | Volcanoclastic breccia | 11.5x6.5x6 | angular | Mn (5 mm) | NA | 0 | yellow-white | NA | NA | - | similar to 61DR3 |
| **62DR** | **1** | Dense, phyric basalt | 37x30x18 | angular | absent | 15 | <5 | dark grey | ol, pl, px? | NA | TS, GC | some intact olivine phenocrysts, greenish weathering spreading from cracks into intact rock, Fe-weathering in some minerals |
| **62DR** | **2** | Dense, phyric basalt | 30x17x16 | angular | Mn (<5 mm) | 15 | <5 | grey | ol, pl, px? | NA | TS, GC, XRD | Olivines partly intact, partly weathered, cracks filled with white substance, some "nests" of mineral assemblages |
| **62DR** | **3** | Dense, phyric basalt | 16x13x10 | angular | Mn (1-5 mm) | 20 | <5 | grey | ol, px | zeolites | - | alteration varying throughout rock, some parts olivines are nearly completely altered/weathered, in other parts intact |
| **62DR** | **4** | Dense, phyric basalt | 23x17x13 | angular | Mn (<1 mm) | 20 | <5 | grey | px (<1 mm) | zeolites | - | possibly remainings of olivine, Fe-weathering |
| **62DR** | **5** | Dense, phyric basalt | 17x12x9 | subangular | Mn (1 mm) | 15 | 0 | grey | px (<1 mm), ol, pl (?) | NA | TS, GC | Fe-weathering, varying alteration throughout the rock |
| **62DR** | **6** | Dense, phyric basalt | 16x11x8.5 | subangular | Mn (<1 cm) | 20 | 0 | grey | px (<3 mm), ol, pl | NA | - | Fe-weathering, varying alteration throughout the rock |
| **62DR** | **7** | Volcanoclastic breccia | 27x21x12 | subangular | Mn (<4.5 cm) | NA | 0 | yellow, white, brown | NA | NA | - | poorly sorted, grain supported; clasts angular to well rounded, some show white veins |
| **62DR** | **8** | Volcanoclastic breccia | 18x11x11 | angular | Mn (<5 cm) | NA | 0 | yellow to brown | NA | NA | - | very angular, very altered looking clasts; breccia poorly sorted, grain supported |
| **62DR** | **9** | Encrusted aphyricbasalt | 9.5x8x5.5 | subangular | Mn (1.5 cm) | NA | <5 | yellow to grey | NA | NA | - | Crust almost completely surrounding basalt, no intern mineral assemblage visible |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **62DR** | **10** | Sedimentary rock | 1x7.5x5.5 | subrounded | Mn (1 mm) | NA | 30-40 | reddish beige | NA | NA | - | |
| **62DR** | **11** | Coral | 19.5x0.7x0.7 | well rounded | absent | - | - | - | - | - | - | |
| **63DR** | **1** | Manganese crust | 6x5x2 | subangular | absent | NA | 0 | black | NA | NA | - | some red weathered parts, some white sediment at bottom of sample |
| **64DR** | **1** | Manganese crust | 14x12x4.5 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **67DR** | **1** | Phyric basalt | 32x20x14 | rounded | Mn (2 cm) | 10 | 0 | dark grey | px or amph <2 mm | Fe oxide? | TS, GC, XRD | grey basalt with brown alteration (Fe oxide?). Alteration is common in the groundmass and along larger black crystal grains (cpx?). Full or complete alteration is common but partial alteration of crystal sections or rims is also present. |
| **67DR** | **2** | Volcanoclastic breccia | 55x38x11 | subangular | Mn (4 cm) | NA | 0 | white | NA | NA | - | Breccia with up to 2.5 cm clasts of brown to grey basalt. |
| **67DR** | **3** | Volcanoclastic breccia | 24x14x6 | subrounded | Mn (1 mm) | NA | 0 | white | NA | NA | TS, GC | Breccia with up to 4 cm clasts of brown to grey basalt. |
| **67DR** | **4** | Volcanoclastic breccia | 28x13x12 | subrounded | Mn (1.5 cm) | NA | 0 | white | NA | NA | - | Breccia with up to 2 cm clasts of brown to grey basalt. |
| **67DR** | **5** | Volcanoclastic breccia | 12x8x4 | subangular | Mn (1 mm) | NA | 0 | white | NA | NA | - | Breccia with up to 2 cm clasts of brown to grey basalt. |
| **67DR** | **6** | Volcanoclastic breccia | 15x14x6 | angular | Mn (4 cm) | NA | 0 | white | NA | NA | - | Breccia with up to 1 cm clasts of brown to grey basalt. |
| **67DR** | **7** | Volcanoclastic breccia | 22x18x6 | subangular | Mn (5 cm) | NA | 0 | white | NA | NA | - | Breccia with up to 2.5 cm clasts of brown to grey basalt. |
| **67DR** | **8** | Phosphorite | 18x16x13 | angular | Mn (3 cm) | NA | 0 | white | NA | Mn | - | Phosphorite with attached Manganese crust |
| **67DR** | **9** | Phosphorite | 21x14x5 | subangular | Mn (3 cm) | NA | 0 | white | NA | Mn | - | Phosphorite with attached Manganese crust |
| **67DR** | **10** | Manganese crust | 15x10x7 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **68DR** | **1** | Volcanoclastic breccia | 20x19x12 | subangular | Mn (3 cm) | NA | <5 | beige | NA | NA | - | Breccia poorly sorted, grain supported; clasts <3 cm; few clasts show grey matrix, most are red and altered |
| **68DR** | **2** | Volcanoclastic breccia | 16x9x6 | subangular | Mn (<3 mm) | NA | <5 | beige | NA | NA | - | Breccia poorly sorted, grain supported; clasts <2.5 cm; some clasts show grey matrix and zeolites, most are red and altered |
| **68DR** | **3** | Volcanoclastic breccia | 19x14x10 | subrounded | Mn (<2 cm) | NA | 0 | beige to salmon | NA | NA | - | Breccia poorly sorted, grain supported; clasts <2 cm; clasts are red and altered; matrix partly red clay |
| **68DR** | **4** | Volcanoclastic breccia | 14x10x8 | angular | Mn (5 mm) | NA | 0 | white to beige | NA | NA | TS | Breccia poorly sorted, grain supported; clasts <2 cm; clasts are red and altered; some clasts include zeolites |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **68DR** | **5** | Encrusted volcanoclastic breccia | 21x18x7 | subrounded | Mn (3 cm) | NA | 10 | beige | NA | NA | - | Breccia poorly sorted, grain supported; clasts <3 cm; clasts are red and altered except for one completely surrounded by crust, that one is grey and vesicular (>20%) |
| **68DR** | **6** | Volcanoclastic breccia | 14x9x7 | rounded | Mn (2 cm) | NA | <5 | beige | NA | NA | - | Breccia poorly sorted, grain supported; clasts <4 cm; clasts are red and altered |
| **68DR** | **7** | Volcanoclastic breccia | 12x9x3 | subangular | absent | NA | <5 | red to white, black | NA | NA | - | Breccia poorly sorted, grain supported; clasts <3 cm; clasts are red and altered vesicular basalts; matrix partly red clay, partly manganese(?) |
| **68DR** | **8** | Encrusted volcanoclastic breccia | 35x26x12 | subrounded | Mn (3.5 cm) | NA | 0 | white | NA | NA | - | Breccia poorly sorted, grain supported; clasts <3.5 cm; clasts are red and altered; matrix partly red clay |
| **68DR** | **9** | Encrusted volcanoclastic breccia | 32x21x11 | subangular | Mn (5.5 cm) | NA | 0 | white | NA | NA | - | Breccia poorly sorted, grain supported; clasts <2 cm; some clasts show grey matrix and zeolites, most are red and altered; matrix partly red clay |
| **68DR** | **10** | Volcanoclastic breccia | 10x8x5 | subangular | Mn (5 mm) | NA | <5 | white | NA | NA | - | Breccia poorly sorted, grain supported; clasts <3 cm; some clasts show grey matrix and zeolites, most are red and altered |
| **69DR** | **1** | Vesicular basalt | 34x24x12.5 | angular | Mn (5 mm) | 10 | 25 | grey | NA | zeolites (?), phl(?) | TS, GC, XRD | Vesicular andesite with elongated vesicles as flow textures. Few vesicles are filled with white (phosphorite?) minerals. Higher silica content inferred from grey colour of the groundmass. |
| **69DR** | **2** | Vesicular basalt | 20x16x15.5 | angular | Mn (5 mm) | 10 | 25 | grey | NA | zeolites (?) phl(?) | TS, GC | Vesicular andesite with elongated vesicles as flow textures. Few vesicles are filled with white (phosphorite?) minerals. Higher silica content inferred from grey colour of the groundmass. |
| **69DR** | **3** | Vesicular basalt | 13x11x8 | angular | Mn (<1 mm) | 10 | 25 | grey | NA | zeolites (?), phl(?) | TS | Vesicular andesite with elongated vesicles as flow textures. Few vesicles are filled with white (phosphorite?) minerals. Higher silica content inferred from grey colour of the groundmass. |
| **69DR** | **4** | Vesicular basalt | 9x6x6 | subangular | Mn (<1 mm) | 10 | 25 | grey | NA | zeolites (?), phl(?) | - | Vesicular andesite with elongated vesicles as flow textures. Few vesicles are filled with white (phosphorite?) minerals. Higher silica content inferred from grey colour of the groundmass. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **69DR** | **5** | Vesicular basalt | 11x9x4.5 | angular | Mn (1 cm) | 10 | 25 | grey | NA | zeolites (?) phl(?) | - | Vesicular andesite with elongated vesicles as flow textures. Few vesicles are filled with white (phosphorite?) minerals. Higher silica content inferred from grey colour of the groundmass. |
| **69DR** | **6** | Volcanoclastic breccia | 7x7x5 | subangular | Mn (1 cm) | NA | 0 | white | NA | Mn | TS | Breccia with up to 2 cm grey vesicular andesite clasts. Grain supported and poorly sorted. |
| **71DR** | **1** | Manganese crust | 13.5x10x4.5 | angular | absent | NA | 0 | black | NA | NA | - | possibly some small basalt clasts included? |
| **71DR** | **2** | Volcanoclastic breccia | 16x10x5 | subangular | Mn (1 cm) | NA | 0 | white | NA | NA | TS | breccia with up to 2 cm brown to grey vesicular basalt clasts. Grain supported and poorly sorted. |
| **71DR** | **3** | Volcanoclastic breccia | 20x11x9 | subrounded | Mn (<5 cm) | NA | 0 | NA | Bottle-green minerals <2 cm | NA | GC | one green mineral included in Mn, others in basalts and more altered (red). Slightly elongated form. The freshest was broken off the rock and sampled in a separate bag, than included in "=03 rest" bag. |
| **72DR** | **1** | Vesicular basalt clast | 8.5x7x4 | subrounded | Mn (2 cm) | 40 | 10 | brown | amph? (<5mm) | NA | TS, GC | TS sample is taken from the phosphorite and Manganese crust. altered brown volcanic rock with plenty of euhedral black grains (amphibole) taken from a breccia with white matrix (phosphorite?) |
| **73DR** | **1** | Dense, phyric basalt | 12x11x6 | angular | Mn (<1 mm) | 25 | 0 | grey | black minerals <1mm | clays | TS, GC, XRD | Fine-grained grey basalt with brown alteration with very few visible phenocrysts |
| **73DR** | **2** | Phosphorite | 12x6x5 | subangular | Mn (<1 mm) | NA | 0 | white | NA | Mn | TS | phosphorite with Manganese crust attached |
| **73DR** | **3** | Dense, phyric basalt | 39x15x11 | subrounded | Mn (3 cm) | 30 | 0 | grey | px <1cm, amph <1mm | clays | TS, GC | Fine-grained grey basalt with brown alteration. Alteration halos are visible in the sample. Basalt cobble with few phenocrysts taken from a phosphorite |
| **73DR** | **4** | Phosphorite | 13x6x6 | subangular | Mn (1 mm) | NA | 0 | white | NA | Mn | TS, GC | TS and GC samples are taken from a 4cm angular basalt pebble found in the phosphorite |
| **73DR** | **5** | Phosphorite | 9x5x5 | subrounded | Mn (<1 mm) | NA | 0 | white | NA | Mn | - | phosphorite with Manganese crust attached |
| **73DR** | **6** | Phosphorite | 11x10x9 | subrounded | Mn (3 cm) | NA | 0 | white | NA | Mn | - | phosphorite with Manganese crust attached |
| **73DR** | **7** | Manganese crust | 15x7x5 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **73DR** | **8** | sponge/coral | - | elongated | - | - | - | - | - | - | - | |
| **74DR** | **1** | Volcanoclastic breccia | 18x10x7 | subrounded | Mn (5 cm) | NA | 0 | white | NA | NA | TS | breccia with up to 3 cm brown basalt. Grain supported and poorly sorted. |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **75DR** | **1** | Volcanoclastic breccia | 7x7x5 | subangular | absent | NA | 0 | white | NA | NA | TS, GC | breccia with up 5cm grey basalt clast. Matrix supported and poorly sorted. |
| **75DR** | **2** | Phosphorite | 20x16x7 | angular | Mn (<1 mm) | NA | 0 | beige | NA | Mn | - | encrusted phosphorite |
| **75DR** | **3** | Phosphorite | 10x6x4 | angular | Mn (<1 mm) | NA | 0 | beige | NA | Mn | TS | encrusted phosphorite |
| **75DR** | **4** | Phosphorite | 9x6x3 | angular | Mn (<1 mm) | NA | 0 | beige | NA | Mn | - | encrusted phosphorite |
| **76DR** | **1** | Manganese crust | 11x10x4 | subangular | absent | NA | 0 | black | NA | NA | - | |
| **76DR** | **2** | Volcanoclastic breccia | 7x7x5 | subangular | absent | NA | 0 | white | NA | NA | TS,GC | breccia with up to 7 cm grey vesicular basalt. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **3** | Volcanoclastic breccia | 16x16x10 | subrounded | Mn (<1 mm) | NA | 0 | white | NA | zeolites? | TS, GC, XRD | breccia with up to 13 cm grey amygdaloidal basalt. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **4** | Vesicular basalt clast | 7x7x5 | subrounded | absent | 30 | 30 | grey | NA | NA | TS,GC | grey vesicular basalt clast |
| **76DR** | **5** | Volcanoclastic breccia | 12x8x8 | subrounded | Mn (<1 mm) | NA | 0 | grey | NA | zeolites? | - | grey amygdaloidal basalt clast |
| **76DR** | **6** | Volcanoclastic breccia | 6x5x3 | subrounded | Mn (<1 mm) | NA | 0 | white | NA | NA | - | breccia with up to 6 cm grey vesicular basalt clast. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **7** | Vesicular Basalt clast | 8x6x5 | subrounded | Mn (<1 mm) | 35 | 35 | grey | NA | NA | - | grey vesicular basalt clast. Alteration halos are visible |
| **76DR** | **8** | Vesicular Basalt clast | 7x5x3.5 | subangular | Mn (<1 mm) | 30 | 40 | grey | NA | NA | - | grey vesicular basalt clast. |
| **76DR** | **9** | Volcanoclastic breccia | 18x13x12 | subrounded | Mn (<1 mm) | NA | 0 | white | NA | NA | - | breccia with grey amygdaloidal basalt. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **10** | Volcanoclastic breccia | 16x14x10 | subangular | Mn (2 cm) | NA | 0 | white | NA | NA | TS, GC, XRD | breccia with up to 10 cm grey basalt. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **11** | Volcanoclastic breccia | 28x18x11 | subangular | Mn (<1 mm) | NA | 0 | white | NA | NA | - | breccia with up to 10 cm grey vesicular basalt. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **12** | Volcanoclastic breccia | 16x9x4 | subangular | absent | NA | 0 | white | NA | NA | - | breccia with up to 5 cm grey vesicular basalt. Grain supported and moderately well-sorted. Phosphorite matrix. |
| **76DR** | **13** | Vesicular basalt clast | 9x6x6 | subangular | Mn (<1 mm) | 30 | 30 | grey | NA | NA | - | grey vesicular basalt clast. |
| **76DR** | **14** | Volcanoclastic breccia | 16x15x10 | subrounded | Mn (<1 mm) | NA | 0 | white | NA | NA | TS,GC | breccia with up to 10 cm grey vesicular basalt. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **15** | Vesicular basalt clast | 8x6x6 | rounded | Mn (<1 mm) | 30 | 45 | grey | NA | zeolites? | TS,GC | grey amygdaloidal basalt clast |

| Station | Sample Nr. | Rock Type | Size (cm) | Shape/ angularity | Encrustation (mm) | Degree of Alteration (%) | Vesicularity (%) | Matrix Colour | Primary Minerals | Secondary Minerals | Samples Taken | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **76DR** | **16** | Volcanoclastic breccia | 9x6x6 | subrounded | absent | NA | 0 | white | NA | NA | - | breccia with up to 10 cm grey vesicular basalt. Grain supported and poorly sorted. Phosphorite matrix. |
| **76DR** | **17** | Vesicular basalt clast | 8x5x4 | subangular | Mn (<1 mm) | 30 | 15 | grey | NA | zeolites? | - | grey amygdaloidal basalt clast |
| **76DR** | **18** | Volcanoclastic breccia | 16x11x11 | subrounded | Mn (<1 mm) | NA | 0 | white | NA | NA | TS | breccia with up to 8 cm grey vesicular basalt. Grain supported and poorly sorted. Some portion of the phosphorite matrix (pinkish) is still soft. |
| **76DR** | **19** | Vesicular basalt clast | 8x6x5 | subrounded | Mn (<1 mm) | 35 | 40 | grey | NA | NA | - | breccia with up to 8 cm grey vesicular basalt. Grain supported and poorly sorted. Some portion of the phosphorite matrix (pinkish) is still soft. |
| **76DR** | **20** | Volcanoclastic breccia | 30x20x20 | subangular | Mn (1 cm) | NA | 0 | white | NA | NA | - | |
| **77DR** | **1** | Dense, phyric basalt | 42x33x30 | subrounded | Mn (1 cm) | 25 | 5 | brown | NA | NA | TS, GC, XRD | big block packed as rest, could not be opened with saw. Probably better GC samples possible with this part |
| **77DR** | **2** | Vesicular basalt | 22x14x13 | subrounded | Mn (3 cm) | 23-30 | 40 | brown grey | NA | zeolites | TS, GC, XRD | minerals were up to 2mm in size, strong alteration makes defining them by eye difficult |
| **77DR** | **3** | Vesicular basalt | 17x13x10 | subangular | Mn (3 cm) | <50 | 50-60 | red/brown/ grey | mafic minerals (1%) | zeolites | - | Fe-hydroxides as alteration product; greenish weathering |
| **77DR** | **4** | Vesicular basalt | 8x8x7 | subangular | Mn (<5 mm) | 40 | 50-60 | red/brown/ grey | NA | zeolites | - | Less Zeolite than 3 |
| **77DR** | **5** | Vesicular basalt | 8x6x5 | subangular | Mn (1 mm) | 40 | 50-60 | red/brown/ grey | NA | zeolites | - | |
| **77DR** | **6** | Vesicular basalt | 6x4x2.5 | subangular | Mn (1 mm) | 30 | 50-60 | red/brown/ grey | NA | zeolites | - | |
| **77DR** | **7** | Manganese crust | 15x13x4 | subangular | absent | 0 | 0 | black | NA | NA | - | |
| **77DR** | **8** | Encrusted breccia | 16x12.5x11 | subangular | Mn (4 cm) | <5 | 0 | greenishto beige | NA | NA | - | intermediate sorted; grain supported; basalt clasts (up to 4 cm). Clasts similar to 77DR6 |

Abbreviation list:
amph = amphibole; il = ilmenite; Mn = manganese; ol = olivine; phl = phosphorite; pl = plagioclase; px = pyroxene; sed = sedimentar

## 10.2 Rock sample photographs


5DR-1


5DR-2

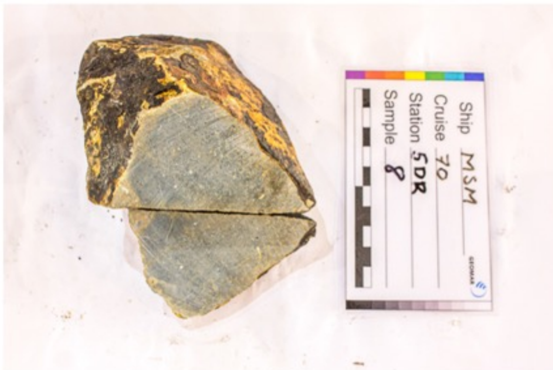

5DR-3


5DR-4


5DR-5


5DR-6


5DR-7

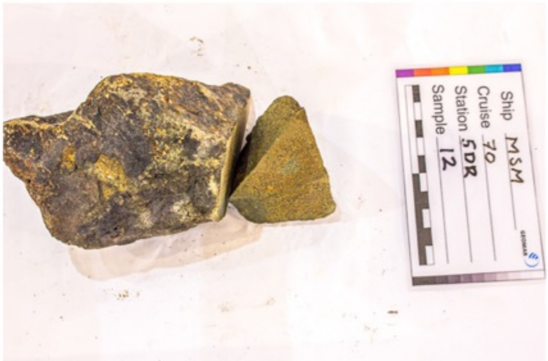



5DR-8

5DR-9

5DR-10

5DR-11



5DR-12

5DR-13

5DR-14

5DR-15

5DR-16


5DR-17

9DR-1a

9DR-1b


10DR-1b


10DR-1a


10DR-2a


10DR-2b


10DR-3b

10DR-3a

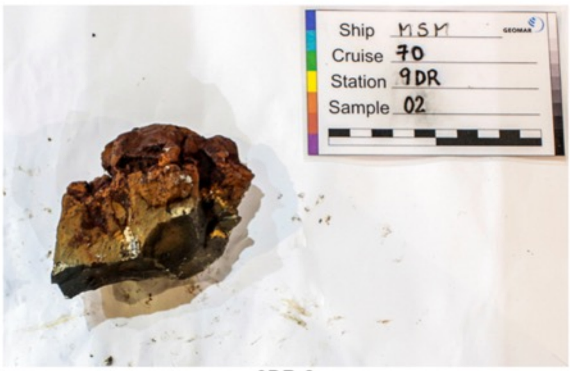
10DR-4a

10DR-4b

10DR-5a

10DR-5b

10DR-6



9DR-2

9DR-3

9DR-4

9DR-5

9DR-6

10DR-7

9DR-1c

11DR-1b

11DR-1a

11DR-2


11DR-3


11DR-4b


11DR-4a


12DR-1


12DR-2


12DR-3b


12DR-3a


12DR-4

12DR-5a

12DR-5b

12DR-6

15DR-1

15DR-2

15DR-3

15DR-Coral

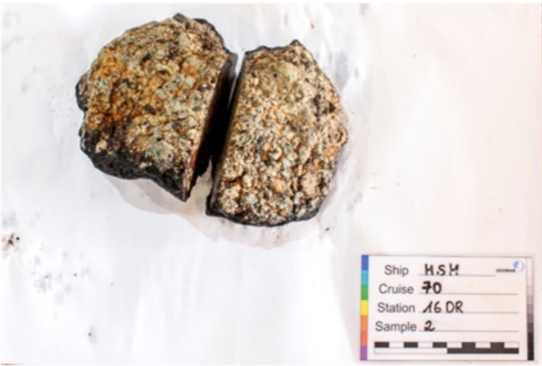
15DR-4

15DR-6


15DR-5

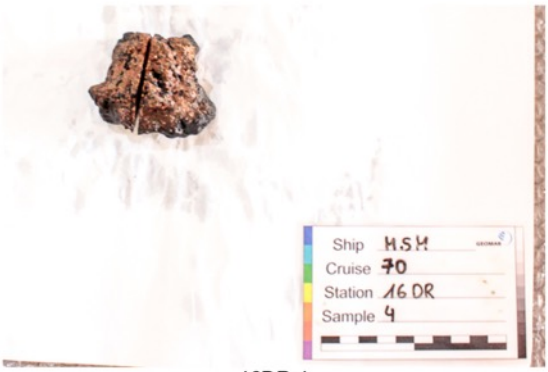

16DR-1


16DR-2a




16DR-2b


16DR-3




16DR-4


16DR-5

15DR-7

15DR-8


15DR-Reserve

17DR-1

17DR-2

17DR-3

17DR-4

17DR-5


17DR-6


18DR-1


18DR-2


18DR-3

18DR-4


18DR-5



20DR-1

20DR-2


20DR-3b


20DR-3a


20DR-4a


20DR-4b


20DR-5b

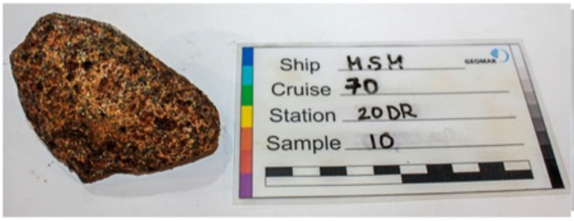

20DR-5a


20DR-6

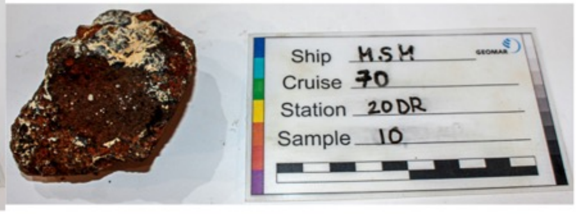

20DR-7


20DR-8


20DR-9




20DR-10a



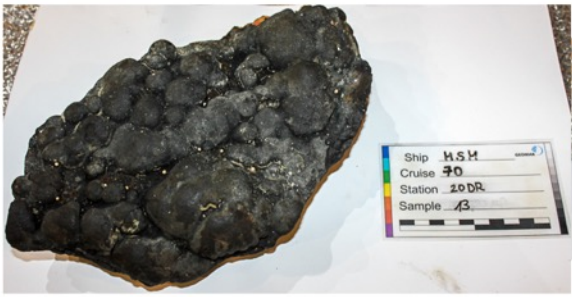

20DR-10b

20DR-11b


20DR-11a

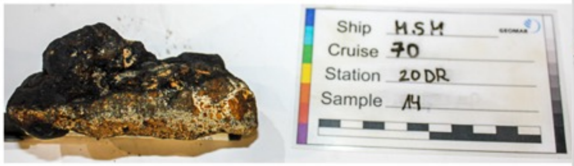

20DR-12b


20DR-12a




20DR-13a


20DR-13b

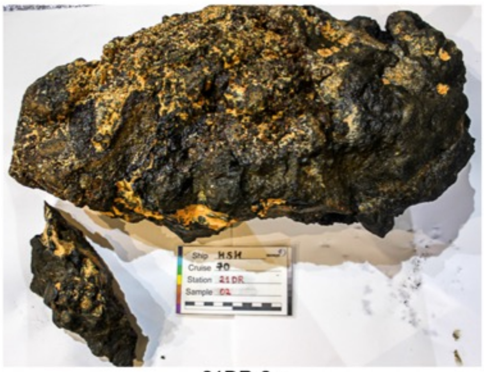



20DR-14


20DR-15

21DR-1a


21DR-1b



21DR-2a

21DR-6a


21DR-6b


21DR-3b


21DR-3a


21DR-4


21DR-5

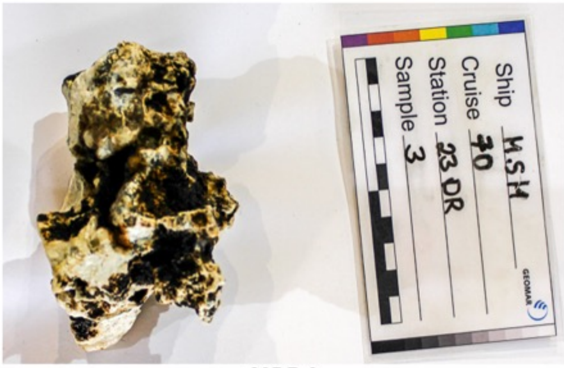
21DR-6c

21DR-2b

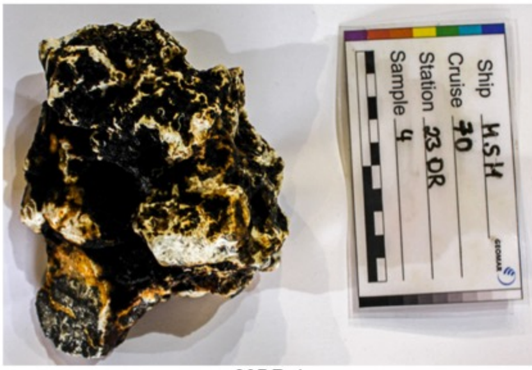
21DR-1c

23DR-1

23DR-2



23DR-3



23DR-4

23DR-5

23DR-6

22DR-1

22DR-2

26DR-1a

26DR-2a

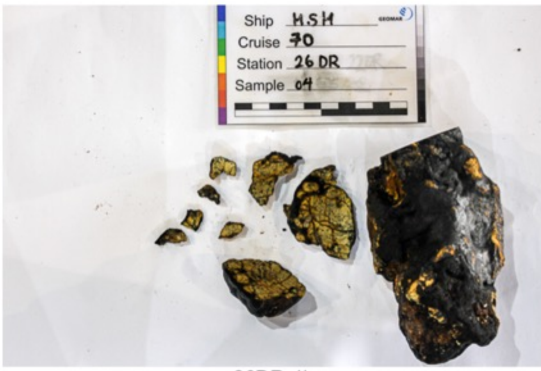
26DR-4a

26DR-6

26DR-1b

26DR-2b

26DR-3



26DR-4b


26DR-5


29DR-1

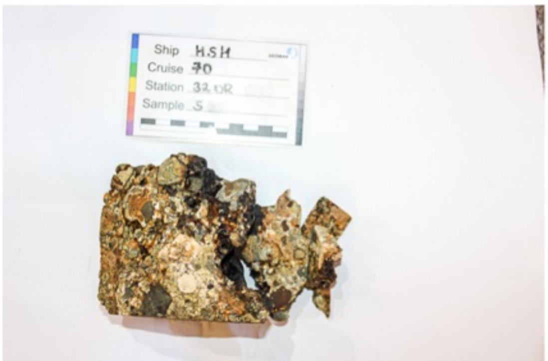

29DR-2


29DR-Sponges


32DR-1


32DR-2


32DR-3




32DR-5

32DR-6

32DR-7

32DR-4

33DR-1

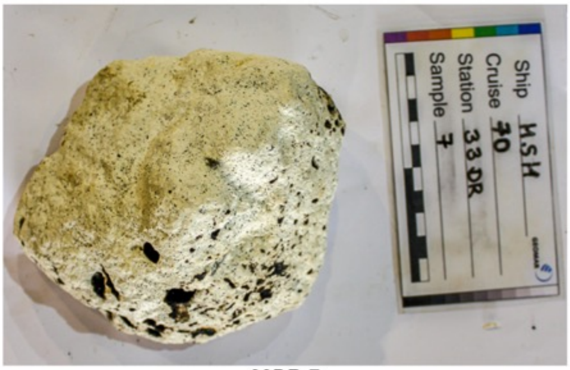
33DR-2

33DR-3

33DR-4

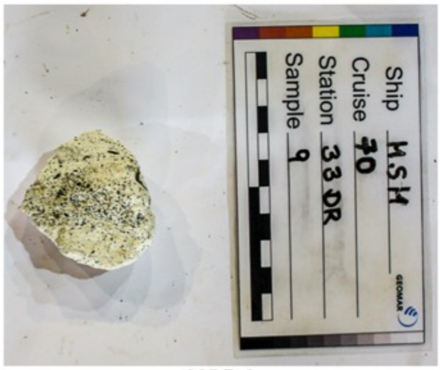
33DR-5

33DR-6



33DR-7

33DR-8



33DR-9

34DR-1

34DR-2

34DR-3

35DR-1


35DR-2


36DR-1


36DR-2

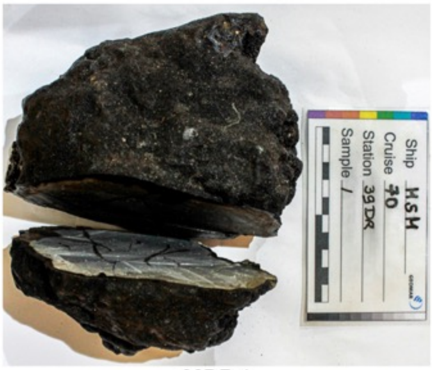

36DR-3


36DR-4


36DR-5


37DR-1

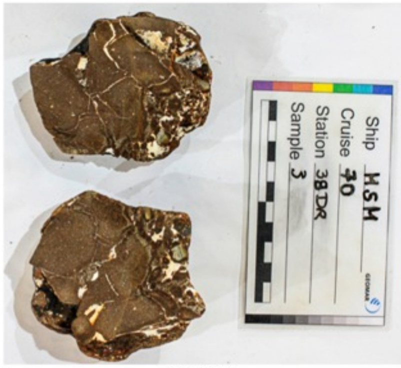

37DR-2



39DR-1

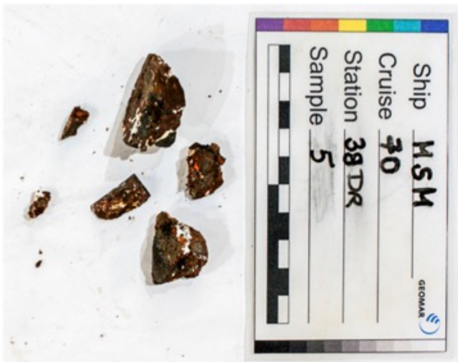
38DR-1

38DR-2

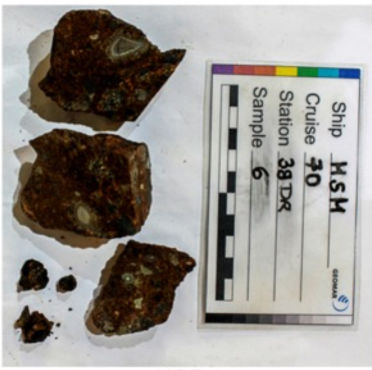


38DR-3

38DR-4



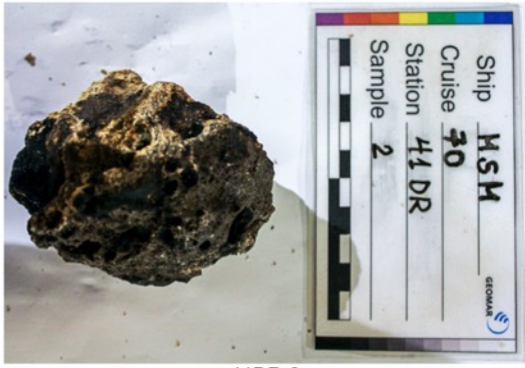
38DR-5



38DR-6

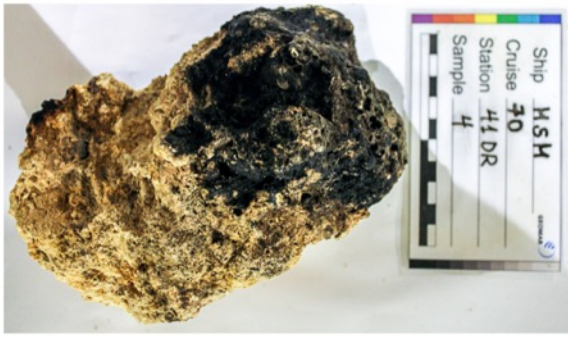
38DR-7

41DR-1

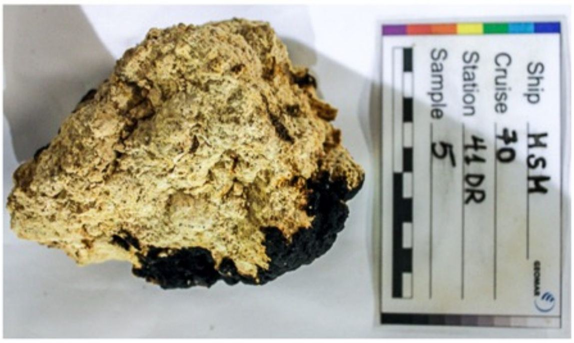


41DR-2

41DR-3

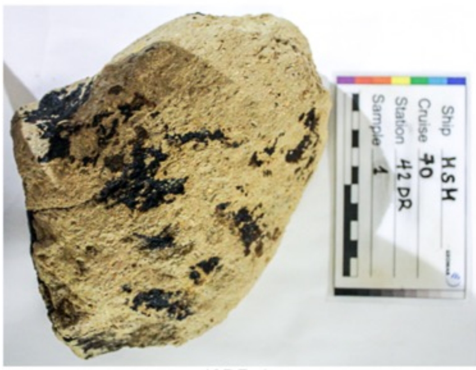


41DR-4

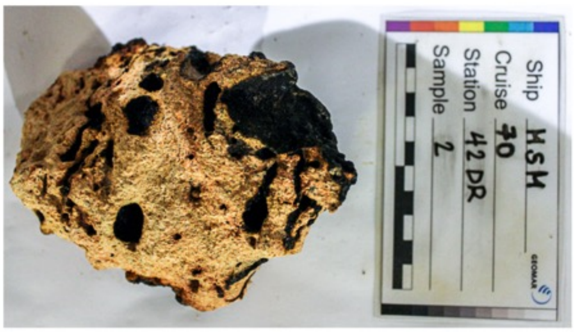


41DR-5

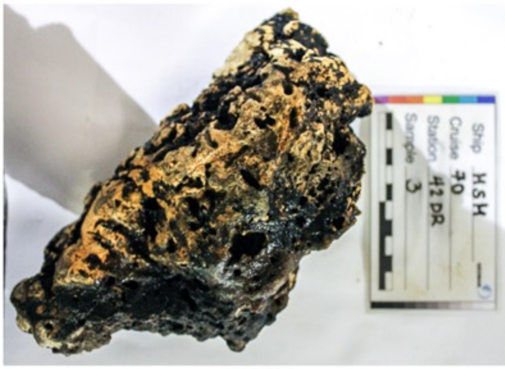
41DR-6



42DR-1a



42DR-2a



42DR-3

42DR-5

42DR-2b

42DR-4

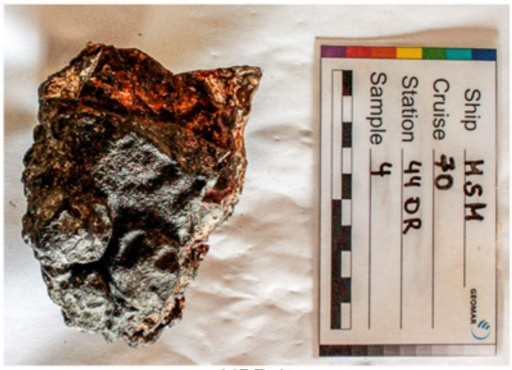
42DR-1b

43DR-1

43DR-2

44DR-2

44DR-3

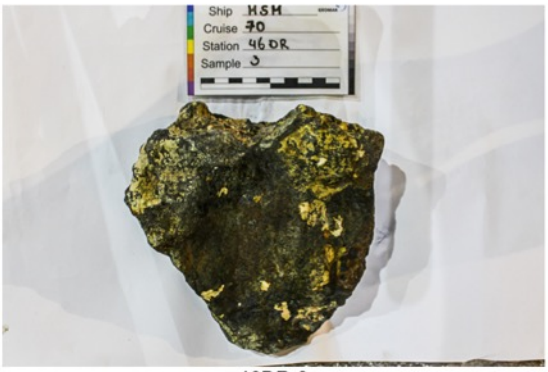


44DR-4a

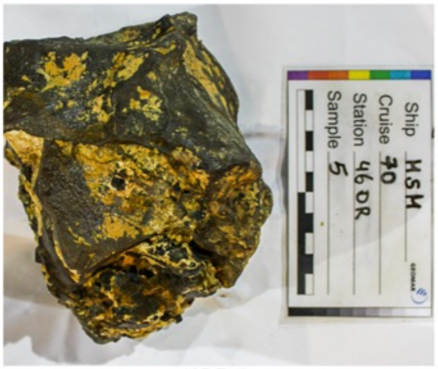
44DR-5

44DR-6


46DR-1



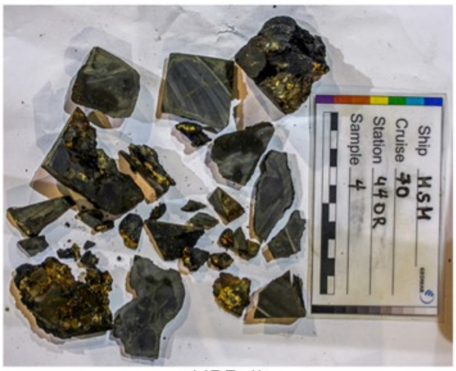
46DR-3



46DR-5a

46DR-6

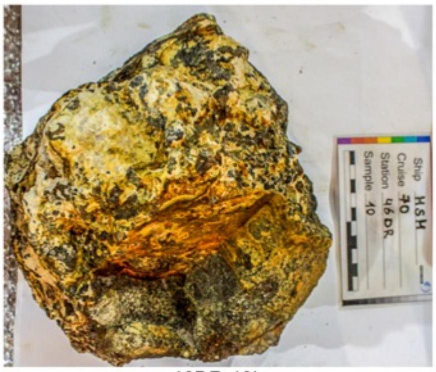
46DR-7



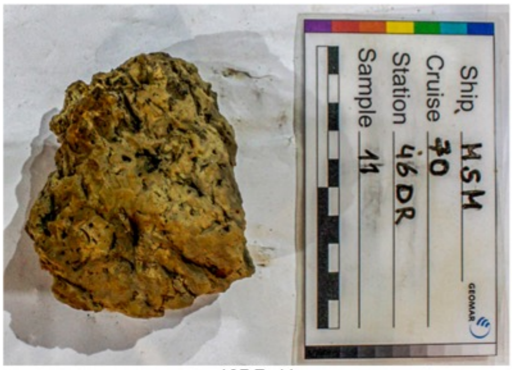
44DR-4b

46DR-9

46DR-10a



46DR-10b

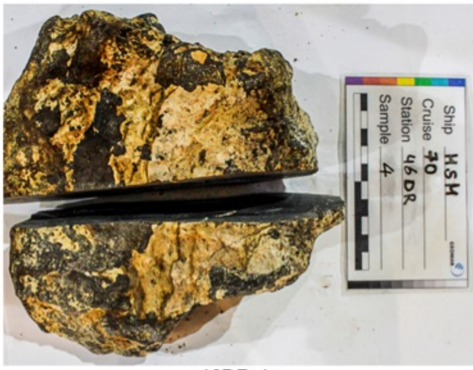


46DR-11

46DR-12

46DR-13

46DR-4b



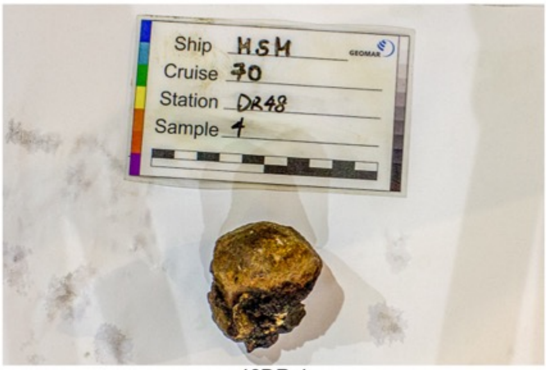
46DR-4a


46DR-5b

48DR-1

48DR-2

48DR-3




48DR-4

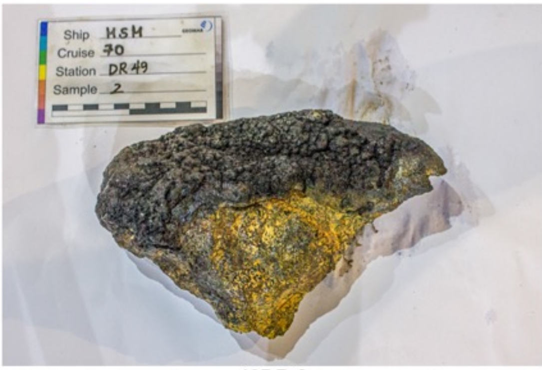

48DR-5


48DR-6


48DR-7


48DR-8

49DR-1

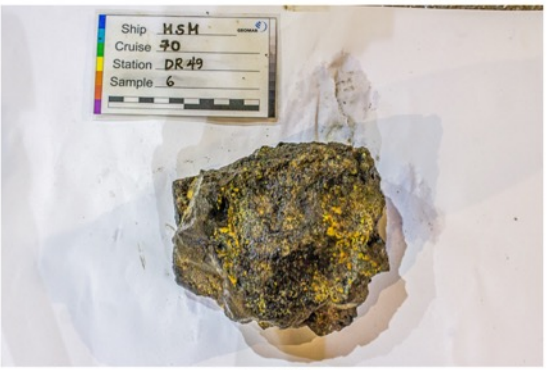



49DR-2


49DR-3


49DR-4


49DR-5



49DR-6

51DR-1

52DR-1

52DR-2

53DR-1

53DR-2

53DR-3

53DR-4


54DR-4

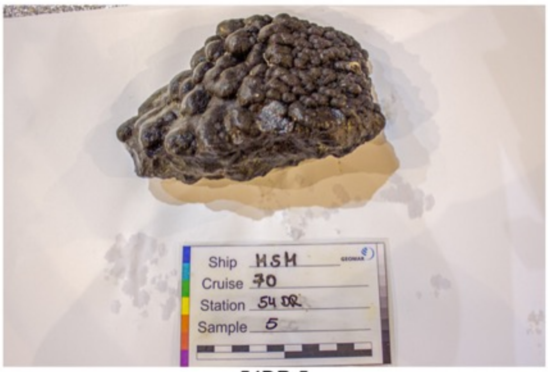

54DR-3a


54DR-3b


54DR-2


54DR-1b


54DR-1a




54DR-5

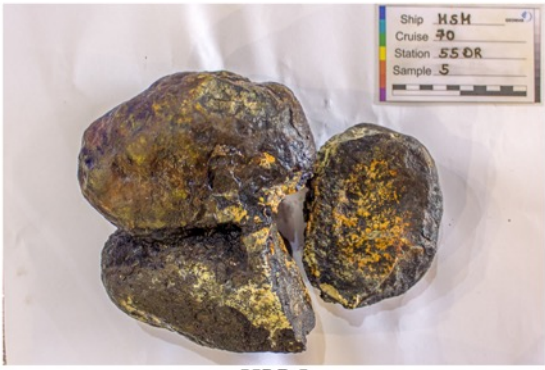

54DR-6

55DR-1

55DR-2

55DR-3

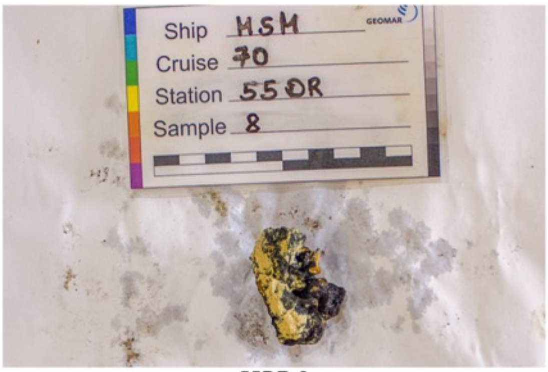
55DR-4



55DR-5

55DR-6

55DR-7

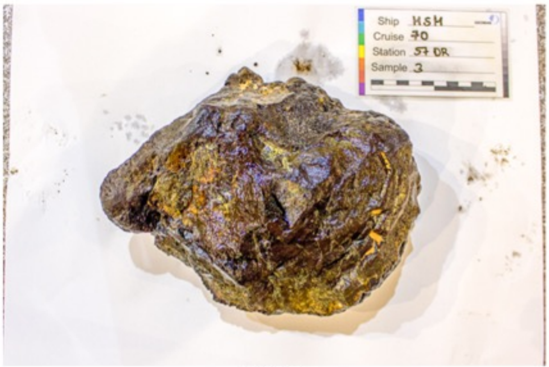


55DR-8


55DR-Reserve


57DR-1_0

57DR-2



57DR-3

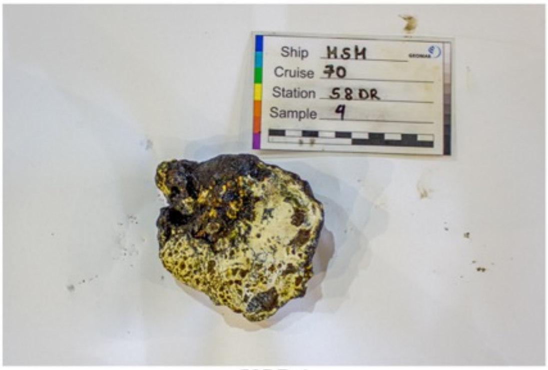
57DR-4

57DR-5


58DR-1


58DR-2_0

58DR-3



58DR-4

58DR-5

57DR-1_1

57DR-1_2

57DR-1_3

57DR-1_4

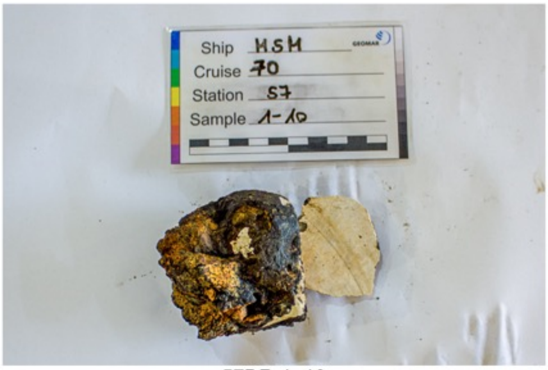
57DR-1_5

57DR-1_6

57DR-1_7

57DR-1_8

57DR-1_9



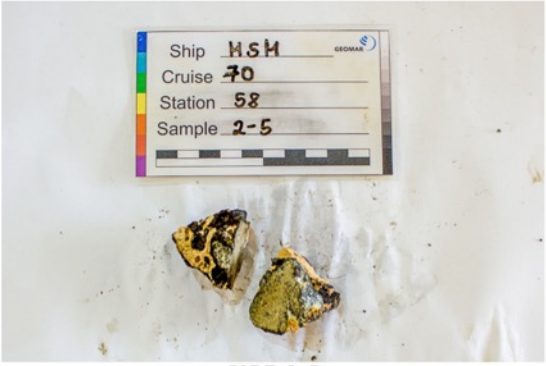
57DR-1_10

58DR-2_1

58DR-2_2

58DR-2_3

58DR-2_4



58DR-2_5

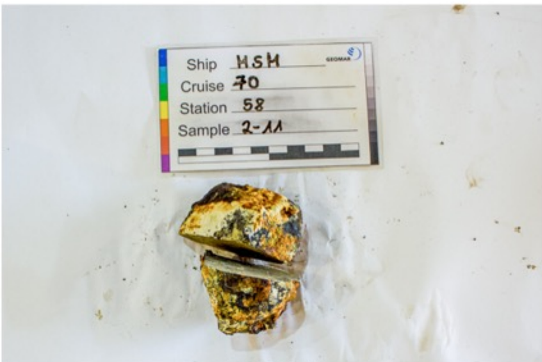
58DR-2_6

58DR-2_7

58DR-2_8

58DR-2_9

58DR-2_10



58DR-2_11

58DR-2_12

58DR-2_13

58DR-2_14


59DR-1_0b


59DR-1_0a

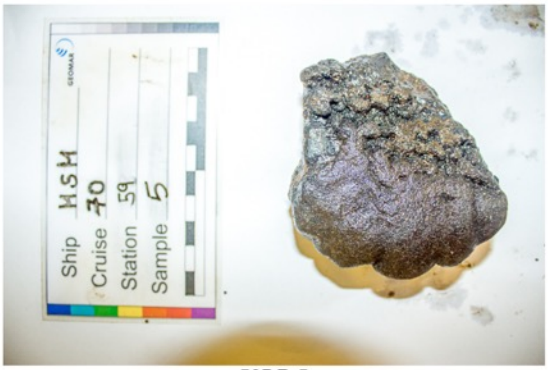
59DR-2b

59DR-2a

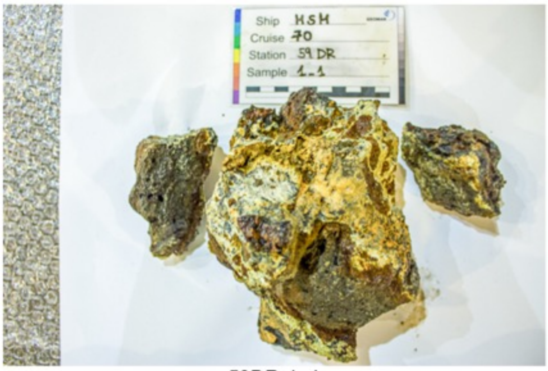
59DR-3b

59DR-3a

59DR-4



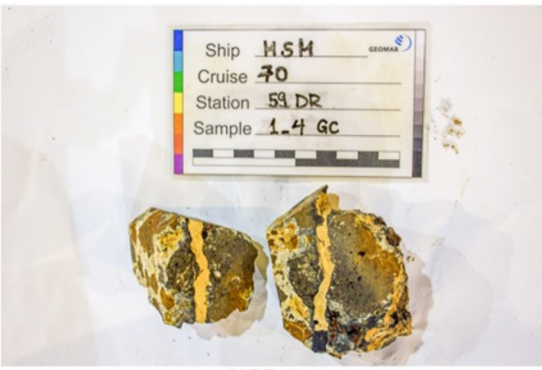
59DR-5



59DR-1_1

59DR-1_2

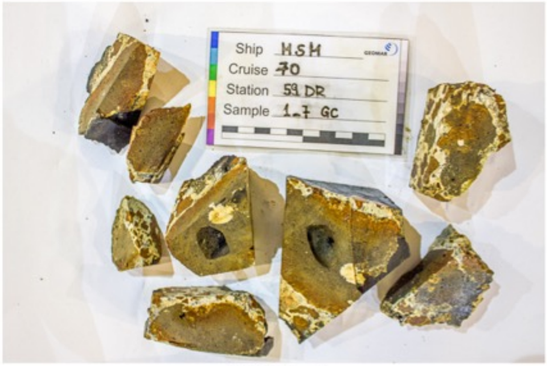
59DR-1_3



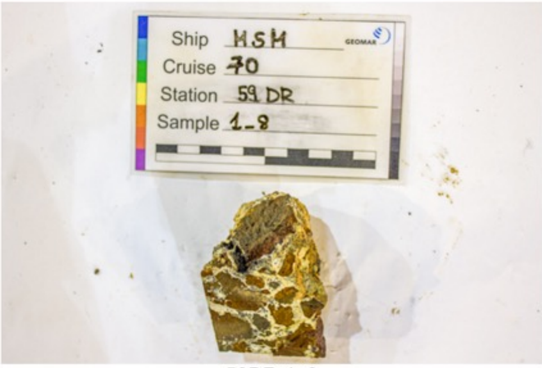
59DR-1_4

59DR-1_5

59DR-1_6



59DR-1_7



59DR-1_8


62DR-1


62DR-2

62DR-3


62DR-4

62DR-5

62DR-6

62DR-7

62DR-8

62DR-9

62DR-10

61DR-1

61DR-2

61DR-4

61DR-5

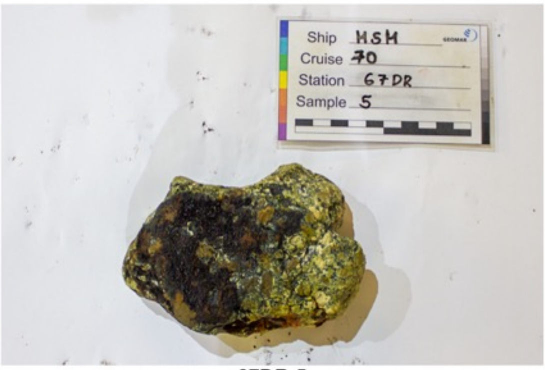
62DR-11

64DR-1

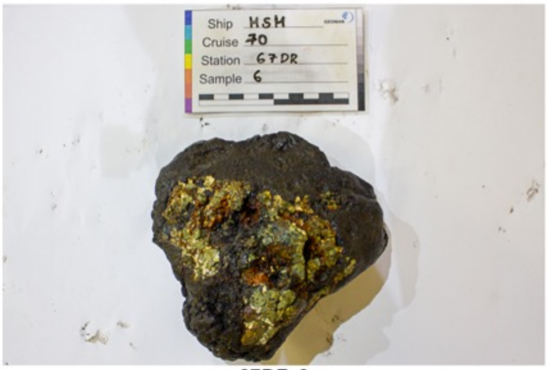

67DR-2

67DR-3

67DR-4



67DR-5

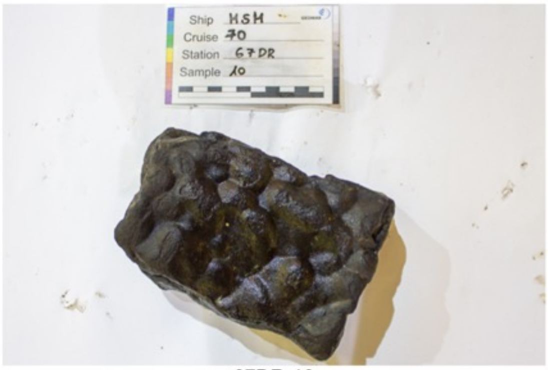


67DR-6


67DR-7


67DR-8


67DR-9




67DR-10


67DR-1


68DR-1


68DR-2


68DR-3


68DR-4


68DR-5


68DR-6


68DR-7


68DR-8


68DR-9


68DR-10


69DR-1

69DR-2

69DR-3

69DR-4

69DR-5

69DR-6

71DR-1

71DR-2

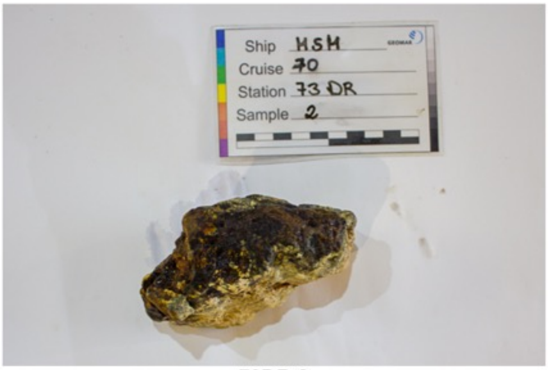
71DR-3b

71DR-3a

72DR-1

73DR-Sponge

73DR-1



73DR-2


73DR-3

73DR-4

73DR-5

73DR-6

73DR-7

74DR-1

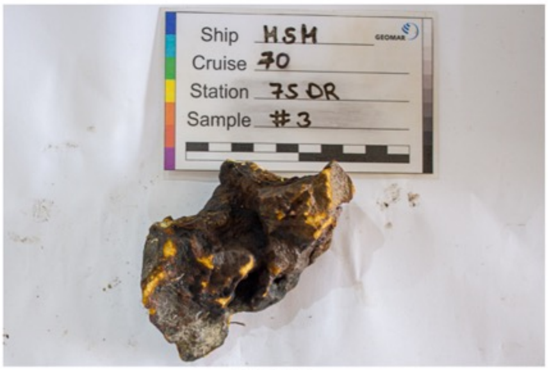
73DR-Reserve3

73DR-Reserve1

73DR-Reserve2

75DR-1

75DR-2



75DR-3

75DR-4

76DR-1

76DR-2

76DR-3

76DR-4

76DR-5

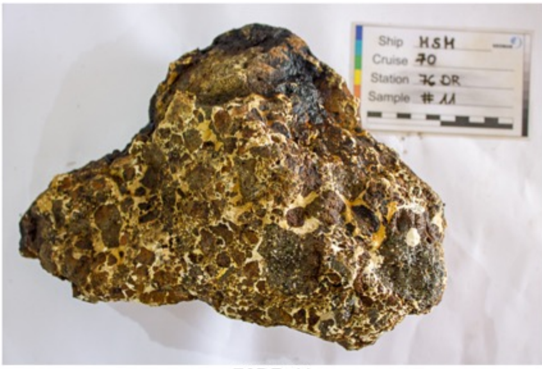
76DR-6

76DR-7

76DR-8

76DR-9

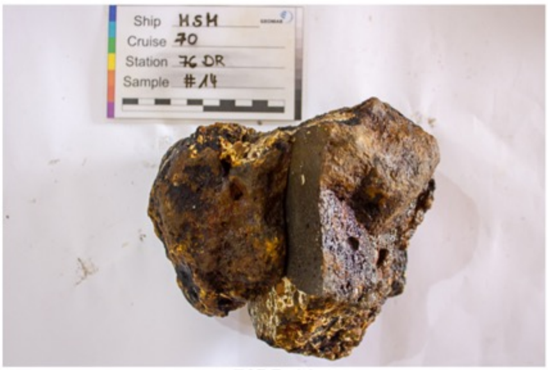
76DR-10



76DR-11

76DR-12

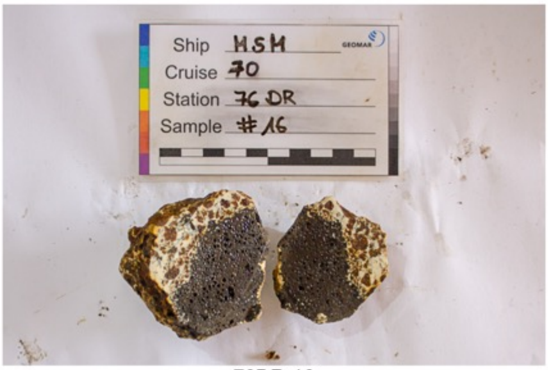
76DR-13



76DR-14

76DR-15

76DR-17



76DR-16

76DR-18

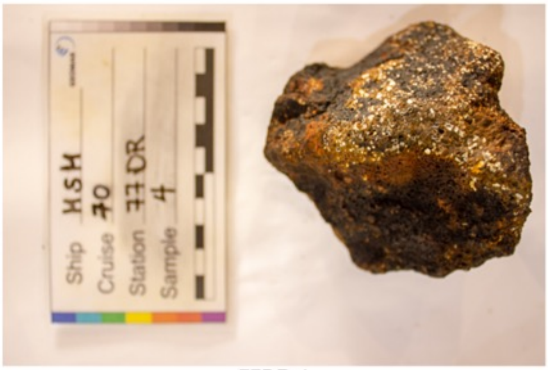
76DR-19


76DR-20


77DR-1


77DR-2

77DR-3

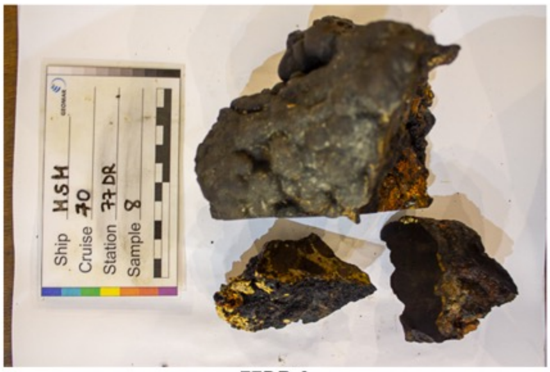


77DR-4

77DR-5

77DR-6

77DR-7

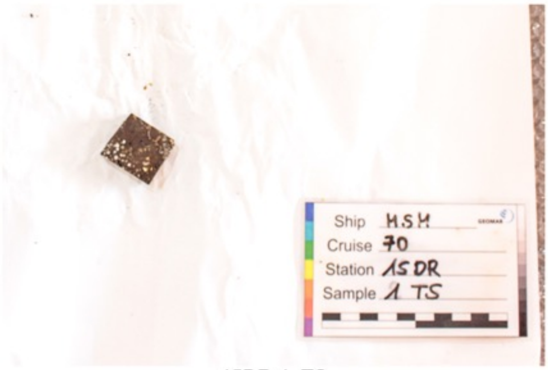


77DR-8

## 10.3 Subsample photographs

GC = block prepared for geochemistry, TS = block prepared for thin sections, XRD = sample for XRD analyses.


15DR-1_GC




15DR-1_TS


15DR-2_GC


15DR-2_TS


15DR-4_GC


15DR-4_TS


15DR-7_TS

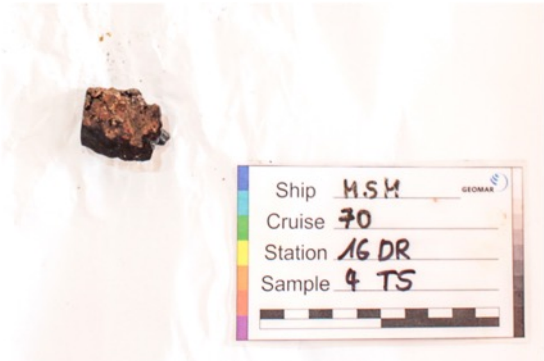

15DR-7_XRD

15DR-8_GC

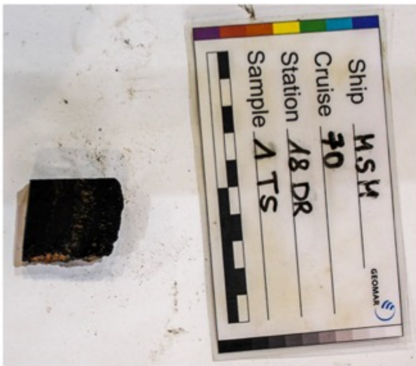
15DR-8_TS

16DR-2_TS

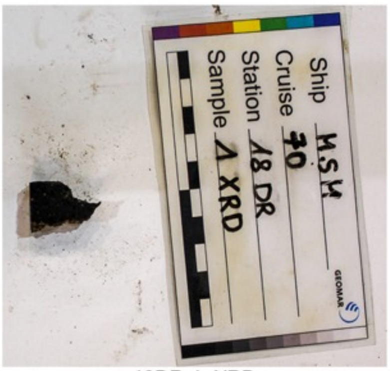
16DR-2_XRD



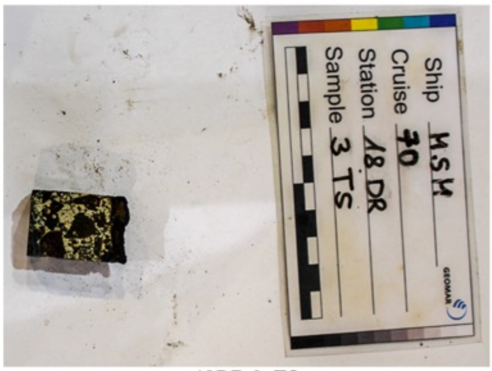
16DR-4_TS



18DR-1_TS



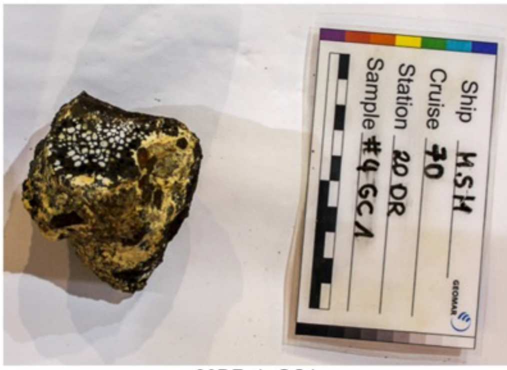
18DR-1_XRD



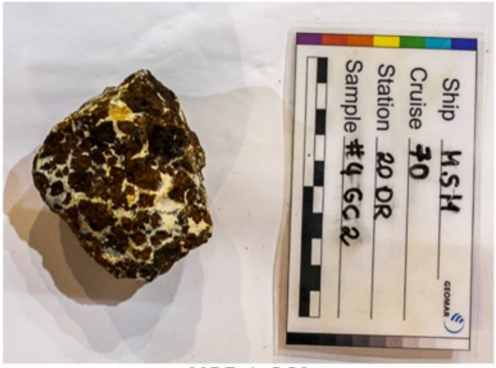
18DR-3_TS


20DR-3_GC

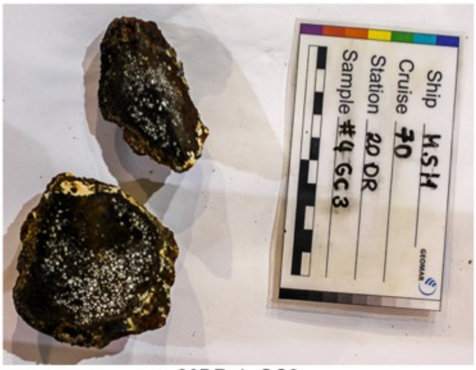

20DR-3_TS




20DR-4_GC1

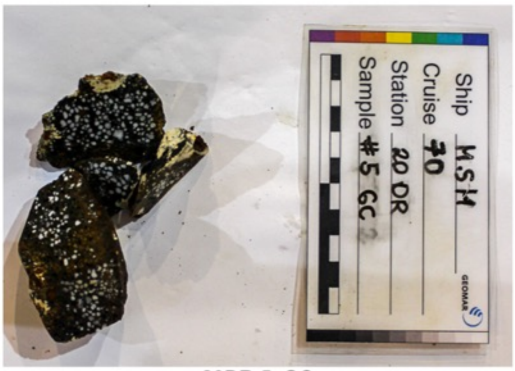



20DR-4_GC2

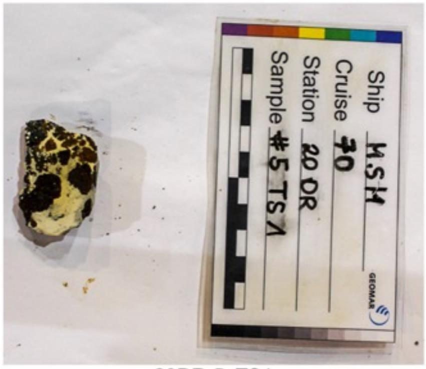



20DR-4_GC3

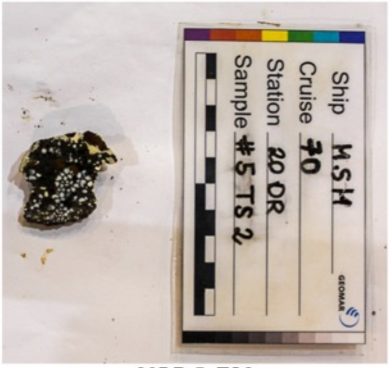

20DR-4_TS2




20DR-5_GC

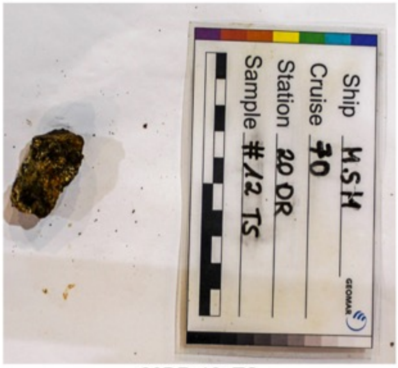



20DR-5_TS1



20DR-5_TS2

20DR-12_GC



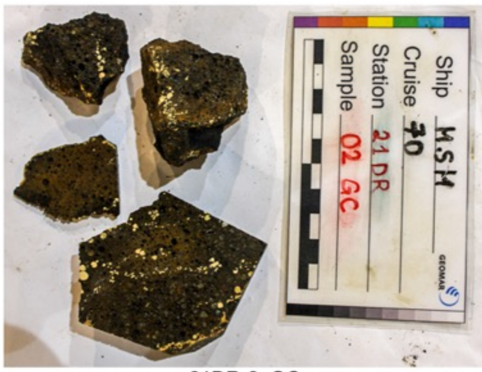
20DR-12_TS

20DR-16_TS

21DR-1_GC

21DR-1_TS

21DR-1_XRD

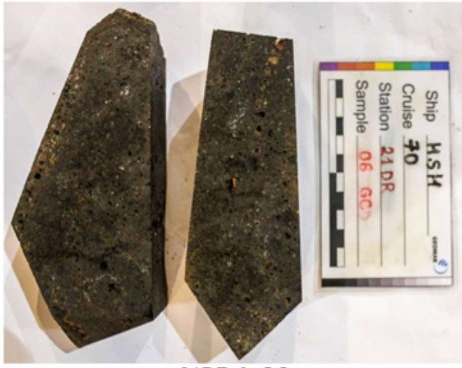


21DR-2_GC

21DR-2_TS

21DR-2_XRD

21DR-4_TS



21DR-6_GC

21DR-6_TS

21DR-6_XRD

23DR-1_GC

23DR-4_XRD

26DR-1_GC

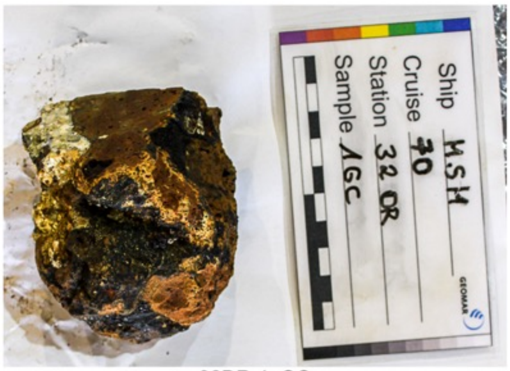
26DR-1_TS

26DR-2_GC

26DR-2_TS

26DR-4_TS

30DR-4_TS



32DR-1_GC

32DR-1_TS

32DR-2_GC

32DR-2_TS

32DR-3_GC

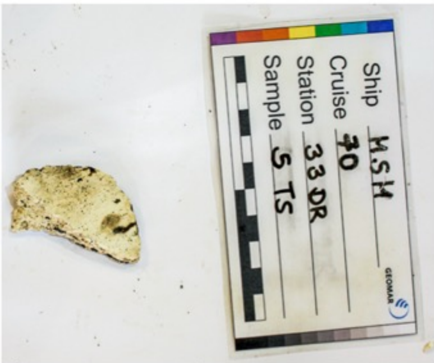
32DR-3_TS

32DR-4_GC

32DR-4_TS

32DR-5_TS

32DR-5_XRD



33DR-5_TS

34DR-2_TS

36DR-1_GC

36DR-1_TS

36DR-2_GC

36DR-2_TS

36DR-3_TS

36DR-4_GC

36DR-4_TS

36DR-6_GC

37DR-1_TS

37DR-2_GC

37DR-2_TS

38DR-1_GC

38DR-1_TS

38DR-2_GC

38DR-2_TS

38DR-5_GC

38DR-5_TS

38DR-7_TS

39DR-1_GC

39DR-1_TS

42DR-2_TS

43DR-1_GC1

43DR-1_GC2a

43DR-1_GC2b

43DR-1_TS

44DR-2_GC

44DR-2_TS

44DR-4_GC

44DR-4_TS

46DR-1_GC

46DR-1_TS

46DR-2_GC

46DR-2_TS

46DR-3_GC

46DR-3_TS

46DR-6_GC

46DR-6_TS

46DR-7_GC

46DR-7_TS

48DR-1_1_GC

48DR-1_1_TS

48DR-1_2_TS

48DR-1_3_GC

48DR-1_3_TS

48DR-4_GC

48DR-4_TS


48DR-6_GC


48DR-6_TS


49DR-3_TS


49DR-4_GC


49DR-5_GC


49DR-5_TS


52DR_1_GC


52DR-1_TS


53DR-1_GC


53DR-1_TS


53DR-2_GC


53DR-2_TS


54DR-1_1_GC


54DR-1_1_TSa


54DR-1_1_TSb


54DR-1_2_GC

54DR-1_2_TSa

54DR-1_2_TSb

54DR-1_3_GC

54DR-1_3_TSa

54DR-1_3_TSb

54DR-1_4_GC

54DR-1_4_TS

54DR-1_5_GC

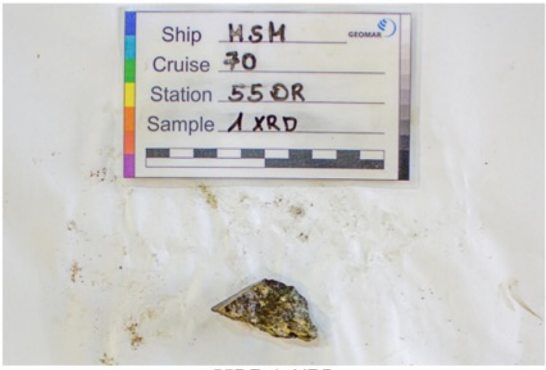
54DR-1_5_TS

54DR-1_6_GC

54DR-1_6_TS

54DR-2_GC

54DR-2_TS



55DR-1_XRD

55DR-2_GC

55DR-2_TS

55DR-2_XRD

55DR-3_GC1

55DR-3_GC2

55DR-3_TS1

55DR-3_TS2

55DR-3_XRD

55DR-4_GC

55DR-4_TS

55DR-4_XRD

55DR-7_TS

55DR-7_XRD

57DR-1_1_GC

57DR-1_1_TS

57DR-1_2_GC

57DR-1_2_TS

57DR-1_3_GC

57DR-1_3_TS

57DR-1_4_GC

57DR-1_4_TS

57DR-1_4_XRD

58DR-1_GC

58DR-2_1_GC

58DR-2_1_TS

58DR-2_1_XRD

58DR-2_2_GC

58DR-2_2_TS

58DR-2_2_XRD

58DR-2_3_GC

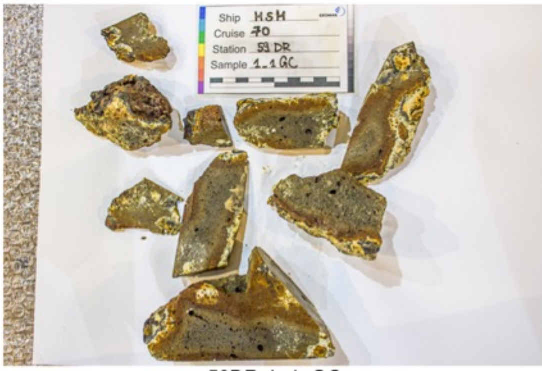
58DR-2_3_TS

58DR-2_TS

58DR-2_XRD

58DR-3_TS

58DR-3_XRD



59DR-1_1_GC

59DR-1_1_TS

59DR-1_5_GC

59DR-1_6_GC

59DR-1_7_GC

59DR-1_7_TS

59DR-1_TS

59DR-1_XRD

61DR-1_GC

61DR-1_TS

61DR-2_GC

61DR-2_TS

61DR-3_TS

61DR-3_XRD

62DR-1_GC

62DR-1_TS

62DR-2_GC

62DR-2_TS

62DR-2_XRD

62DR-5_GC

62DR-5_TS

67DR-1_GC

67DR-1_TS

67DR-1_XRD

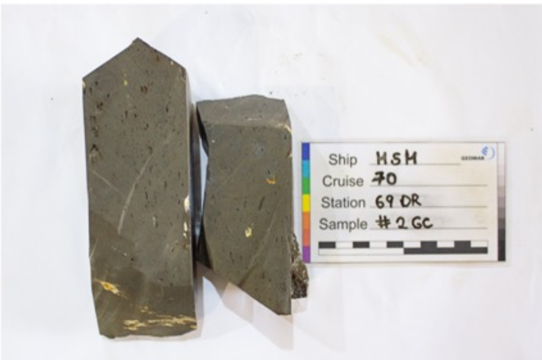
67DR-3_XRD

68DR-4_TS

69DR-1_GC

69DR-1_TS

69DR-1_XRD



69DR-2_GC

69DR-2_TS

69DR-3_GC

69DR-3_TS

69DR-6_TS

71DR-2_TS

72DR-1_GC

72DR-1_TS

73DR-1_GC

73DR-1_TS

73DR-1_XRD

73DR-2_TS

73DR-3_GC

73DR-3_TS

73DR-4_GC

73DR-4_TS

75DR-1_GC

75DR-1_TS

75DR-3_TS

76DR-2_GC

76DR-2_TS

76DR-3_GC

76DR-3_TS

76DR-3_XRD

76DR-4_GC

76DR-4_TS

76DR-10_GC

76DR-10_TS

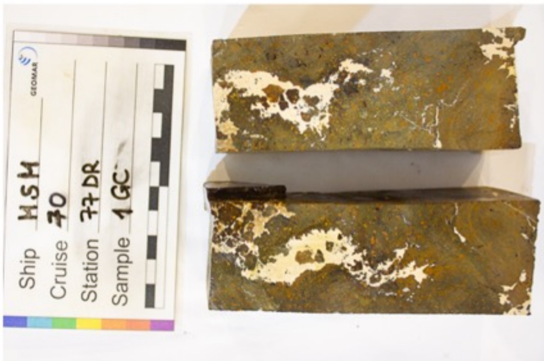
76DR-10_XRD

76DR-14_GC

76DR-14_TS

76DR-15_GC

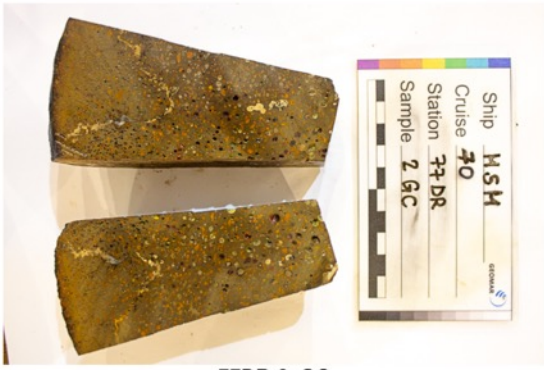
76DR-15_TS



77DR-1_GC

77DR-1_TS

77DR-1_XRD



77DR-2_GC

77DR-2_TS

77DR-2_XRD

77DR-5_GC

77DR-5_TS

77DR-6_GC


77DR-6_TS