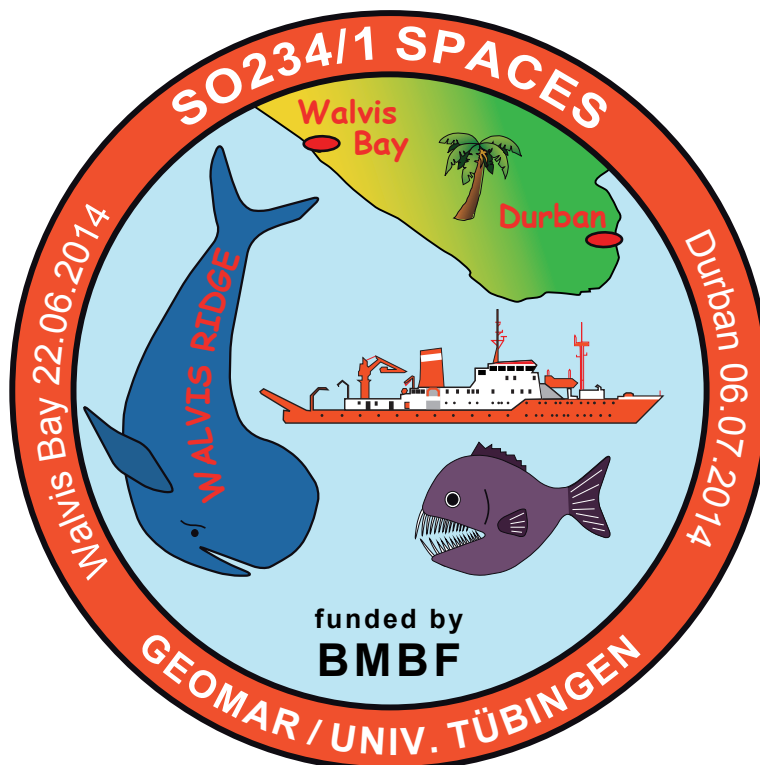




Helmholtz-Zentrum für Ozeanforschung Kiel

RV SONNE
Fahrtbericht / Cruise Report
SO234/1
"SPACES"

Science on the Assessment
of Complex Earth System Processes
22.06. – 06.07.2014
Walvis Bay / Namibia - Durban / South Africa



Berichte aus dem GEOMAR
Helmholtz-Zentrum für Ozeanforschung Kiel

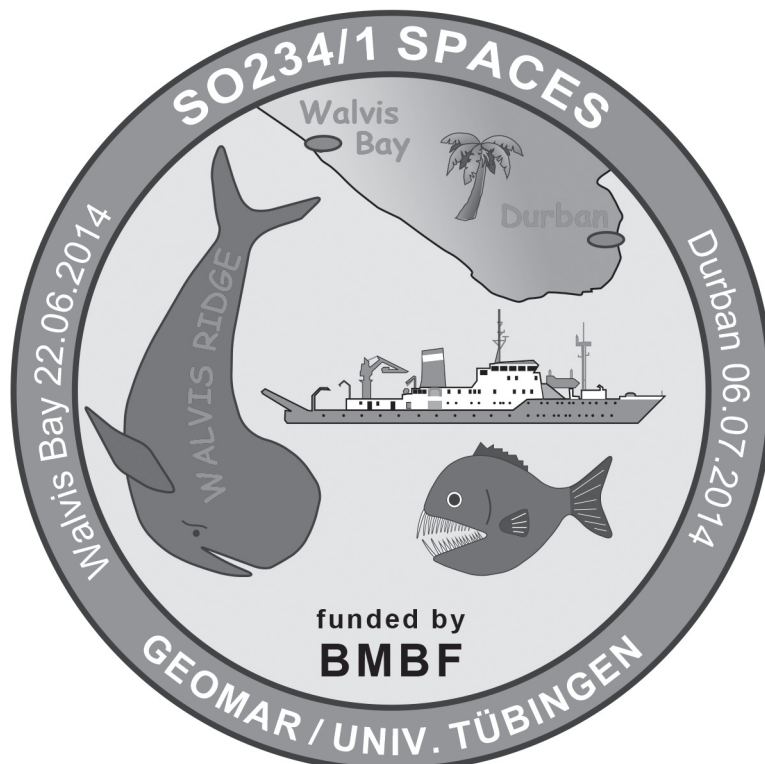
Nr. 17 (N. Ser.)
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Nr. 17 (N. Ser.)

September 2014
ISSN Nr.: 2193-8113



Das GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
ist Mitglied der Helmholtz-Gemeinschaft
Deutscher Forschungszentren e.V.

The GEOMAR Helmholtz Centre for Ocean Research Kiel
is a member of the Helmholtz Association of
German Research Centres

Herausgeber / Editor:

Reinhard Werner and Hans-Joachim Wagner and the shipboard scientific party

GEOMAR Report

ISSN Nr. 2193-8113, DOI 10.3289/GEOMAR_REP_NS_17_2014

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SUMMARY

SO-234/1 was a training and capacity building cruise for students from southern Africa and Germany in the framework of the BMBF-funded SPACES program (Science for the Assessment of Complex Earth System Processes), a cooperative research project initiated by the relevant ministries in Namibia, South Africa, Angola and Germany. Scientifically, SO-234/1 continued geological studies regarding the temporal and geochemical evolution of the Walvis Ridge (Southeast Atlantic) conducted on the precursor SO-233 expedition, and was broadened by biological studies by University of Tübingen scientists, which aimed to get a better understanding of the adaptations of visual systems in mesopelagic animals to bioluminescence. The educational aspects on SO-234/1 comprised fully integration of the students into all scientific work on board and various lectures and courses given by the senior scientists during transit times.

The working area of SO-234/1 included several seamounts, such as the Ewing Seamount, and a section of the southeastern margin of the Walvis Ridge. Due to the fair weather conditions and the excellent support from the master and crew, SO-234/1 completed 18 sampling stations within only four working days. Rock sampling has been conducted using chain bag dredges. The seven SO-234/1 dredge hauls recovered *in situ* rocks from up to 3,500 m water depth, among them fairly fresh lava fragments and volcanoclastic rocks suitable for volcanological, geochemical, and geochronological analyses. Additionally, a TV-grab station has been conducted at Ewing Seamount but the grab failed to return hard rocks. The group of biologists conducted ten trawls at depths between 400 and 1,000 m using a rectangular midwater Tucker Trawl with an opening of 16 square meters. All trawls were successful and brought numerous animals from the junction of the meso- and bathypelagic habitats including, apart from fishes, several cephalopods, crustaceans, deep-sea jellyfish, ctenophors and many salp colonies.

ZUSAMMENFASSUNG

Die FS SONNE-Reise SO-234/1 war eine Ausbildungsfahrt für Studenten/innen aus dem südlichen Afrika und Deutschland im Rahmen des vom BMBF geförderten SPACES-Programms (Science for the Assessment of Complex Earth System Processes), einem Kooperationsprojekt, das von den jeweiligen Ministerien von Namibia, Südafrika, Angola und Deutschland initiiert wurde. Wissenschaftlich setzte SO-234/1 die geologischen Untersuchungen von SO-233 zur zeitlichen und geochemischen Entwicklung des Walvisrückens im Südostatlantik fort und wurde durch biologische Arbeiten der Universität Tübingen erweitert, durch die ein besseres Verständnis der Anpassung visueller Systeme mesopelagischer Tiere an Biolumineszenz erreicht werden soll. Das Ausbildungsprogramm von SO-234/1 beinhaltete sowohl die vollständige Integration der Studenten/innen in die wissenschaftlichen Arbeiten an Bord als auch mehrere Präsentationen und Seminare während der Transits.

Das Arbeitsgebiet von SO-234/1 umfasste einen Abschnitt des südöstlichen Randbereichs des Walvisrückens und mehrere nahe des Rückens gelegene Seamounts, darunter den Ewing Seamount. Aufgrund guter Wetterbedingungen und der exzellenten Unterstützung durch Kapitän und Mannschaft konnten während SO-234/1 insgesamt 18 Beprobungsstationen in nur 4 Arbeitstagen durchgeführt werden. Alle 7 Dredgezüge von SO-234/1 erbrachten anstehendes Gestein aus bis zu 3.500 m Wassertiefe, darunter relativ frische Lavafragmente und Vulkaniklastika, die sich für vulkanologische, geochemische und geochronologische Analysen eignen. Außerdem wurde der TV-Greifer am Ewing Seamount eingesetzt, der aber nur Sediment zu Tage förderte. Die Biologiegruppe führte 10 Fischzüge in Wassertiefen zwischen 800 und 1.000 m mit einem pelagischen "Tucker Trawl" durch, das über eine rechteckige, 16 m² große Öffnung verfügt. Alle Fischzüge verliefen erfolgreich und erbrachten eine Vielzahl von Tieren aus der Grenzregion zwischen dem meso- und dem bathypelagischen Lebensraum. Darunter befanden sich neben Fischen verschiedene Cephalopoda (Kopffüßer), Crustacea (Krebstiere), Tiefseequallen, Ctenophora (Rippenquallen) und viele Salpen (Kolonien von Manteltieren).

1. ACKNOWLEDGEMENTS

We would especially like to thank Captain Meyer and the crew of the R/V SONNE. Their hard work, high level of experience, willingness to help, and the pleasant working atmosphere on board contributed significantly to the success of SO-234/1 but also made sure that we felt quite comfortable onboard. In particular we were impressed by the efforts of the crew to maintain R/V SONNE and her facilities just two months before the vessel will be out of service.

We thank the Government of Namibia for granting permission to work within their territorial waters. We also gratefully acknowledge the support of the German Foreign Office and the German Embassy in Windhoek in this matter.

Special thanks to curator Eckhard Bedbur, who provided a wide range of rock hand samples from the Geologisches Museum of the University Kiel for training and educational purposes.

The SO-234/1 cruise was funded by the “Bundesministerium für Bildung und Forschung” (BMBF) in the framework of the SPACES program. We are grateful to the BMBF for continuing support of marine research. Additional funding has been provided by the GEOMAR Helmholtz Centre for Ocean Research Kiel, the University of Tübingen and the University of Queensland.

2. PARTICIPANTS

2.1 Ship's Crew

| | | | |
|-----------------------|----------------------|-----------------------|--------------------------|
| Meyer, Oliver | Master | Guzman, Werner | Chief Engin. |
| Büchele, Heinz Ulrich | Chief Mate | Pieper, Carsten | 2 nd Engineer |
| Masemann, Hendrik | 2 nd Mate | Horsel, Roman | 2 nd Engineer |
| Aden, Nils | 2 nd Mate | Krawczak, Ryszard | Motorman |
| Borchert, Wolfgang | Head WTD | Thimm, Sebastian | Motorman |
| Meinecke, Stefan | WTD | Blohm, Volker | Fitter |
| Heuser, Sabine | Surgeon | Beyer, Thomas | Electrician |
| Wieden, Wilhelm | Chief Cook | Schmandke, Harry | Chief Steward |
| Garnitz, Andre | 2 nd Cook | Royo, Luis | 2 nd Steward |
| Schrapel, Andreas | Boatswain | Kuhn, Ben | Apprentice |
| Jürgen Kraft | A.B. | Barkow, Michael | A.B. |
| Stengl, Günther | A.B. | Mohrdiek, Finn | A.B. |
| Fricke, Ingo | A.B. | Kallenbach, Christian | A.B. |
| Suhr, Robert | A.B. | | |

2.2 Shipboard Scientific Party



The SO-234/1 Shipboard Scientific Party (photo Ulrich Mattheus)

In alphabetical order:

| | | |
|-----------------------|---------------------|-------------------------|
| De Busserolles, Fanny | Scientist (Biology) | King Abdullah Univ. |
| Douglas, Roland | Scientist (Biology) | City Univ. London |
| Flynn, Adrian | Scientist (Biology) | Univ. Queensland/Fathom |
| Fretzdorff, Susanne | Scientist (Geology) | PtJ |
| Geldmacher, Jörg | Scientist (Geology) | GEOMAR |
| Homrighausen, Stephan | Scientist (Geology) | GEOMAR |
| Kapuire, Edison | Student (Biology) | UNAM |
| Kipf, Andrea | Scientist (Geology) | GEOMAR |
| Knauer, Roland | Journalist | Viering & Knauer |
| Ladehoff, Maike | Student (Biology) | Univ. Hamburg |
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| Mattheus, Ulrich | MTA (Biology) | Univ. Tübingen |
| Mühlberger, Fabian | Student (Biology) | Univ. Göttingen |
| Naidoo, Leesa | Student (Biology) | Univ. KwaZulu-Natal |

| | | |
|----------------------|-------------------------|----------------------------|
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| Tom, Desmond | Student (Biology) | Ministry Fish. & Mar. Res. |
| Wagner, Hans-Joachim | Head Biology Group | Univ. Tübingen |
| Werner, Reinhard | Chief Scientist | GEOMAR |

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| | |
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| GFZ | Centre for GeoInformation Technology CeGIT, Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany (http://cegit.gfz-potsdam.de) |
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| Univ. Queensland | University of Queensland, Brisbane St Lucia, QLD 4072, Australia (www.uq.edu.au) |
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3. BACKGROUND OF SO-234/1 SPACES

(R. Werner, H.-J Wagner)

R/V SONNE cruise SO-234/1 was a training and capacity building cruise for students from southern Africa and Germany in the framework of the BMBF-funded SPACES program (Science for the Assessment of Complex Earth System Processes, <https://www.ptj.de/wtz-suedliches-afrika>), a cooperative research project initiated by the relevant ministries in Namibia, South Africa, Angola and Germany. Ten students from southern Africa and Germany have been invited to attend in SO-234/1 and participate in the geological and biological investigations carried out on that cruise. This research-based capacity building should bring together researchers and students from Africa and Germany on board R/V SONNE. A second major goal was educating students in different marine disciplines (bathymetry, geology, and biology). Scientifically, SO-234/1 continued and complemented bathymetric mapping and hard rock sampling at the eastern Walvis Ridge conducted on the precursor R/V SONNE cruise SO-233 WALVIS II (www.geomar.de/forschen/expeditionen; www.oceanblogs.org/walvis2) and was broadened by biological studies of the University of Tübingen, aimed to get a better understanding of the adaptations of visual systems in mesopelagic animals to bioluminescence. The scientific objectives of SO-234/1 were as follows:

Geology: The major targets of SO234/1 rock sampling were to fill a sample gap at the southeastern margin of the Walvis Ridge (at c. 22° - 23° S) and to sample and map some adjacent seamounts, among them Ewing Seamount, whose formation is most likely related to the Walvis Ridge magmatism. The Walvis Ridge is a textbook example of a hotspot track connected to a continental flood basalt province and also represents the Atlantic “type locality” for the enriched mantle one (EM-I) geochemical endmember in intraplate volcanic rocks. Despite its importance in the global hotspot reference frame, endmember geochemical composition and open questions regarding formation and evolution, basement sampling of the Walvis Ridge remained poor prior to SO-233, in particular along its easternmost 1,500 km. SO-233 carried out for the first time systematic bathymetric mapping, sediment profiling, and sampling of the volcanic rocks along that eastern part the Walvis Ridge which should be completed by SO-234/1. Ar/Ar ages and a comprehensive geochemical data set (major and trace elements and Sr-Nd-Pb-Hf-O isotopes) of a detailed suite of igneous samples from the Walvis Ridge are necessary 1) to test for age progressive volcanism along the ridge, 2) to differentiate between classical hotspot and plate fracturing models for its formation, 3) to provide constraints on the origin and temporal and spatial evolution of melting conditions and source compositions (in particular the EM I endmember) and 4) to establish how far the geochemical zonation into two subtracks (Rhode et al. 2013) can be followed along the Walvis Ridge towards the northeast.

Biology: Most animals of the deep-sea water column have conspicuous and/or large eyes indicating that visual orientation and/or communication plays an important part in their behaviour. However, at 200 m only 1% of sunlight is available, and below 1,000 m sunlight is completely absent. Instead of this familiar source of light, the great majority of deep-sea fauna relies on bioluminescence, generally produced by bacteria in specialised light organs. However, the visual images created by bioluminescence are much different from the general, scenic illumination resulting from sunlight and therefore have lead to the evolution of special adaptations in the visual systems, and the eyes in particular. SO-234/1 aimed to study the eyes of mesopelagic cephalopods, crustacians and teleosts and investigate regeneration mechanisms of their visual pigment (rhodopsin). Previous anecdotal observations have indicated that it takes longer and higher intensities to completely bleach deep-sea rhodopsin compared to terrestrial visual pigments. Using biochemical, electrophysiological and morphological experiments, it was planned to determine the dynamics and cellular mechanisms of deep-sea rhodopsin regeneration. This project will also be of interest to conservationists because it will show whether searchlight used by submersibles can cause permanent damage to the animals thus illuminated. In a second line of experiments we targeted fish of the opisthoproctid genus in order to extend our concept on the evolution of mirror-eyes in diverticula to a genetic and phenetic level. Finally, fresh material should help to explain the source of bacteriochlorophyll in the retina of Malacosteus.

4. CRUISE NARRATIVE

(R. Werner, H.-J. Wagner)

The Leg 1 of the R/V SONNE expedition SO-234 commenced from the port of Walvis Bay in Namibia. It was planned that the SO-234/1 scientific party (11 scientists, 10 students, and one journalist) board the R/V SONNE on June 22nd in the morning. The full utilization of the port and heavy sand storms, however, resulted that the scientists had to embark one day earlier than originally planned and that R/V SONNE left the port at noon on June 22nd - also one day earlier than scheduled. From Walvis Bay we sailed westward approximately 320 nautical miles in marvelous sunny and calm conditions. In the afternoon of June 23rd SONNE arrived at our working area at the southeastern margin of the Walvis Ridge (Fig. 4.1).

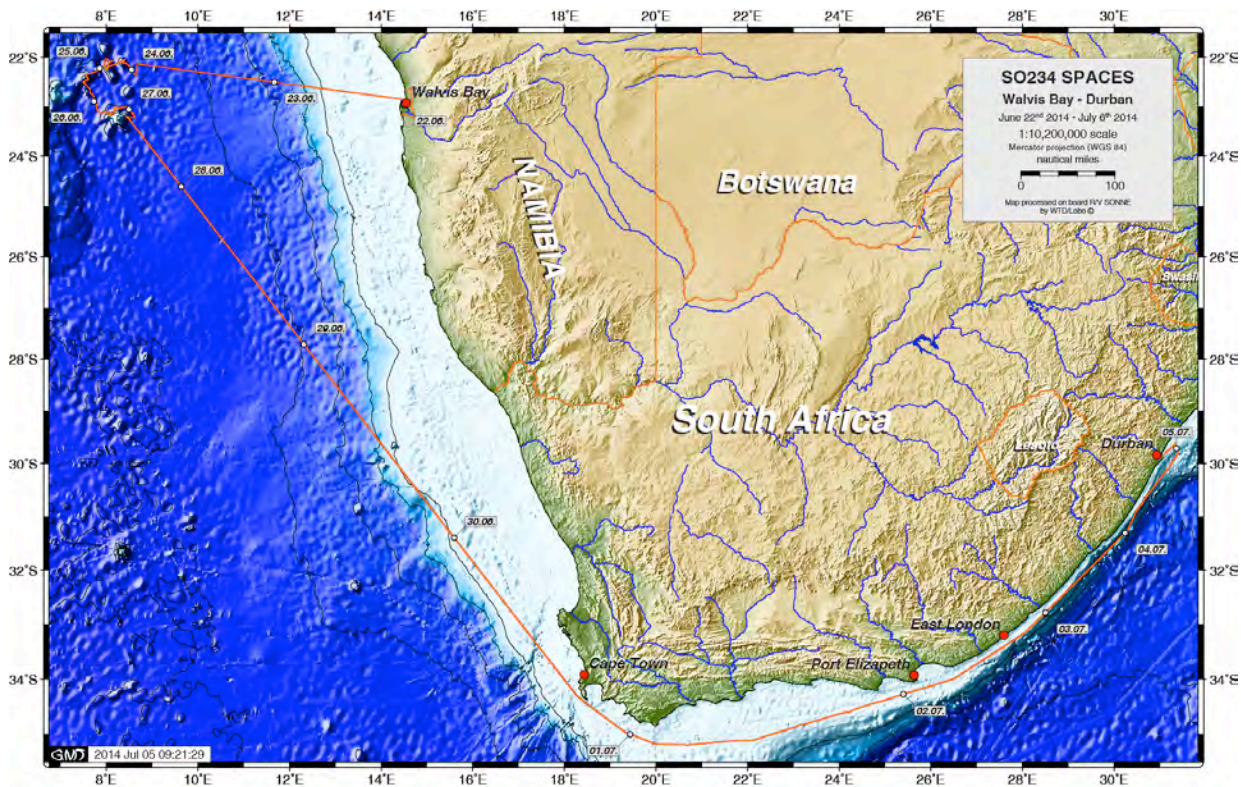


Fig. 4.1: Track chart of R/V SONNE cruise SO234/1.

The working area of SO-234/1 comprised several seamounts, such as the Ewing Seamount which rises more than 4,000 m above the abyssal plain, and a section of the southeastern margin of the Walvis Ridge (Fig. 4.2). Here we alternately conducted EM120 multi-beam surveys, rock sampling using heavy chain bag dredges, and biological stations using a rectangular midwater Tucker Trawl. Whenever possible, trawls have been carried out on transits between dredge stations to save working time (Fig. 4.2). Additionally, sub-bottom profiling using the ATLAS PARASOUND system has been conducted in between the sampling stations and on transits. Due to the fair weather conditions and the excellent support from the master and the crew, we were able to complete 18 sampling stations (Fig. 4.2) besides extensive mapping and profiling within only four working days.

Seven dredge hauls recovered *in situ* rocks from up to 3,500 m water depth. Many dredges, however, yielded carbonates, which most likely represent relics of fossil coral reefs. Luckily, some dredge hauls also returned lava fragments and volcanoclastic rocks suitable for volcanological, geochemical, and geochronological analyses. Among others, we dredged fairly fresh, feldspar-phyric lava at a hitherto un-sampled section of the southeastern margin of the Walvis Ridge, so that this sampling gap has been filled.

The group of biologists conducted ten trawls at depths between 400 and 1,000 m. All trawls were successful and brought numerous animals from the transition of the meso- and bathypelagic habitats including, apart from fishes, several cephalopods, crustaceans, deep-

sea jellyfish, ctenophors and many salp colonies. As for the species of fish caught, there were the “inevitable” and dominant cyclothone species (making up for the most numerous vertebrate on earth), but also there were many lanternfish species, hatchetfish, a number of anglerfish, pelican eels, viperfish and some more rare species such as a pearleye. For subsequent studies of the adaptive mechanisms of visual systems to perceive bioluminescence, eyes and brains were dissected and fixed so they could be further examined in the respective home labs. In addition, muscle and liver tissue was collected for molecular and genetic studies on the phylogeny of mirror eyes.

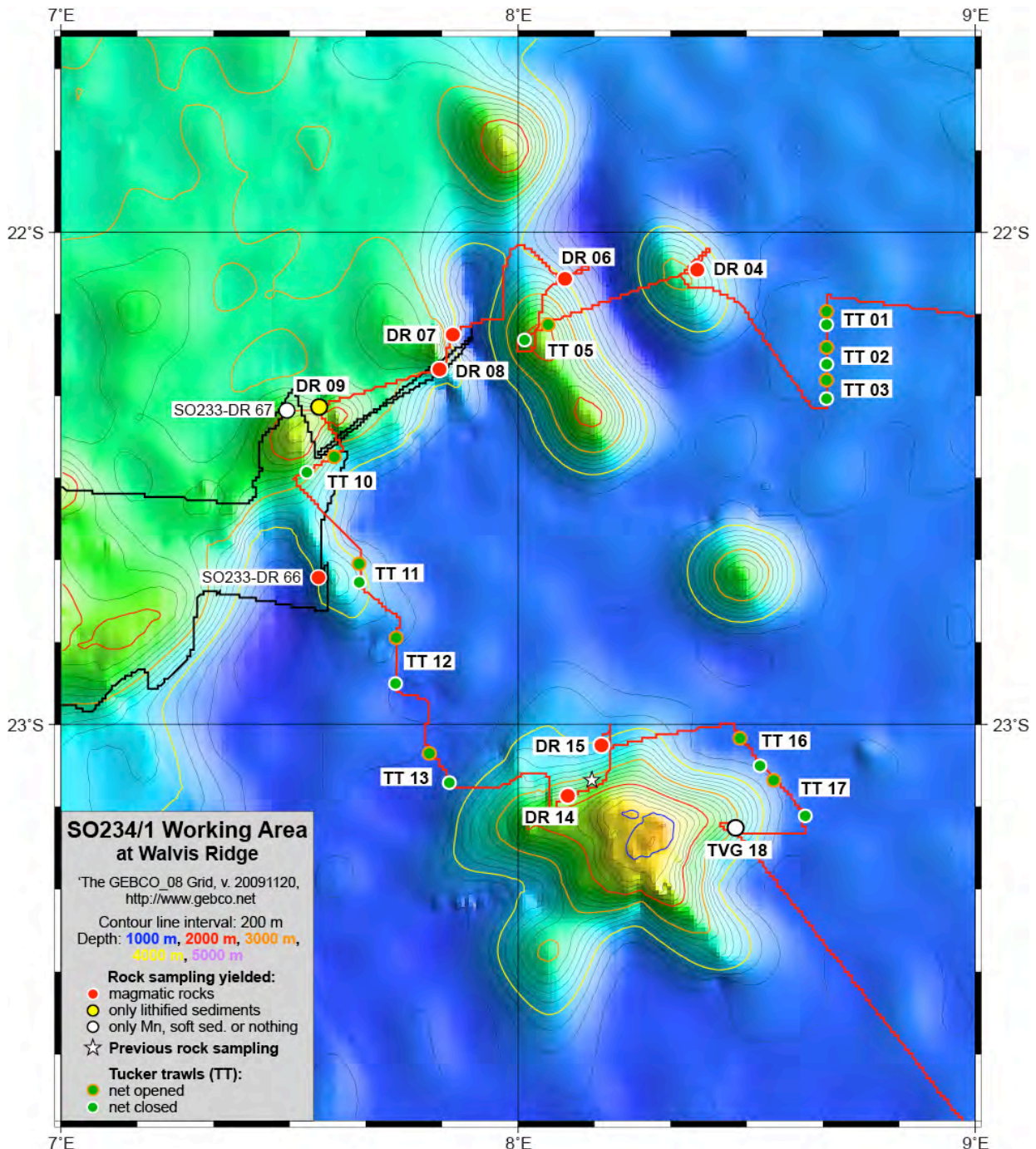


Fig. 4.2: Station map of R/V SONNE cruise SO-234/1.

As a result of the long transit to Durban, a TV-grab station on June 27th at noon was the final deployment of this cruise. The camera of the grab delivered spectacular views from the eastern flank of the Ewing Seamount, which showed, among other things, steep rock ledges closely overgrown with deep sea corals and other benthic fauna. Unfortunately, this "landscape" was too rough for sampling with the TV-grab, so that an attempt to sample rocks

yielded just a small amount of carbonate mud. After the TV-grab was safely fixed on deck, R/V SONNE started the c. 1,600 nm long transit around southern Africa to Durban, located at the eastern coast of South Africa (Fig. 4.1). In the evening of June 28th, we celebrated the success of this short cruise with a hump party in the geo-lab.

Thanks to the prudent scheduling of captain Oliver Meyer, we passed the Cape of Good Hope and Cape Agulhas in calm weather conditions despite the stormy season. Apart from the extensive cleaning and packing, we were thus able to use the transit for a series of talks and seminars on geology, biology, cartography, and project management. On July 5th, R/V SONNE entered the port of Durban. After unloading and container packing, the SO-234/1 scientists and students disembarked on Sunday, July 6th in the late morning, looking back on a short but successful training and capacity building cruise, which gave the students not only insights into marine science but was also great experience for them.

5. TRAINING AND CAPACITY BUILDING

(R. Werner, H-J. Wagner)

The educational work with the students on SO-234/1 comprised (1) fully integration of the students into the scientific work on board during the four working days of the cruise and (2) various lectures and courses given by the senior scientists during transit times. Additionally, the students have been involved in the preparation of the labs and the scientific equipment before station work and in demobilization of the equipment at the end of the cruise. During all activities, the students were very eager and dedicated and completed their assigned tasks with great enthusiasm. They have described their impressions at www.oceanblogs.org/walvis2.

5.1 PROFILING, SAMPLING, AND SAMPLE PREPARATION

During the working days, profiling and sampling has been conducted around-the-clock. Accordingly, the students were grouped into two twelve-hour shifts. All students participated in both geological and biological sampling independent from their branch of study. This interdisciplinary approach aimed to give each student insights into the different marine disciplines and scientific procedures carried out on board. Generally the work on board focused on profiling, station selection, sampling, and sample preparation for home-based analyses. Only very limited analytical work has been carried out during the cruise. Activities of the students during their shifts included “hands-on” experience and “learning by doing” under instruction by experienced scientists. A TV-grab deployment at the end of the station work aimed to give the students an impression on morphology and *in situ* marine benthos of the features, which have been mapped and sampled the days before.

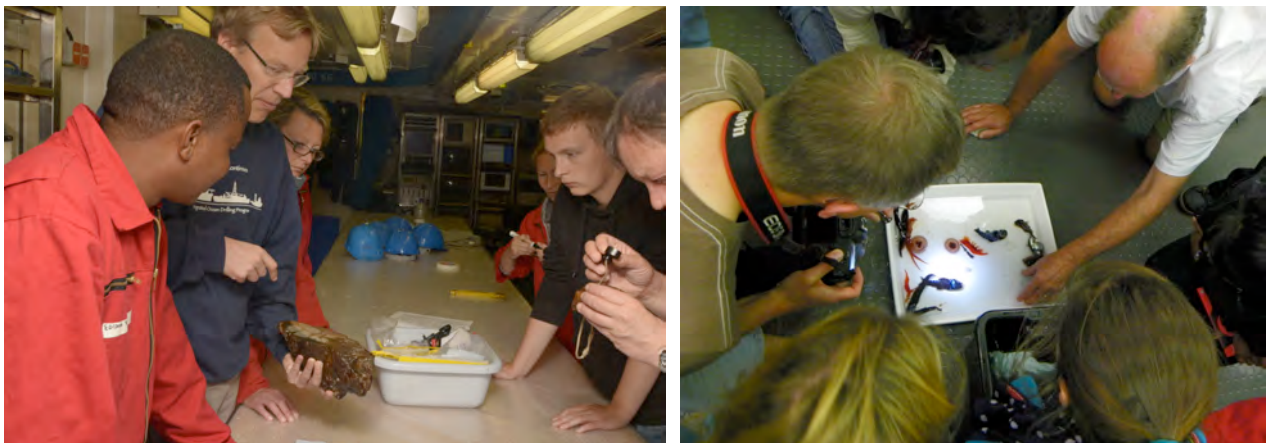


Fig. 5.1 Left: Scientists explain to students the type and composition of a lava sample (photo: Roland Knauer). **Right:** Scientists identify specimens from a catch together with students (photo: Susanne Fretzdorff).

The students watched and assisted in the following activities of the geological investigations:

1. Operation of the EM120 multi-beam echo-sounder and the ATLAS PARASOUND sub-bottom profiler.
2. Evaluation and interpretation of multi-beam data using KONGSBERG and FLEDERMAUS software.
3. Identification of geomorphological units based on morphological characteristics.
4. Selection of appropriate sampling stations and individual dredge tracks.
5. Preparation and performance of dredge hauls.
6. Preparation of rock samples for optical evaluation on board and for home-based analyses (includes cleaning, prescreening, cutting by rock saw, labeling etc.)
7. Evaluation and description of rock samples using hand lenses and a binocular microscope (Fig. 5.1). Properties to be examined included:
 - a. Degree and kind of weathering/secondary minerals

- b. Encrustations
- c. Lithology
- d. Internal structure and texture
- e. Mineral content
- f. Characteristics of the rock matrix (groundmass)

Additionally the students have been fully integrated in the EM120 and PARASOUND watches which were required around-the-clock except during station work. Each student and geologist on board was assigned a daily two hour time slot during which she/he was responsible for the proper data recording of these devices.

During the biological station work, each trawl yielded a great variety of mesopelagic fauna so that the students could study the general appearance of the animals from this region (Fig. 5.1). Only a part of the catches was required for the scientific projects. Students therefore had two options: (1) they could use the remaining specimens for own experiments (see below), or (2) watch and assist the scientists doing their various experiments. More specifically, students had the opportunity to learn about the following activities and topics:

1. Preparing the net and assisting in trawl procedures
2. Preparation of the catch for inspection and triage
3. Identification of specimens from the catch
4. Preservation of specimens in various solutions, depending on further use:
 - a. Cryofixation
 - b. Chemical fixation for light microscopy
 - c. Chemical fixation for electron microscopy
 - d. Preservation for molecular biology
 - e. Preservation for museum purposes (potentially new species)
5. Dissection of eyes and octavolateral systems (fishes)
6. Dissection of brains (fishes)
7. Dissection of other organ systems (all types of animals)
8. Supravital labeling of sensory projections (neurobiotin)
9. Experiments in rhodopsin regeneration (biochemistry)
10. ERG experiments and recordings (electrophysiology)

5.2 LECTURES AND SEMINARS

Even before the first sample came on board, Ron Douglas gave a very spirited and colorful introduction on the deep-sea habitat, its inhabitants, and how they are caught and studied. Furthermore, he gave a brief overview on bioluminescence and visual systems, so that the students were initiated to the field of investigation. Upon completion of the station work, the scientists offered a series of courses and evening presentations (Fig. 5.2).

Two of the highlights were the seminar of Jörg Geldmacher entitled "Introduction to igneous rocks for absolute beginners" which even got some biologists enthusiastic about magmatic rocks, and the "hands on" seminar "Dissection of sensory systems in fish" by Hans-Joachim Wagner, Fanny de Busserolles, Ulrich Mattheus, and Adrian Flynn.

The seminar "Introduction to igneous rocks" covered all aspects of volcanism and the formation and characteristics of igneous rocks. Using 50 hand rock samples that were particular provided for this seminar by the Geologisches Museum of the University Kiel the participants learned to classify magmatic and volcanic rocks by basic criteria such as grain size, texture and color.

The seminar "Dissection of sensory systems in fish" gave the students the opportunity to dissect specimens from the trawls that had been preserved in formalin. Special attention was given to the sensory systems and the brain. As a theoretical introduction, Hans-Joachim Wagner improvised a short overview on the structure and function of the central nervous system and the various senses in humans and fish using simple white board drawings. Ron Douglas gave another introduction in the organization of the eye. For the practical work, the students formed rotating groups of three (limited by the number of stereo microscopes). Three activities were offered:

1. Taxonomy: How do I identify a fish? (Adrian Flynn)

2. Sensory systems: Dissection of a fish eye; isolation of the retina and the tapetum (Fanny de Busserolles)
3. Fish CNS: Dissection of fish brains and spinal cords (Hans-Joachim Wagner und Ulrich Mattheus)

Following a short introduction, students were able to perform the dissections autonomously. The brain dissections were performed on several fish species with different dominant sensory systems in order to demonstrate the adaptive radiation: *Sternoptyx* as a visual animal with a large optic tectum; a Melamphaeid species with small eyes and well developed lateral lines and correspondingly a large rhombencephalon; a deep-sea eel with a well developed olfactory system; and a viperfish presenting an unspecialized situation with no dominant sense. A deep-sea squid eye and brain were also dissected, as a kind of evolutionary contrast, showing convergence. The students were very eager and dedicated and took numerous photos of their dissection work.

Events on the Transit to Durban:
(all talks will be in Englisch)

Sunday, 29.06., 19:00:
19:00, Mess Room: "Mirror Eyes in Barreleyes" by Jochen

Monday, 30.06., 19:00:
19:00, Mess Room: "Scientific project management " by Susanne and "The confusing spatial reference and some GIS stuff " by Matthias
21:00: Soccer World Cup: Germany - Algeria

Tuesday, 01.07:
8:30 - 11:30, Konferenzraum: "Einführung in die Gesteinskunde für Anfänger" (Schwerpunkt magmatische Gesteine) - Seminar von Jörg (in Deutsch)
19:00, Mess Room: "Laternfish vision" by Fanny

Wedensday, 02.07:
8:30 - 11:30, Conference Room: "Introduction to igneous rocks to absolute beginners" - seminar by Jörg (in English)
19:00, Mess Room: "Laternfish ecology & biogeography" by Adrian

Thursday, 03.07:
08:30 - c. 15:00, Wet-Lab: "Dissection of sensory systems in fish" - seminar by Jochen and Ulli
19:00, Mess Room: Walvis Ridge evening - extended version:

- (1) "Birth, life, and death of an island volcano and related things" by Reinhard
- (2) "Why do we study the Walvis Ridge" by Stephan
- (3) "Geological evolution of the Walvis Ridge" by Milena

Friday, 04.07.:
18:00: Soccer World Cup: Germany vs. France

Fig. 5.2: Notice placed at R/V SONNE's white board announcing the lectures and seminars scheduled on the transit from the SO-234/1 working area to Durban (in due consideration of the soccer world cup 2014).

6. GEOLOGY

(R. Werner, J. Geldmacher, S. Homrighausen, S. Fretzdorff, A. Kipf, M. Schroeder)

6.1 METHODS

6.1.1 Bathymetry (Simrad Kongsberg EM120)

Data acquisition

Since June 2001 the R/V SONNE has been equipped with a Simrad Kongsberg EM120 multi-beam echo sounder system for continuous mapping of the seafloor. The EM120 system consists of several units. A transmitter/receiver transducer array is fixed in a mills cross below the keel of the vessel. A preamplifier unit contains the preamplifiers for the received signals. The transceiver unit contains the transmitter and receiver electronics and processors for beam-forming and control of all parameters with respect to gain, ping rate and transmit angles. The system has serial interfaces for vessel motion sensors, such as roll, pitch and heave, external clock and vessel position. The system also includes a Intel based (Windows XP) operator station. The operator station processes the collected data, applying all corrections, displays the results and logs the data to internal or external disks. The EM120 system has an interface to a sound speed sensor, which is installed near by the transducers.

The EM120 system uses a frequency of about 12 KHz with a whole angular coverage sector of up to 150° (75° per port-/starboard side, Fig 6.1). When one ping is sent, the transmitting signal is formed into 191 beams by the transducer unit through the hydrophones. The beam spacing can be defined in equidistant or equiangular modes or in a mix of both. The ping-rate depends on the water depth and the runtime of the signal through the water column. The variation of angular coverage sector and beam pointing angles was set automatically. This optimized the number of usable beams.

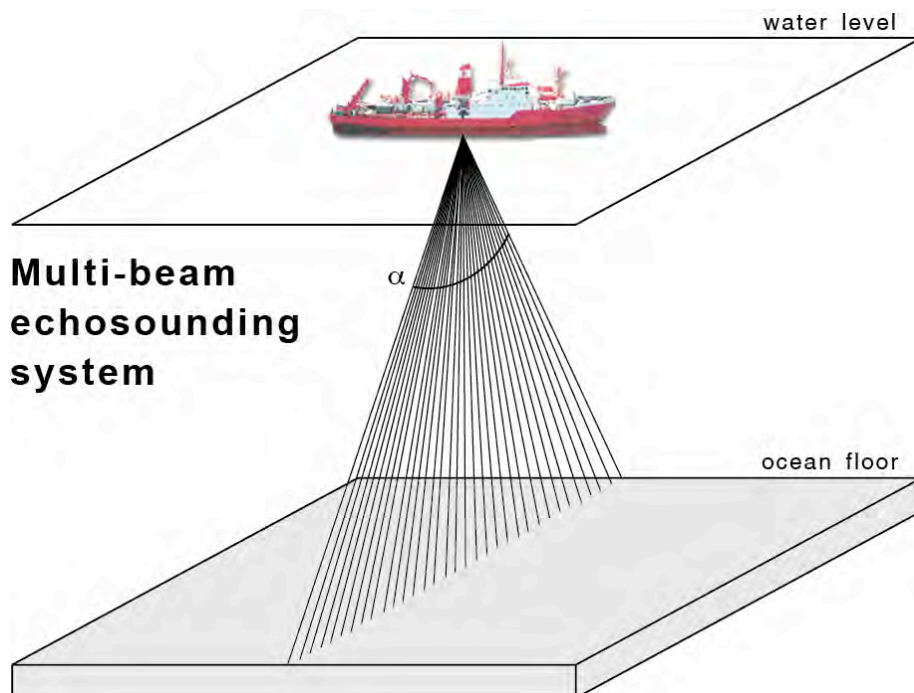


Fig. 6.1: Schematic sketch illustrating the principle mode of operation of multi-beam echo-sounding systems. The whole angular coverage sector (α) of the Simrad Kongsberg 120 system amounts is up to 150°.

During a survey the transmitter fan is split into individual sectors with independent active steering according to vessel roll, pitch and yaw. This forces all soundings on a line perpendicular to the survey line and enables a continuous sampling with a complete coverage. Pitch and roll movements within ± 10 degrees are automatically compensated by the software. Thus, the EM120 system can map the seafloor with a swath width about up to six times the

water depth. The geometric resolution depends on the water depth and the used angular coverage sector and is less than 10 m at depths of 2,000 - 3,000 m.

The accuracy of the depth data obtained from the system is usually critically dependent upon weather conditions and the use of a correct sound velocity profile. The sound profile has been determined using a CTD on the precursor cruise SO-233 when R/V SONNE arrived at the Walvis Ridge, ensuring the use of the correct sound velocity on this cruise.

Data processing

The collected data were processed onboard with the EM120 coverage software. The post-processing was done on two other workstations by the accessory Neptune software. The Neptune software converted the raw data in 9 different files which contains information about position, status, depth, sound velocity and other parameters and are stored in a SIMRAD binary format.

The data cleaning procedure was accomplished by the Neptune software. The first step was to assign the correct navigational positions to the data without map projections. The second step was the depth corrections, for which a depth threshold was defined to eliminate erratic data points. In the third part of post-processing statistical corrections were applied. Therefore, a multitude of statistical functions are available in a so called BinStat window where the data are treated by calculating grid cells with an operator-chosen range in x and y direction. Each kind of treatment is stored as rule and has an undo option. For the calculation the three outermost beams (1 - 3 and 188 - 191) were not considered. Also a noise factor, filtering and a standard deviation were applied to the calculated grid. All this work was done by the system operators of R/V SONNE. After the post-processing the data have been exported in an ASCII x,y,z file format with header information and was transferred to other workstations where assembling, girding and contouring with the GMT software (Wessel and Smith 1995) and/or Fledermaus version 7.3.4 by Interactive Visualization Systems Inc. were done.

6.1.2 Sediment Echo-Sounding (Atlas PARASOUND)

Sub-bottom profilers (or sediment echo-sounding systems) are used to display sub-seafloor geological structures as, for example, marine sediment successions. The ATLAS PARASOUND sub-bottom profiler acts as a low-frequency sediment echo-sounder and as high-frequency narrow-beam sounder to determine the water depth. The sub-bottom profiler is based on the parametric effect, which is produced by additional frequencies through nonlinear acoustic interaction of finite amplitude waves. In principle, if two sound waves of similar frequencies (18 kHz and e.g. 22 kHz) are emitted simultaneously, a signal of the difference frequency (e.g. Secondary Low Frequency of 4 kHz) is generated for sufficiently high primary amplitudes. This new component is traveling within the emission cone of the original high frequency waves, which are limited to an angle of only 4.5° for the equipment used (Fig. 6.2). The resulting footprint size of only 7 % of the water depth is much smaller than for conventional systems and both vertical and lateral resolution is significantly improved.

The ATLAS PARASOUND system is permanently installed on R/V SONNE. The hull-mounted transducer array has 128 elements within an area of 1 m². It requires up to 70 kW of electric power due to the low degree of efficiency of the parametric effect. The PARASOUND sub-bottom profiler on R/V SONNE is equipped with the digital data acquisition software from ATLAS Hydrographic, which is subdivided in ATLAS Parastore and ATLAS Hydromap Control. ATLAS Parastore allows the buffering, transfer and storage as well as the visualization of the digital echograms at very high repetition rates. ATLAS Hydromap Control is responsible for user defined modifications of the system (e.g. pulse rate or mode) and supports the operator in running the system properly.

PARASOUND data have been recorded during all SO-234/1 bathymetric surveys and on transits in international waters. On the cruise, however, only online profiles displayed on the screen have been used. The data acquisition included PHF and SLF data. All data have been copied on an external hard disk and sorted by the operator into folders according to data type (PHF, SLF / ASD, PS3, SEGY) and recording dates (0 to 24 hours UTC). After the cruise, the entire PARASOUND data set will be transferred to co-operating specialists for further shore based processing and analyses and archived in international data bases.

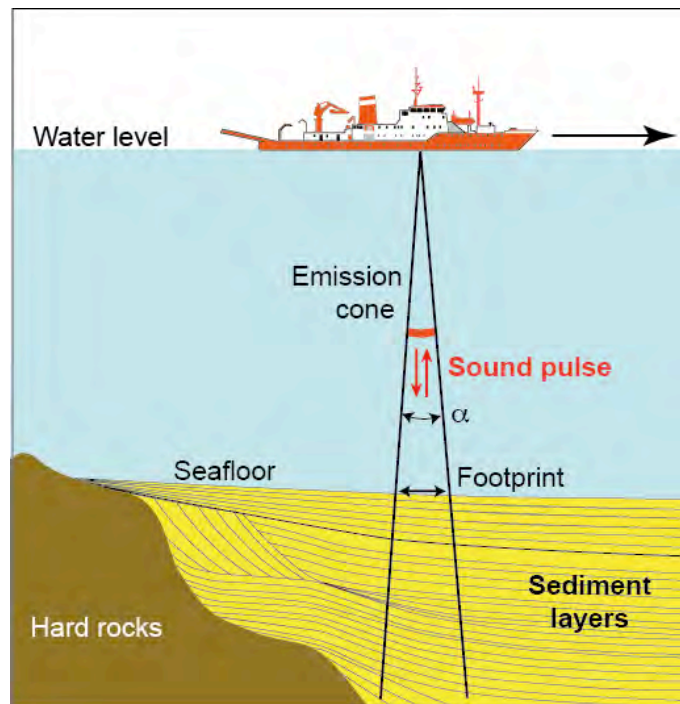


Fig. 6.2: Schematic sketch illustrating the principle mode of operation of sub-bottom profilers. The extremely narrowed beam of the ATLAS PARASOUND system of 4.5° (α) allows to resolve even small-scale bottom structures and offers a deeper penetration of up to ~ 200 m into the seafloor.

6.1.3 Dredging, Site Selection, and Laboratory Work

Rock sampling on SO-234/1 was carried out using rectangular chain bag dredges. Chain bag dredges are similar to large buckets with a chain bag attached to their bottom and steel teeth at their openings (Fig. 6.3), which are dragged along the ocean floor by the ship's winch.

General station areas were chosen on the basis of a number of existing datasets. These mainly include bathymetric data recorded on the precursor cruise SO-233 and predicted bathymetry, derived from gravity data and ship depth soundings (etopo by Smith and Sandwell [1997] and "The GEBCO_08 Grid, version 20091120", <http://www.gebco.net>).

The final selection of dredge sites was critically dependent on detailed multi-beam echo-sounding surveys carried out at each station before dredging. Final positioning of the vessel over the dredge sites was done using the bathymetric data gained on the surveys as well as allowing for weather and drift conditions. Dredge tracks were usually located - depending on the morphology of the structures - on steep slopes, at plateau edges, at scarps, canyon walls, and on the flanks of cones and of larger seamounts. This was mainly done to avoid areas of thick sediment cover.

Shipboard Procedure

Once onboard, a selection of the rocks were cleaned and cut using a rock saw. They were then examined with a hand lens and microscope, and grouped according to their lithologies and degree of submarine weathering. The immediate aim was to determine whether material suitable for geochemistry and radiometric age dating had been recovered. Suitable samples have an unweathered and unaltered groundmass, empty vesicles, glassy rims (ideally), and any phenocrysts that are fresh. If suitable samples were present, the ship moved to the next station. If they were not, then the importance of obtaining samples from the particular station was weighted against the available time.

Fresh blocks of representative samples were then cut for thin section and microprobe preparation, geochemistry and further processes to remove manganese and alteration products and/or to extract glass (if applicable). Each of these sub-samples, together with any remaining bulk sample, was described, labeled, and finally sealed in either plastic bags or bubble wrap for transportation to GEOMAR.



Fig. 6.3 Above: Handling of a chain bag dredge on deck (photo: Kaj Hoernle). **Left:** The dredge comes back on board after a haul (photo: Roland Knauer).

Shore Based Analyses

Magmatic rocks sampled by R/V SONNE from the ocean floor will be analyzed using a variety of different geochemical methods. The ages of whole rocks and minerals will be determined by $^{40}\text{Ar}/^{39}\text{Ar}$ laser dating. Major element geochemistry by X-ray fluorescence (XRF) and electron microprobe (EMP) will constrain magma chamber processes within the crust, and also yield information on the average depth of melting, temperature and source composition to a first approximation. Phenocryst assemblages and compositions will be used to quantify magma evolution, e.g. differentiation, accumulation and wall rock assimilation. Petrologic studies of the volcanic rocks will also help to constrain the conditions under which the melts formed (e.g., melting depths and temperatures). Further analytical effort will concentrate on methods that constrain deep-seated mantle processes. For example, trace element data determined by inductively coupled plasma mass spectrometry (ICP-MS) will help to define the degree of mantle melting and help to characterize the chemical composition of the source. Long-lived radiogenic isotopic ratios measured by Thermal Ionization Mass Spectrometry (TIMS) and Multi-collector ICP-MS such as $^{87}\text{Sr}/^{86}\text{Sr}$, $^{143}\text{Nd}/^{144}\text{Nd}$, $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, $^{208}\text{Pb}/^{204}\text{Pb}$, and $^{176}\text{Hf}/^{177}\text{Hf}$ are independent of the melting process and reflect the long-term evolution of a source region and thus serve as tracers to identify mantle and recycled crustal sources. Additionally, morphological studies and volcanological analyses of the dredged rocks will be used to constrain eruption processes, eruption environment and evolution of the volcanoes. Through integration of the various geochemical parameters, the morphological and volcanological data, and the age data the origin and evolution of the sampled structures can be reconstructed.

Non-magmatic rocks and Mn-Fe oxides recovered by dredging will be made available to co-operating specialists for further shore based analyses.

6.2. ROCK SAMPLING REPORT AND PRELIMINARY RESULTS

The following section gives background information and short summaries of the features sampled and/or mapped on SO-234/1 and the rocks recovered from them. Refer to Appendix I and II for exact latitude, longitude, and depth of dredge sites and more detailed rock

descriptions. Figure 4.2 shows an overview map with all SO-234/1 sampling sites. Distances, dimensions and heights given in this chapter are approximate and are only included to give a rough idea of dimensions of morphological features. Distances between seamounts are given between the seamount tops. All photos shown in this chapter are taken by GEOMAR.

The major objective of SO-234/1 rock sampling was to fill a sampling gap between c. 20°40'S und 25°20'S at the eastern flank of the Walvis Ridge. The precursor cruise SO-233 aimed for systematic sampling of the Walvis Ridge, which could be successfully completed except for that area (Fig. 6.4) where bad weather conditions and subsequent time constraints prevented comprehensive rock sampling.

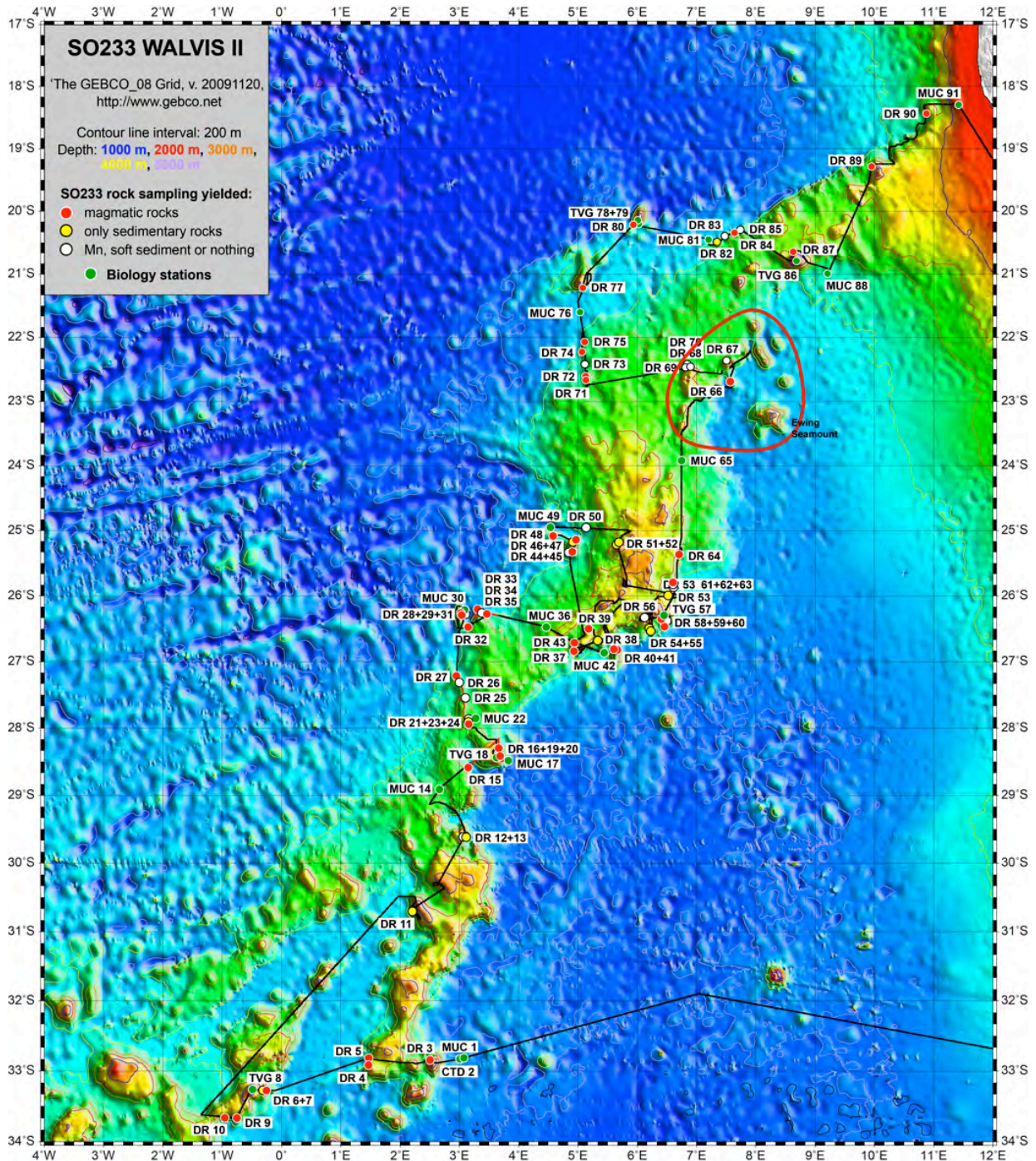


Fig. 6.4: Ship's track (black line) and sampling stations (colored dots) of R/V SONNE cruise SO-233 WALVIS II which aimed for systematic rock sampling along both flanks of the Walvis Ridge. Note that only a single dredge haul recovered magmatic rocks (DR 66) from a c. 500 km long section of the eastern flank between SO-233 stations DR 64 (c. 25°20'S) and DR 87 (c. 20°40'S) and that the prominent seamounts east off the ridge between 22°00'S and 23°30'S remained un-sampled. Accordingly, the red-encircled area represented a sampling gap at the Walvis Ridge prior to SO-234/1.

Therefore, magmatic rock samples were available only from a single dredge station (SO233-DR 66) along a c. 500 km long section of the eastern flank of the Walvis Ridge (Fig. 6.4). Even though the dredge haul SO233-DR 66 yielded fresh volcanic rocks being suitable for geochemical analyses and age dating, these rocks were recovered from a N-S trending volcanic rift extending from a large guyot located on the margin of the rift (Fig. 6.5) and thus may not represent the ridge basement but a later stage of magmatism. Therefore SO-234/1 aimed to recover additional magmatic samples from the ridge margin in the area between c. 22° and 23°S (i.e. approximately in the center of the sampling gap). Additionally dredge targets were several seamounts being located to the east of that section of the Walvis Ridge on the abyssal plain, among them Ewing Seamount (Figs. 4.2, 6.4).



Fig. 6.5: 3D-map showing SO-234/1 and SO-233 mapping and hard rock sampling at the eastern margin of the Walvis Ridge between c. 22° and 22°40' S (view from SE to NW, exaggeration: 3x; interval of contour lines: 100 m). SO-233 and SO-234/1 dredge stations are marked by yellow dots.

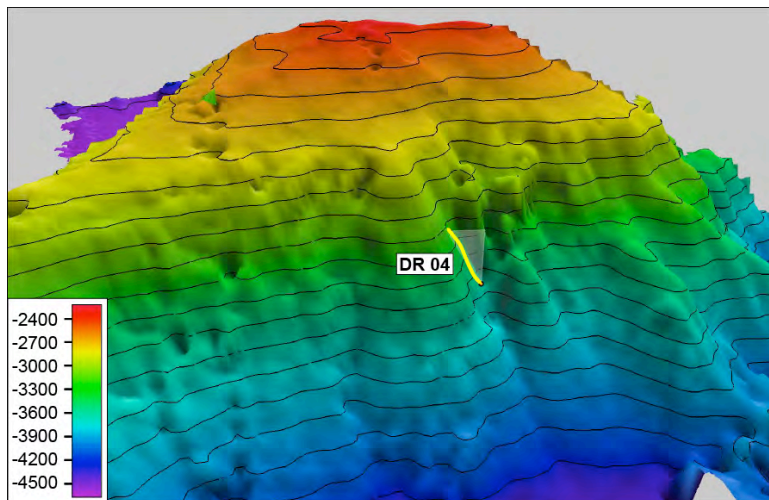


Fig. 6.6: 3D-map showing dredge track SO234/1-DR 04 at the eastern flank of "Seamount A" (view from NE to SW; data sources, exaggeration, and contours as in Fig. 6.5).



Fig. 6.7: Fairly fresh porphyritic lava of DR 04.

The first dredge station of cruise SO-234/1 (SO234-DR 04) has been carried out at an oval-shaped, unnamed seamount located on the abyssal plain approximately 15 nm off the eastern margin of the Walvis Ridge (herein called "Seamount A", Figs. 6.5, 6.6). Seamount A is c. 2,000 m high and measures c. 30 x 18 km at its base in c. 4,400 m water depth. It possesses a guyot-like morphology with steep flanks and an erosional plateau at the top. Guyots are former ocean island volcanoes, that were eroded at sea level and then submerged into the

deep sea. The current water depth above the erosional plateau indicates that the volcano drowned about 2,350 m since the onset of erosion. Dredge haul DR 04 was carried out at the eastern flank of Seamount A in c. 3,600 m below sea level (b.s.l.) (Fig. 6.6). Unfortunately, the dredge got irretrievably stuck directly at the starting point of the dredge track and had to be released by the vessel. Nevertheless, DR 04 returned one porphyric lava fragment (Fig. 6.7). The lava is only moderately altered, slightly vesicular (c. 3% filled vesicles) and contains c. 15% plagioclase (< 5 mm) and c. 5 - 10% pyroxene phenocrysts. Since this lava fragment appears to be suitable for geochemical analyses and for age dating, it was decided to leave "Seamount A" and to continue dredging further west at the Walvis Ridge flank.

Between c. 22°00' and 22°40'S, the eastern ridge margin rises from its toe in c. 4,500 - 4,400 m b.s.l. up to c. 2,900 - 2,700 m b.s.l. Morphologically, its most remarkable features are two large oval-shaped guyots situated on the edge of the margin (herein called "eastern" and "western" guyot, Fig 6.5). Due to time constraints these guyots could not be completely mapped on the SO-234/1 and SO-233 cruises, but according to the predicted bathymetry the eastern guyot measures c. 40 x 25 km and the western c. 30 x 20 km at their bases. The center of the erosional platforms of both guyots (and of third guyot c. 35 nm further west) is located uniformly in 1,450 - 1,600 m b.s.l. and the plateau margins in 1,800 m b.s.l. The inward shoaling of the platform is consistent with subsidence occurring contemporaneously with erosion at sea level to form the platform. The uniform depth of the three platforms suggests a similar age and subsidence history of these former island volcanoes. Distinct ridges emanate from the base of the guyots in southern or western directions, which reach lengths of up to 25 km. These ridges are interpreted as volcanic rift zones formed during the shield stage of the volcanoes. As mentioned above, the successful dredge haul in that area of the precursor cruise SO-233 sampled the rift of the western guyot (SO233-DR 66, Fig. 6.5). Another morphological feature of this section of the Walvis Ridge margin are numerous small volcanic cones (up to c. 3 km in diameter and c. 450 m high), which are scattered on the flanks of the guyots, the volcanic rifts, and the ridge margin (e.g. Figs. 6.5, 6.8, 6.10). We note, however, that such cones do not appear on the erosional plateaus of the guyots so that it remains unclear if the cones have been formed contemporaneously with the island volcanoes or during a later stage of volcanism.

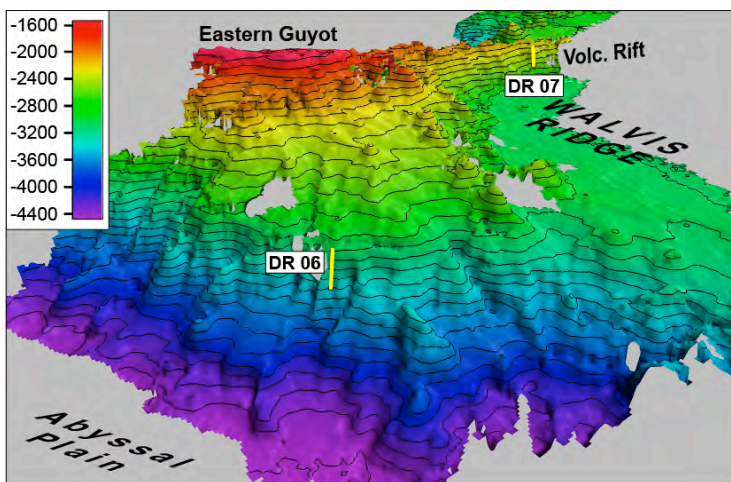


Fig. 6.8: 3D-map showing SO-234/1 dredge tracks DR 06 at the ridge margin near the eastern guyot and DR 07 on a volcanic rift emanating from that guyot (view from ENE to WSW; data sources, exaggeration, and contours as in Fig. 6.5).



Fig. 6.9: Porphyric lava with attached volcanoclastic material of DR 06.

Dredge site SO234/1-DR 06 aimed to sample the Walvis Ridge basement c. 15 nm west of DR 04. Unfortunately, multi-beam mapping revealed that the steepest and therefore most suitable slopes for dredging at the ridge margin extend underneath the guyots and cones whose lava and volcanoclastic deposits may have overprinted the ridge basement. In the absence of alternative sites, the dredge haul has been carried out between c. 3,250 and 2,950 m b.s.l. near the eastern guyot (Fig. 6.8) but we cannot rule out that it sampled volcanic rocks

of the guyot instead of the ridge basement. The dredge returned some angular lava fragments and volcanoclastic material. The volcanoclastic material was partly attached to the lava fragments (Fig. 6.9) and contains angular clasts being lithologically very similar to the lava fragments. These rocks may therefore represent a (top?) breccia of a lava flow. The lava fragments are moderately altered, have only a few open vesicles (1-2%), and are porphyritic with c. 15 - 20% plagioclase and (< 3 mm) c. 4 - 7% altered olivine (< 3 mm) phenocrysts in a fine-grained brownish matrix. The next dredge SO234/1-DR 07 was conducted c. 30 km WSW of DR 06 at the northern flank of a volcanic rift extending from the eastern guyot to the west (Fig. 6.9). The dredge recovered volcanic rocks, carbonate, and Mn-crusts from c. 2,620 - 2,300 m water depth. The volcanic rocks are dense, Mn-encrusted and highly altered reddish-brown lava fragments with pervasive alteration resulting in thin carbonate veins, Mn-intrusions, and replacement of primary phases by phyllosilicates. Although these rocks are most likely not suitable for meaningful analyses, R/V SONNE headed further SSW to the ridge margin since SO-233 had already recovered a suitable and representative sample from these rift structures (SO233-DR66, see above). SO234/1-DR 08 was conducted at the upper ridge margin (c. 2,900 - 2,700 m) in between the eastern and the western guyot (Fig. 6.10) and aimed again to sample the Walvis Ridge basement. The dredge recovered altered, Mn-encrusted volcanoclastic rocks and carbonates. The volcanoclastic material consists of a fine-grained, completely altered matrix and mm- to dm-sized lava clasts (Fig. 6.11). The clasts are slightly to highly vesicular with up to 35% filled vesicles (up to 8 mm) and contain up to c. 7% altered olivine phenocrysts and partly small plagioclase needles. Completely palagonitized relicts of glassy rims are recognizable at some of these clasts (Fig. 6.11). The clasts (or at least some of them) appear to be suitable for geochemical analyses but careful examination of thin sections is required before preparation. The next dredge SO234/1-DR 09 was located at the northern slope of the western guyot c. 3 km west of the previous cruise SO-233 dredge station DR 67 (Fig. 6.10). SO234/1-DR 09 aimed to dredge this guyot again since SO233-DR 67 failed to return rocks (dredge got lost) and could not be repeated due to deteriorating weather conditions. Unfortunately, the new dredge haul yielded exclusively carbonate blocks. Due to time constraints, further dredge attempts have not been made at the western guyot and R/V SONNE left the Walvis Ridge margin and headed towards Ewing Seamount.

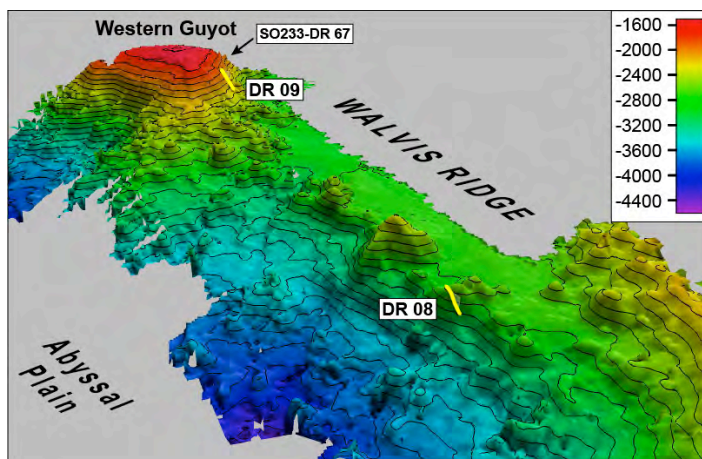


Fig. 6.10: 3D-map showing SO-234/1 dredge tracks DR 08 at the ridge margin and DR 09 at the western guyot. Note the numerous small cones in that area (view from E to W; data sources, exaggeration, and contours as in Fig. 6.5).



Fig. 6.11: Volcanoclastic rocks with lava clasts recovered by dredge haul DR 08. The dark brown rim of central clast is a relict of a former glassy margin.

Ewing Seamount is located on the abyssal plain c. 60 nm southeast of the eastern margin of the Walvis Ridge and is by far the largest seamount in that area (Figs. 4.2, 6.4). According to the predicted bathymetry it is an E-W-trending, oval-shaped feature measuring c. 70 x 50 km at its base. It elevates from c. 4,500 m to c. 700 m b.s.l. and shows two major extensions (or coalesced seamounts) towards the SE and SW. Only small parts of this huge seamount could get mapped on SO-234/1 (Fig. 6.12). Multi-beam mapping at its northern flank revealed a gentle lower slope followed by a steep step from 2,900 to 2,100 m b.s.l. and an inward shoaling erosional plateau. The southeastern flank of Ewing Seamount is steeper than the

northern flank with the plateau edge at c. 2,000 m. As observed at the guyots on the Walvis Ridge margin, volcanic rifts emanate from Ewing Seamount in various directions. The central area of Ewing Seamount have not been mapped but according to the predicted bathymetry there must be a c. 1,000 m high edifice on the erosional plateau, possibly suggesting renewal of the volcanic activity after erosion.

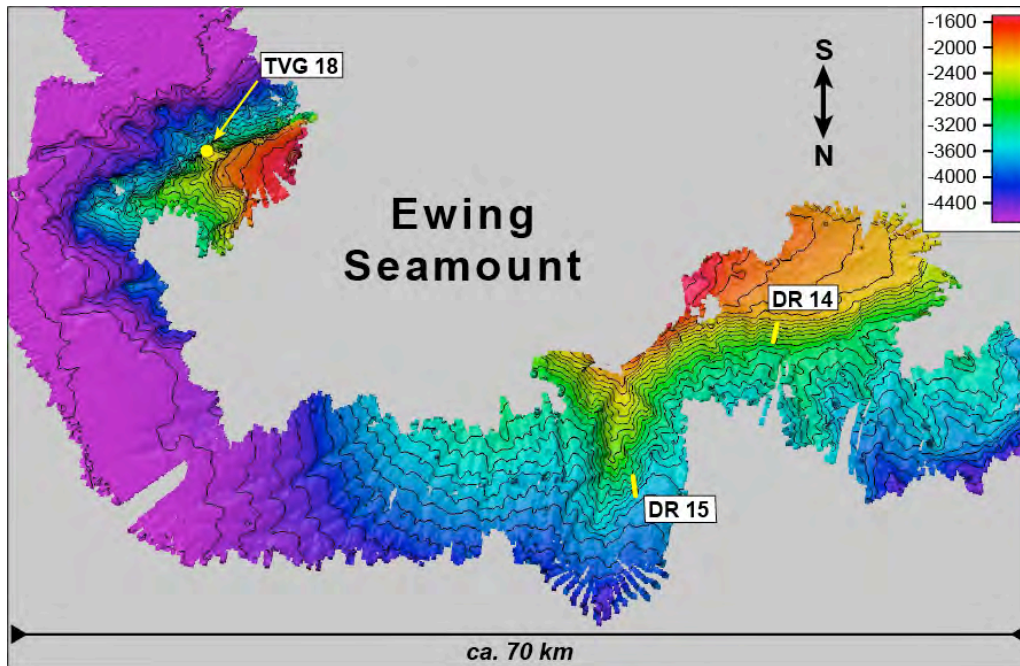


Fig. 6.12: SO-234/1 multi-beam mapping and sampling at Ewing Seamount (80° top view from north; exaggeration and contours as in Fig. 6.5).

The first sampling attempt at Ewing Seamount (SO234/1-DR 14) was made at the steep step of its northern flank from c. 2,730 to 2,270 m b.s.l. (Fig. 6.12). DR 14 yielded moderately altered volcanoclastic rocks and carbonates. The volcanoclastic material consists of subangular brown and black lava clasts in a fine-grained white to brown matrix. The clasts are cm-sized and show a vesicularity of c. 5 - 25%. Plagioclase and clinopyroxene phenocrysts occur spotted in the clasts and as individual minerals within the matrix. Some of the clasts are probably suitable for geochemical analyses. The second dredge at Ewing Seamount (SO234/1-DR 15) has been carried out from 3,450 m to 3,100 m b.s.l. close to the southern tip of a volcanic rift emanating from the northern flank towards the north (Fig. 6.12). DR 15 yielded a 23 x 16 x 14 cm sized angular lava bloc and some fragments of fine-grained brownish sediments. The lava is moderately altered and has c. 25% vesicles up to 3 mm in size, c. 20% of them are filled with white or light grey material (calcite?). The groundmass is fine grained and contains plagioclase and c. 3% altered olivine phenocrysts. Overall, sampling of Ewing Seamount yielded volcanic rocks suitable for geochemical analyses and maybe also for age dating. The last station at Ewing Seamount was a TV-grab (SO234/1-TVG 18) conducted at a pedestal at its upper southeastern flank (Fig. 6.12). The TV-grab is essentially a huge digger shovel with an attached camera so that it is possible to see in the ship's lab the seafloor and what is sampled. After reaching the edge of the pedestal, the TV-grab camera showed spectacular views of a very steep and rough slope with bizarre ledges populated by marine benthos. Sampling of hard rocks, however, failed because of the rough terrain and the TV-grab returned just c. 10 kg of soft sediment.

In summary, all SO-234/1 dredge hauls recovered *in situ* rocks from up to 3,600 m water depth. Igneous rocks suitable for geochemical analyses and partly also for age dating have been obtained from "Seamount A", at two locations at the margin of the Walvis Ridge, and at Ewing Seamount. Therefore hard rock sampling of SO234/1 reached its major goal to fill the sampling gap in this area. Even if it is not clear yet if the actual ridge basement could be successfully sampled. The morphology of the sampled guyots on the ridge margin clearly indicates, that they once formed a volcanic archipelago, which has been eroded to sea level

by wave activity after the volcanoes became extinct. As the crust beneath the archipelago cooled, it subsided and the volcanoes sank beneath sea level. The carbonates found in four of seven dredges most likely represent relics of coral reefs which once grew on the former wave cut top of the volcanoes in an early stage of subsidence. The erosional plateau of Seamount A is located in greater water depth than the plateaus of the guyots on the ridge margin, the same applies to the mapped part of the plateau at Ewing Seamount. That implies a different age and/or a different subsidence history for these volcanoes. Therefore, we speculate that Seamounts A and at least the base of Ewing Seamounts are older than the guyots on the ridge margin. This earlier phase of magmatism may be related to the formation of the Walvis Ridge basement.

7. BIOLOGY

(H.J. Wagner, F. de Busserolles, R. Douglas, A. Flynn, U. Mattheus)

7.1 METHODS

7.1.1 Midwater Trawl Net *(A. Flynn, H.-J. Wagner)*

A controllable opening-closing Rectangular Midwater Trawl Net (aka Tucker Trawl) system was used for deepwater specimen collection down to 1,000m. Two such systems have been developed and constructed by Harbor Branch Oceanographic Institute and the University of Queensland under the Australian Research Council's Deep Australia research grant. The net is sent down closed, opened at depth, closed after a period of time, and recovered.



Fig. 7.1: 3D model of the opened RMT-16 trawl net system with closing cod-end.

The net system consists of four components: A two-part RMT net, a 4-bar opening-closing support system, a collection cod-end, and an electronic control and instrumentation unit. The RMT net is composed of a forward section of 5mm knotless nylon, mated to a 1m diameter stainless steel ring, followed by a 291 μ m nitex mesh section. We used the RMT-16 (16m²

projected mouth area) net configuration. Four stainless steel bars are used as a support structure. The uppermost bar is the tow bar, which also holds the instrumentation and release mechanism. Below the tow bar, the upper and lower net bars support the net, which is sent down closed (bars together at top), opened at fishing depth, and then closed (bars together at bottom). Finally, a weight bar consisting of a series of lead rings is used to keep the net mouth facing forward.



Fig. 7.2: RMT-16 prior to deployment (left) and test lift on aft deck of R/V SONNE (right).

The net control unit provides a means of opening and closing the net, as well as monitoring the net's depth, temperature, and speed through the water. This eliminates the guess-work of determining net depth from wire-angle, and using timers and messengers to trigger opening and closing, as in other designs. The unit is battery operated and may be run in real-time via a two-wire communications cable or pre-programmed to run automatically without supervision if such a cable is unavailable. On this expedition, we connected the control unit through R/V SONNE's W1 winch, which contains 7,000m of armored electro-optical cable. All trawls except the last were conducted in real-time from R/V SONNE's geological laboratory using a laptop PC running the RMT's topside control, monitoring, and data logging software.

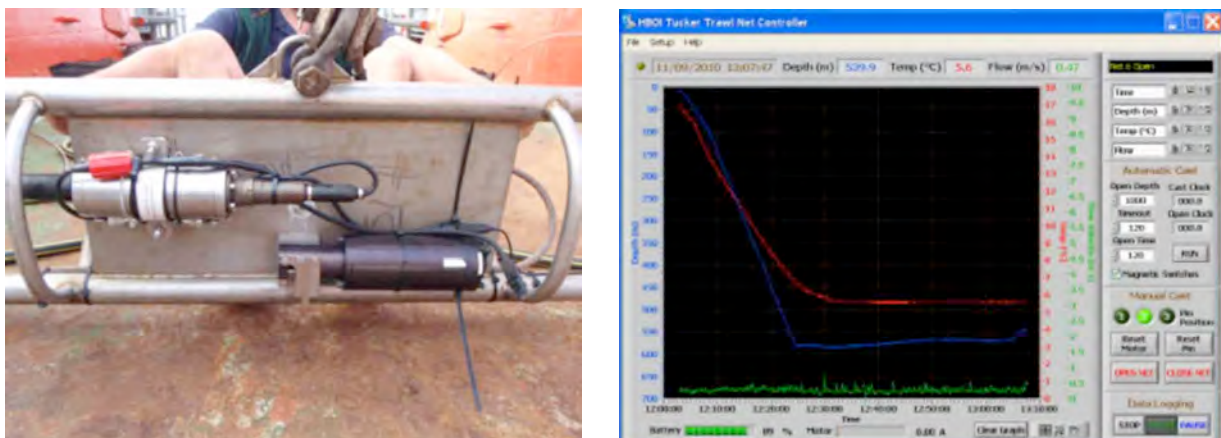


Fig. 7.3: RMT Net control unit (left, black) and software graphical user interface (right).

At the end of the trawl net, a simple PVC "bucket" cod end with 700 μ m mesh was used for the trawls of this cruise.



Fig. 7.4: Bucket cod-end (left).

During trawl #9, the connector between the coax cable and the control box had developed a leak short circuiting the controls; consequently the net came up in the open state. For the last trawl opening and closing of the net was controlled by a timer device.

All 10 catches during this cruise produced good results in terms of quantity of specimens and surprisingly also in terms of the integrity. The great majority of jellyfish, cephalopods and shrimp were alive and so were about 50% of the fish caught. Initially we trawled at a speed of 1.5 knots; in view of the good preservation of the specimens, and in order to further increase the catch we increased the ship's speed to up to 2 knots, without noticeable negative effects.

7.1.2 Dissection microscopes

Three dissecting microscopes were set up: two in the wet lab, and one in the chemi lab.



Fig. 7.5: Adrian Flynn identifies a specimen from the catch.

7.2 EXPERIMENTS CONDUCTED, COMPLETED, FIRST RESULTS

7.2.1 Phylogeny of Eye Differentiation in Barreleyes:

We have investigated and reported on the different structure and function of the mirrors in the ocular diverticula of *Dolichopteryx longipes* (Wagner et al. 2009) and *Rhynchohyalus natalensis* (Partridge et al., 2014) and studied four additional opisthoproctid species with diverticula that may be interpreted as more primitive versions of those found in the above species. Using molecular data from published literature on the following genes: CO1, 16S (mtDNA); MYH, ZIC1, RAG1 (nuclear) we are trying to establish the phylogenetic relationship of the various opisthoproctid species in order to better understand the evolution of the characteristic diverticula. Unfortunately these datasets are incomplete and require additional analysis of fresh material. Our hopes to catch further specimens during this cruise were not fulfilled and we have to wait for other cruises by friendly colleagues to help us to progress in this project. We have also tried museum material but this has turned out to be unsuitable.

7.2.2 *Malacosteus*

Unfortunately, there was also no *Malacosteus* in the catches. Therefore we also need support from our colleagues to provide more material.

7.2.3 *Evermanella*

A live specimen of *Evermanella balbo* (Fig. 7.6) caught during the last trawl showed a conspicuous refractive structure at the edge of the cornea and the junction to the lateral wall of the tubular eye. A similar structure has been previously described as “lens pad” in pearleyes (Scopelarchids), where it is derived from corneal tissue. Preliminary observations indicate that in *Evermanella*, the refractive tissue is distinct from the cornea and possibly formed by the skin. The specimens was fixed in glutaraldehyde in order to allow fine structural analysis of this structure in the home lab (Tübingen)



Fig. 7.6: Lens-pad-like refractive structure in the tubular eye of *Evermanella balbo*

7.2.4 Pigment Regeneration

This project was mainly a collaboration of Profs. Partridge and Douglas. Following the requirement of a medical fitness test for participation in this cruise it turned out that Prof. Partridge had cardiovascular problems he wasn't aware of and which could not be adequately managed before the start of the expedition. Therefore Prof. Partridge was prevented from participating, and the project on pigment regeneration had to be abandoned. The place of J. Partridge was offered to Dr. F. de Busserolles, who had already been on the R/V SONNE 209 expedition.

7.2.5 Visual Ecology of the Lanternfish Family (Myctophidae) (F. de Busserolles, S. Collin, H.-J. Wagner)

The lanternfish family (Myctophidae) is one of the most abundant groups of mesopelagic fishes in the world with more than 250 representative species from 33 genera. They are present worldwide and live at the surface down to depths exceeding 1,000 m, thereby playing a major role in oceanic ecosystems by transferring energy to deeper levels through their daily vertical migrations. These vertical migrations are for the purposes of feeding but there is large inter- and intra-specific variability depending on life stage and season. Like most mesopelagic organisms, lanternfishes are bioluminescent. They possess two kinds of bioluminescent structures; the photophores found on the ventral and ventrolateral parts of the body and the luminous organs and tissue patches present on the head, body and/or tail. While the photophores are thought to play a major role in camouflage by counter-illuminating the underside of the body, luminous organs are thought to play several different roles in intra- and interspecific communication, distraction or illumination. Luminous tissue patterns are highly variable between species and, in some cases, are sexually dimorphic, indicating that the visual system must play an important role in finding reproductive partners.

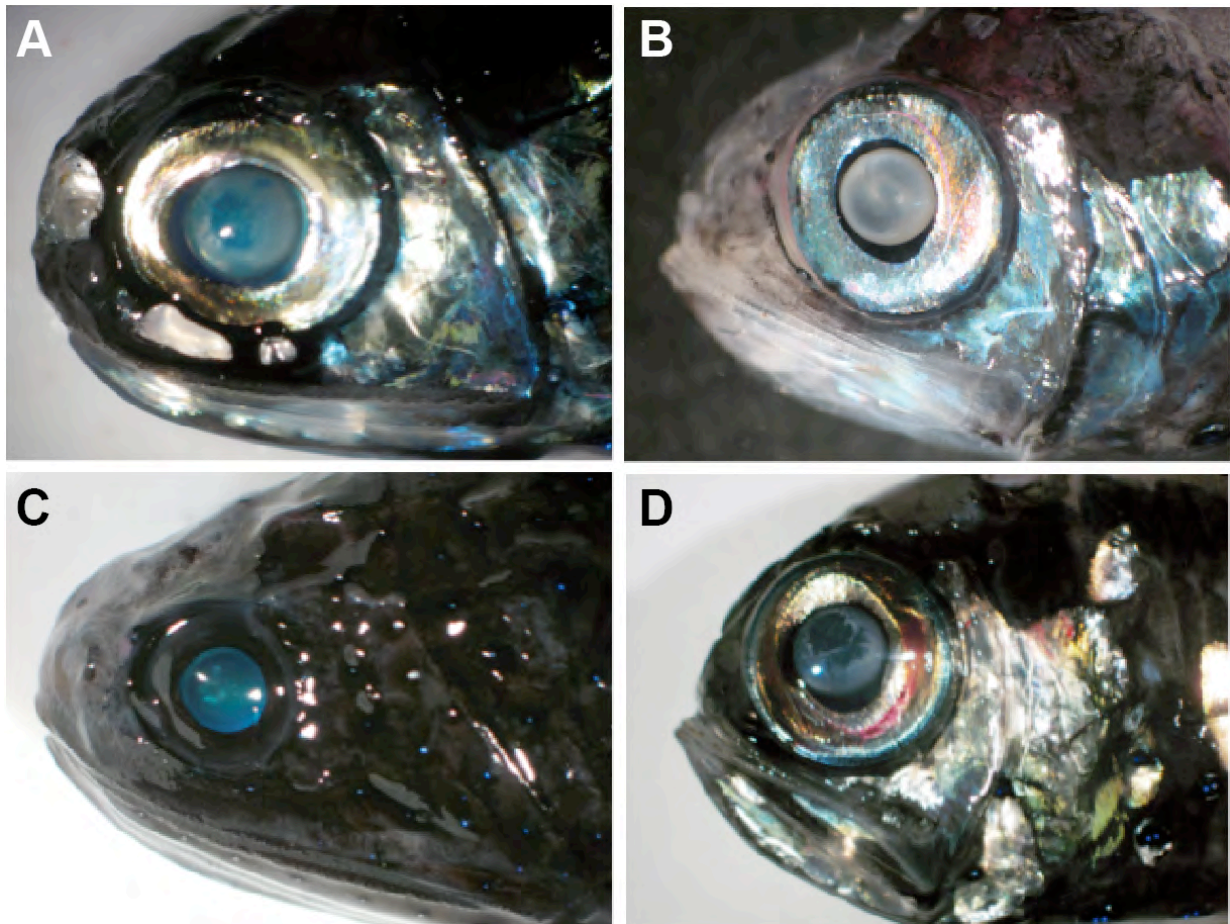


Fig. 7.7: Lateral views of the head of myctophid species collected during this cruise. Note the relative differences in eye size, tapetal eye-shine and the position of the eyes to the mouth. A. *Diaphus hudsoni*, B. *Metelectrona ventralis*, C. *Notoscopelus multipunctatus*, D. *Electrona risso*.

Overall, the abundance of lanternfishes and the high level of variability in their depth distribution, vertical migration patterns and luminous tissue dimorphisms, make this group an important model for visual adaptation studies. However, very little information is available about their visual capabilities with respect to their photic environment.

Much effort on this cruise has been dedicated to collecting tissue samples from representative species from as many genera as possible. In total around 50 specimens belonging to 16 different species from 11 genera were sampled on this cruise (Fig. 7.7).

For each species, we recorded a number of ocular features (tapetal eye-shine, pupil shape, the position of the aphakic gap and eye size) and preserved tissue samples (eyes, brain, muscle tissue) in different ways for the following analyses:

Ocular and retinal anatomy. Micro-dissection of the eye and histology of the retina will be performed. Analysis will be done using light and electron microscopy in order to observe the eye structure (cornea, lens and retina). We expect to find some differences between species from different environments and presenting different behaviours.

Topography of neurones. The topographic distribution of retinal neurons (photoreceptors and ganglion cells) can provide important information about regions of acute vision and what part(s) of a species' visual field it most targets for a range of visual behaviors. Topographic maps of photoreceptors and ganglion cells densities will be realised for each species using stereology. Retinal regions with high densities of cells or specialisations will be targeted and visual perception will be evaluated by measuring spatial resolving power in these regions (photoreceptor and ganglion cells only).

Immunohistochemistry. Amacrine cells are neural cells that are present in very high densities in the ganglion cell layer of lanternfishes. In some species, they can be very hard to be distinguished from the ganglion cells by morphological characteristics only. Previous studies have shown that their inclusion in topographic analysis biased the true distribution of ganglion cells and resulted in an overestimation of the spatial resolving power. It is therefore essential to be able to distinguish amacrine cells from ganglion cells reliably in those fishes. During this cruise, some lanternfish eyes were specifically preserved for immunohistochemistry. Amacrine cells will be labelled on section and wholemounds using different antibodies in order to identify their distribution, types, functions.

Spectral sensitivity. Adaptations for low light vision will be assessed by analysing photoreceptors in details using light and transmission electron microscopy. We expect to find some differences between species from different environments and presenting different behaviours.

Brain analysis. The structure and size of the different brain areas will be analysed for each species in order to evaluate the importance of vision in relation to other sensory inputs. A combination of volumetric analyses, histology and MRI will be used.

Evolutionary history and visual ecology. Finally, phylogenetic comparative analyses will use the data collected during this cruise and the data already available in the literature, to try to link visual specialisations with ecological and environmental variables, taking into account the evolutionary history of the family.

8. REFERENCES

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Appendix 1 (SO-234/1 Station List)

| Type | Stat. | Location | total volume | Sample summary | DR on bottom/TT opened | | DR off bottom/TT closed | | depth (m) | |
|------|-------|--|--------------|--|------------------------|---------|-------------------------|---------|-----------|------|
| | | | | | lat °S | long °E | lat °S | long °E | begin | end |
| TT | 1 | abyssal plain E of northern Walvis Ridge | | various marine organism | -22,162 | 8,664 | -22,189 | 8,664 | 4399 | 4403 |
| TT | 2 | abyssal plain E of northern Walvis Ridge | | various marine organism | -22,235 | 8,664 | -22,269 | 8,665 | 4420 | 4414 |
| TT | 3 | abyssal plain E of northern Walvis Ridge | | various marine organism | -22,301 | 8,664 | -22,338 | 8,664 | 4418 | 4422 |
| DR | 4 | seamounts E of northern Walvis Ridge | 1 rock | lava fragments | -22,078 | 8,384 | -22,062 | 8,384 | 3605 | 3602 |
| TT | 5 | seamounts E of northern Walvis Ridge | | various marine organism | -22,188 | 8,060 | -22,220 | 8,009 | 1936 | 1619 |
| DR | 6 | north. part of Walvis Ridge, eastern flank | 4 rocks | lava fragments, volcanoclastic rock | -22,096 | 8,097 | -22,102 | 8,092 | 3251 | 2955 |
| DR | 7 | north. part of Walvis Ridge, eastern flank | huge bloc | lava fragments, carbonate, Mn-crust | -22,209 | 7,853 | -22,214 | 7,848 | 2621 | 2300 |
| DR | 8 | north. part of Walvis Ridge, eastern flank | few rocks | volcanoclastic rocks, carbonates | -22,279 | 7,824 | -22,281 | 7,818 | 2869 | 2691 |
| DR | 9 | broad part of Walvis Ridge, eastern area | 1/6 full | carbonates (fossil reef debris) | -22,355 | 7,563 | -22,361 | 7,561 | 2276 | 1952 |
| TT | 10 | abyssal plain E of northern Walvis Ridge | | various marine organism | -22,456 | 7,596 | -22,487 | 7,536 | 3434 | 3030 |
| TT | 11 | abyssal plain E of northern Walvis Ridge | | various marine organism | -22,672 | 7,650 | -22,710 | 7,650 | 4434 | 4370 |
| TT | 12 | abyssal plain E of northern Walvis Ridge | | various marine organism | -22,822 | 7,730 | -22,915 | 7,729 | 4375 | 4604 |
| TT | 13 | abyssal plain E of northern Walvis Ridge | | various marine organism | -23,056 | 7,802 | -23,115 | 7,846 | 4658 | 4566 |
| DR | 14 | northern Flank of Ewing Seamount | few rocks | volcanoclastic rocks, carbonates | -23,142 | 8,103 | -23,149 | 8,105 | 2728 | 2265 |
| DR | 15 | northern Flank of Ewing Seamount | few rocks | lava fragments, solidified sediment | -23,040 | 8,176 | -23,046 | 8,179 | 3450 | 3122 |
| TT | 16 | abyssal plain NE of Ewing Seamount | | various marine organism (<i>net did not close</i>) | -23,025 | 8,476 | -23,081 | 8,520 | 4401 | 4387 |
| TT | 17 | abyssal plain NE of Ewing Seamount | | various marine organism | -23,110 | 8,549 | -23,182 | 8,618 | 4372 | 4360 |
| TVG | 18 | eastern flank of Ewing Seamount | almost empty | carbonate mud | -23,207 | 8,467 | -23,212 | 8,472 | 2120 | 2552 |

DR: Chain Bag Dredge
 TT: Tucker Trawl
 TVG: TV-Grab

Appendix 2 (Station Details and Rock Description)

SO234-TT1

Description of Location and Structure: Abyssal plain east of the seamount cluster off the eastern margin of the northern part of the Walvis Ridge.

TT open UTC 23/06/14 14:43hrs, lat 22°09.70'S, long 8°39.85'E, depth 4400m

TT closed UTC 23/06/14 15:44hrs, lat 22°11.31'S, long 8°39.85'E, depth 4403m

total volume: several mesopelagic animals

Comments: max. rope length 1035-1175m

SO234-TT2

Description of Location and Structure: Abyssal plain east of the seamount cluster off the eastern margin of the northern part of the Walvis Ridge.

TT open UTC 23/06/14 17:34hrs, lat 22°14.07'S, long 8°39.86'E, depth 4420m

TT closed UTC 23/06/14 19:01hrs, lat 22°16.12'S, long 8°39.87'E, depth 4414m

total volume: several mesopelagic animals

Comments: max. rope length 920-940m

SO234-TT3

Description of Location and Structure: Abyssal plain east of the seamount cluster off the eastern margin of the northern part of the Walvis Ridge.

TT open UTC 23/06/14 20:32hrs, lat 22°18.04'S, long 8°39.84'E, depth 4419m

TT closed UTC 23/06/14 22:21hrs, lat 22°20.49'S, long 8°39.85'E, depth 4422m

total volume: several mesopelagic animals

Comments: max. rope length 1040-1070m

SO234-DR4


Description of Location and Structure: Seamount cluster off the eastern margin of the northern part of the Walvis Ridge. Northeastern seamount, middle section of eastern slope.

Dredge on bottom UTC 24/06/14 03:29hrs, lat 22°04.65'S, long 8°23.01'E, depth 3605m

Dredge off bottom UTC 24/06/14 05:21hrs, lat 22°03.72'S, long 8°23.04'E, depth 3602m

total volume: one volcanic rock

Comments: lava fragment, bridge took over

| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
|--------------|---|----|------|-------|--------|-----|-----|-------|---|
| SO234-DR-4-1 | 1. Rock Type: volcanic (moderately altered) 2. Size: 14x11x10 cm 3. Shape / Angularity: subangular 4. Color of cut surface: brownish - greenish - grey 5. Texture / Vesicularity: vesicularity ~ 3 % (all filled), porphyritic 6. Phenocrysts: ~ 15 % Plg (< 5 mm), ~ 5 - 10 % Cpx? (< 5 mm) 7. Matrix: fine grained 8. Secondary Minerals: vesicles filled with chalcedone ? 9. Encrustations: Mn crust < 3 mm 10. Comment: needs careful TS examination (phenocrysts and matrix), matrix or Plg phenocrysts could be suitable for age dating | x | x | 2-4? | | | | |  |

SO234-TT5

Description of Location and Structure: Above top plateau of a seamount on the eastern margin of the northern part of the Walvis Ridge.





TT open UTC 24/06/14 09:45hrs, lat 22°11.30'S, long 8°03.59'E, depth 1937m

TT closed UTC 24/06/14 12:09hrs, lat 22°13.17'S, long 8°00.52'E, depth 1620m


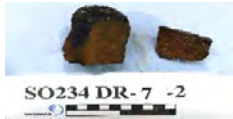

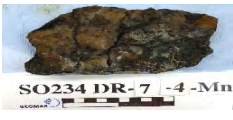
total volume: several mesopelagic animals


Comments: max. rope length 1268-1560m

Appendix 2 (Station Details and Rock Description)







| SO234-DR6 | | | | | | | | | |
|--|---|----|------|-------|--------|-----|-----|-------|---|
| Description of Location and Structure: Northern part of Walvis Ridge, southwestern section, eastern margin. Middle section of the northeastern slope of a large guyot situated on the margin the ridge. Dredge on bottom UTC 24/06/14 16:39hrs, lat 22°05.75'S, long 08°05.79'E, depth 3251m Dredge off bottom UTC 24/06/14 17:53hrs, lat 22°06.11'S, long 08°05.53'E, depth 2955m total volume: four rocks Comments: volcanic rocks (lava), one litholgy | | | | | | | | | |
| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
| SO234-DR-6-1 | 1. Rock Type: volcanic (moderately altered) 2. Size: 23x27x1 cm 3. Shape / Angularity: subangular 4. Color of cut surface: grey - brown 5. Texture / Vesicularity: porphyritic 6. Phenocrysts: ~ 5 - 7 % altered Ol (< 2mm), ~ 20 % Plg (< 2 mm) 7. Matrix: fine grained 8. Secondary Minerals: Cc veins 9. Encrustations: Mn crust < 0.5 cm 10. Comment: second half is volcanoclastic, two TS are from the volcanoclastic part. Maybe gm / Plg phenocrysts suitable for Ar/Ar? | 4 | X | 3? | | | | |  |
| SO234-DR-6-2 | 1. Rock Type: volcanic (moderately altered) 2. Size: 14x11x8 cm 3. Shape / Angularity: subangular 4. Color of cut surface: brown 5. Texture / Vesicularity: vesicularity ~ 1 - 2 % (open), porphyritic 6. Phenocrysts: ~ 5 % altered Ol (< 3 mm), ~ 17 % Plg (< 2 mm) 7. Matrix: fine grained 8. Secondary Minerals: Cc veins 9. Encrustations: Mn crust up to 0.3 mm 10. Comment: volcanoclastic material attached | 1 | X | | | | | |  |
| SO234-DR-6-3 | 1. Rock Type: volcanic clast (moderately altered) 2. Size: 15x10x8 cm 3. Shape / Angularity: subangular 4. Color of cut surface: brown 5. Texture / Vesicularity: vesicularity ~ 2 % (open), porphyritic 6. Phenocrysts: ~ 4 % altered Ol (< 3 mm), ~ 15 % Pl (< 3 mm) 7. Matrix: fine grained 8. Secondary Minerals: nothing 9. Encrustations: Mn crust up to 4 mm 10. Comment: volcanoclastic material is attached to the clast (second half of the rock) | 3 | | | | | | |  |
| SO234-DR-6-4 | 1. Rock Type: volcanoclastic rock (moderately altered) 2. Size: 8x7x5 cm 3. Shape / Angularity: subangular 4. Color of cut surface: greenish - brownish clast in white - yellow matrix 10. Comment: Several up to 3cm volcanic (basaltic?) clast which could be further separated if necessary | 1 | | | | | | |  |

Appendix 2 (Station Details and Rock Description)

| SO234-DR7 | | | | | | | | | |
|--|--|----|------|-------|--------|-----|-----|-------|---|
| Description of Location and Structure: Northern part of Walvis Ridge, southwestern section, eastern margin. Northern slope of Dredge on bottom UTC 24/06/14 23:04hrs, lat 22°12.51'S, long 7°51.17'E, depth 2621m Dredge off bottom UTC 25/06/14 00:30hrs, lat 22°21.83'S, long 7°50.87'E, depth 2300m total volume: four rocks Comments: carbonate sediments and altered volcanic rocks | | | | | | | | | |
| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
| SO234-DR-7-1 | 1. Rock Type: volcanic rock (highly altered) 2. Size: 6x8x10 cm 3. Shape / Angularity: subangular 4. Color of cut surface: orange - brown 5. Texture / Vesicularity: no vesicles 6. Phenocrysts: not recognizable 7. Matrix: originally fine grained (Px, Fsp) 8. Secondary Minerals: porrosive alteration resulting in thin Cc veins, Mn intrusions and phyllosilicates 9. Encrustations: Mn crust < 3 mm | 1 | | | | | | |  |
| SO234-DR-7-2 | 1. Rock Type: volcanic rock (highly altered) 2. Size: 8x5x6 cm 3. Shape / Angularity: subangular 4. Color of cut surface: orange - brown 9. Encrustations: Mn crust < 5 mm 10. Comment: similar to DR7-1 | | | | | | | |  |
| SO234-DR-7-3S | 1. Rock Type: sediment (Carbonate) 2. Size: 100x50x40 cm 3. Shape / Angularity: subangular 4. Color of cut surface: white | | | | | x | | |  |
| SO234-DR-7-4-Mn | 1. Rock Type: Mn-crust 2. Size: 9X15X3 cm 3. Shape / Angularity: subrounded 4. Color of cut surface: black | | | | | | | |  |

| SO234-DR8 | | | | | | | | | |
|--|--|----|------|-------|--------|-----|-----|-------|---|
| Description of Location and Structure: Northern part of Walvis Ridge, southwestern section, eastern margin. Main slope of the Dredge on bottom UTC 25/06/14 03:14hrs, lat 22°16.73'S, long 7°49.43'E, depth 2869m Dredge off bottom UTC 25/06/14 04:15hrs, lat 22°16.84'S, long 7°49.06'E, depth 2691m total volume: few rocks Comments: volcanics, volcanoclastic rocks and sediments | | | | | | | | | |
| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
| SO234-DR-8-1 | 1. Rock Type: volcanoclastic rock (highly altered) 2. Size: 8x6x7 cm 3. Shape / Angularity: subangular 4. Color of cut surface: black 5. Texture / Vesicularity: vesicularity ~ 35 % (filled, < 8 mm) 6. Phenocrysts: ~ 7 % altered Ol (< 2 mm) 7. Matrix: fine grained 8. Secondary Minerals: white material filled vesicles 9. Encrustations: Cc encrustation 10. Comment: needs careful TS examination | x | x | | | | | |  |

Appendix 2 (Station Details and Rock Description)

| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
|---------------|---|----|------|-------|--------|-----|-----|-------|---|
| SO234-DR-8-2 | 1. Rock Type: volcanoclastic rock (highly altered) 2. Size: 12x11x7 cm 3. Shape / Angularity: subangular 4. Color of cut surface: black - brownish 10. Comment: similar to DR8-1, but more altered, Mn crust (< 3 mm), ~ 10 % OI, larger vesicles which are more connected | x | | | | | | |  |
| SO234-DR-8-3 | 1. Rock Type: volcanoclastic rock (highly altered) 2. Size: 10x8x5 cm 3. Shape / Angularity: subangular 4. Color of cut surface: brownish - reddish- black clasts in white matrix 5. Texture / Vesicularity: angular - subangular aphyric clasts (< 5 cm) with 10 % vesicularity 7. Matrix: fine grained | | | | | | | |  |
| SO234-DR-8-4 | 1. Rock Type: volcanoclastic rock (highly altered) 2. Size: 8x7x3 cm 3. Shape / Angularity: subangular 4. Color of cut surface: greenish - reddish - black clast in white matrix 10. Comment: similar to DR8-3, but more altered and the clasts are smaller | | | | | | | |  |
| SO234-DR-8-5 | 1. Rock Type: volcanoclastic rock (highly altered) 2. Size: 10x10x9 cm 3. Shape / Angularity: subangular 4. Color of cut surface: reddish - greenish clasts in white matrix 10. Comment: similar to DR8-3, but more altered | | | | | | | |  |
| SO234-DR-8-6 | 1. Rock Type: volcanoclastic rock (highly altered) 2. Size: 8x7x6 cm 3. Shape / Angularity: subangular 4. Color of cut surface: reddish - greenish clasts in white matrix 10. Comment: similar to DR8-3, but more altered | | | | | | | |  |
| SO234-DR-8-7S | 1. Rock Type: sediments (fossil coral reef) 2. Size: 10x10x4 cm 3. Shape / Angularity: tabular, subrounded 4. Color of cut surface: white | | | | | x | | |  |

SO234-DR9

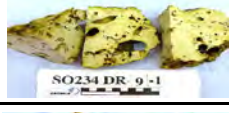

Description of Location and Structure: Central Walvis Ridge, eastern part. Middle section of the northern slope of a guyot., c. 2 nm

Dredge on bottom UTC 25/06/14 08:12hrs, lat 22°21.30'S, long 7°33.78'E, depth 2276m

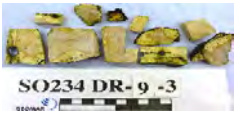
Dredge off bottom UTC 25/06/14 08:12hrs, lat 22°21.30'S, long 7°33.78'E, depth 2276m

total volume: few rocks

Comments: sediments

| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
|----------------|--|----|------|-------|--------|-----|-----|-------|---|
| SO234-DR-9-1-S | 1. Rock Type: sediment (fossil reef) 2. Size: 50x30x15 cm 3. Shape / Angularity: rounded 4. Color of cut surface: white | | | | | x | | |  |
| SO234-DR-9-2-S | 1. Rock Type: sediment (fossil reef) 2. Size: 14x11x7 cm 3. Shape / Angularity: subangular 4. Color of cut surface: white | | | | | x | | |  |

Appendix 2 (Station Details and Rock Description)

| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
|----------------|--|----|------|-------|--------|-----|-----|-------|---|
| SO234-DR-9-3-S | 1. Rock Type: sediment (fossil reef) 2. Size: 7x6x5 cm 3. Shape / Angularity: subangular 4. Color of cut surface: beige | | | | | x | | |  |

SO234-TT10

Description of Location and Structure: Abyssal plain between eastern margin of the northern Walvis Ridge and Ewing Seamount.

TT open UTC 25/06/14 12:02hrs, lat 22°27.35'S, long 7°35.76'E, depth 3434m

TT closed UTC 25/06/14 14:30hrs, lat 22°29.23'S, long 7°32.17'E, depth 3031m

total volume: several mesopelagic animals

Comments: max. rope length 779-929m

SO234-TT11

Description of Location and Structure: Abyssal plain between eastern margin of the northern Walvis Ridge and Ewing Seamount.

TT open UTC 25/06/14 17:16hrs, lat 22°40.33'S, long 7°38.98'E, depth 4434m

TT closed UTC 25/06/14 19:16hrs, lat 22°42.58'S, long 7°39.00'E, depth 4370m

total volume: several mesopelagic animals

Comments: max. rope length 922-1062m

SO234-TT12

Description of Location and Structure: Abyssal plain between eastern margin of the northern Walvis Ridge and Ewing Seamount.

TT open UTC 25/06/14 21:39hrs, lat 22°49.32'S, long 7°43.81'E, depth 4376m

TT closed UTC 26/06/14 00:44hrs, lat 22°54.87'S, long 7°43.72'E, depth 4604m

total volume: several mesopelagic animals

Comments: max. rope length 1475-1605m

SO234-TT13

Description of Location and Structure: Abyssal plain between eastern margin of the northern Walvis Ridge and Ewing Seamount.

TT open UTC 26/06/14 03:47hrs, lat 23°03.35'S, long 7°48.13'E, depth 4657m

TT closed UTC 26/06/14 06:45hrs, lat 23°06.90'S, long 7°50.73'E, depth 4566m

total volume: several mesopelagic animals

Comments: max. rope length 1095-1195m

SO234-DR14


Description of Location and Structure: Ewing Seamount off the eastern margin of the central part of the Walvis Ridge. Middle section of the northern slope.

Dredge on bottom UTC 26/06/14 11:20hrs, lat 23°08.50'S, long 8°06.16'E, depth 2728m



Dredge off bottom UTC 26/06/14 12:41hrs, lat 23°08.92'S, long 8°06.29'E, depth 2265m

total volume: few rocks

Comments: volcanoclastic rocks

| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
|---------------|---|----|------|-------|--------|-----|-----|-------|---|
| SO234-DR-14-1 | 1. Rock Type: volcanoclastic rock (moderately altered) 2. Size: 11x8x5 cm 3. Shape / Angularity: subangular 4. Color of cut surface: brown, darkbrown and black clasts in white to brown matrix 5. Texture / Vesicularity: subrounded - subangular clasts up to 5 cm with vesicularity ~ 5 - 25 % 6. Phenocrysts: spottet Plg and Cpx in clasts 7. Matrix: clasts consists of Cpx and Plg 8. Secondary Minerals: Cc fillings and Mn 9. Encrustations: Mn crust < 3 mm 10. Comment: TS from the biggest clast, maybe one clast big enough for GC - bloc | x | | | | | | |  |

Appendix 2 (Station Details and Rock Description)

| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
|-----------------|---|----|------|-------|--------|-----|-----|-------|---|
| SO234-DR-14-2 | 1. Rock Type: volcanoclastic rock (highly altered) 2. Size: 10x8x5 cm 3. Shape / Angularity: subangular 4. Color of cut surface: brown - darkbrown clasts in brown matrix 10. Comment: similar to DR14-1, but more altered and smaller clasts | x | | | | | | |  |
| SO234-DR-14-3-S | 1. Rock Type: sediment (fossil reef) 2. Size: 11x8x6 cm 3. Shape / Angularity: subangular 4. Color of cut surface: white | x | | | | x | | |  |

SO234-DR15




Description of Location and Structure: Ewing Seamount off the eastern margin of the central part of the Walvis Ridge. Northern tip

Dredge on bottom UTC 26/06/14 17:04hrs, lat 23°02.37'S, long 8°10.54'E, depth 3450m

Dredge off bottom UTC 26/06/14 18:17hrs, lat 23°2.77'S, long 8°10.71'E, depth 3100m

total volume: few rocks

Comments: volcanic rocks and sediments

| SAMPLE # | SAMPLE DESCRIPTION | TS | CHEM | Ar/Ar | GL/MIN | SED | REF | NOTES | PICTURE |
|---------------|--|----|------|-------|--------|-----|-----|-------|---|
| SO234-DR-15-1 | 1. Rock Type: volcanic (moderately altered) 2. Size: 23x16x14 cm 3. Shape / Angularity: angular 4. Color of cut surface: grey, altered rim brown 5. Texture / Vesicularity: vesicularity ~ 25 % (20 % filled, < 3 mm), porphyritic 6. Phenocrysts: ~ 3 % altered Ol (< 3mm) 7. Matrix: fine grained 8. Secondary Minerals: white material in vesicles (Cc ?) 9. Encrustations: Mn-crust < 2 mm. 10. Comment: thick Cc veins? in rock (< 5 mm) | x | x | | | | | |  |
| SO234-DR-15-2 | 1. Rock Type: sediment 2. Size: 12x12x5 cm 3. Shape / Angularity: subangular 4. Color of cut surface: brown - grey 9. Encrustations: Mn crust < 2 mm 10. Comment: clear signs of bioturbation | | | | | | | |  |
| SO234-DR-15-3 | 1. Rock Type: sediment 2. Size: 18x7x6 cm 3. Shape / Angularity: rounded 4. Color of cut surface: brown - grey 10. Comment: similar to DR15-2 | | | | | | | |  |

SO234-TT16

Description of Location and Structure: Abyssal plain northeast of Ewing Seamount.

TT open UTC 26/06/14 22:53hrs, lat 23°01.51'S, long 8°28.57'E, depth 4400m

TT closed UTC 27/06/14 01:04hrs, lat 23°04.83'S, long 8°31.19'E, depth 4387m

total volume: several mesopelagic animals

Comments: max. rope length 669-720m

SO234-TT17

Description of Location and Structure: Abyssal plain northeast of Ewing Seamount.

TT open UTC 27/06/14 03:25hrs, lat 23°06.62'S, long 8°32.96'E, depth 4372m

TT closed UTC 27/06/14 06:27hrs, lat 23°10.93'S, long 8°37.08'E, depth 4360m

total volume: several mesopelagic animals

Comments: max. rope length 1200m

Appendix 2 (Station Details and Rock Description)

SO234-TVG18

Description of Location and Structure: Ewing Seamount off the eastern margin of the central part of the Walvis Ridge. Middle section of western slope, top of small cone-like structure.

TVG on bottom: UTC 27/06/14 10:30hrs lat 23°12.39'S long 08°12.39'E depth 2120m

TVG off bottom: UTC 27/06/14 11:20hrs lat 23°12.74'S long 08°28.15'E depth 2552m

total volume: less than half box

Comments: muddy to silty sediment consisting of forams

Abbreviations in Table Header:

TS: thin section billet

CHEM: chemistry slab to prepare materials for geochemical analysis

Ar/Ar: estimate of sample quality for $^{40}\text{Ar}/^{39}\text{Ar}$ dating

GL/MIN: potential glass and / or mineral separates

SED: sediment

REF: reference sample for immediate transport to home institution after cruise

Abbreviations for Minerals and Materials:

Fsp: feldspar

Plg: plagioclase

Ol: olivine

Px: pyroxene

CPx: clinopyroxene

Opx: orthopyroxene

Cc: clacite

Mn: manganese

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