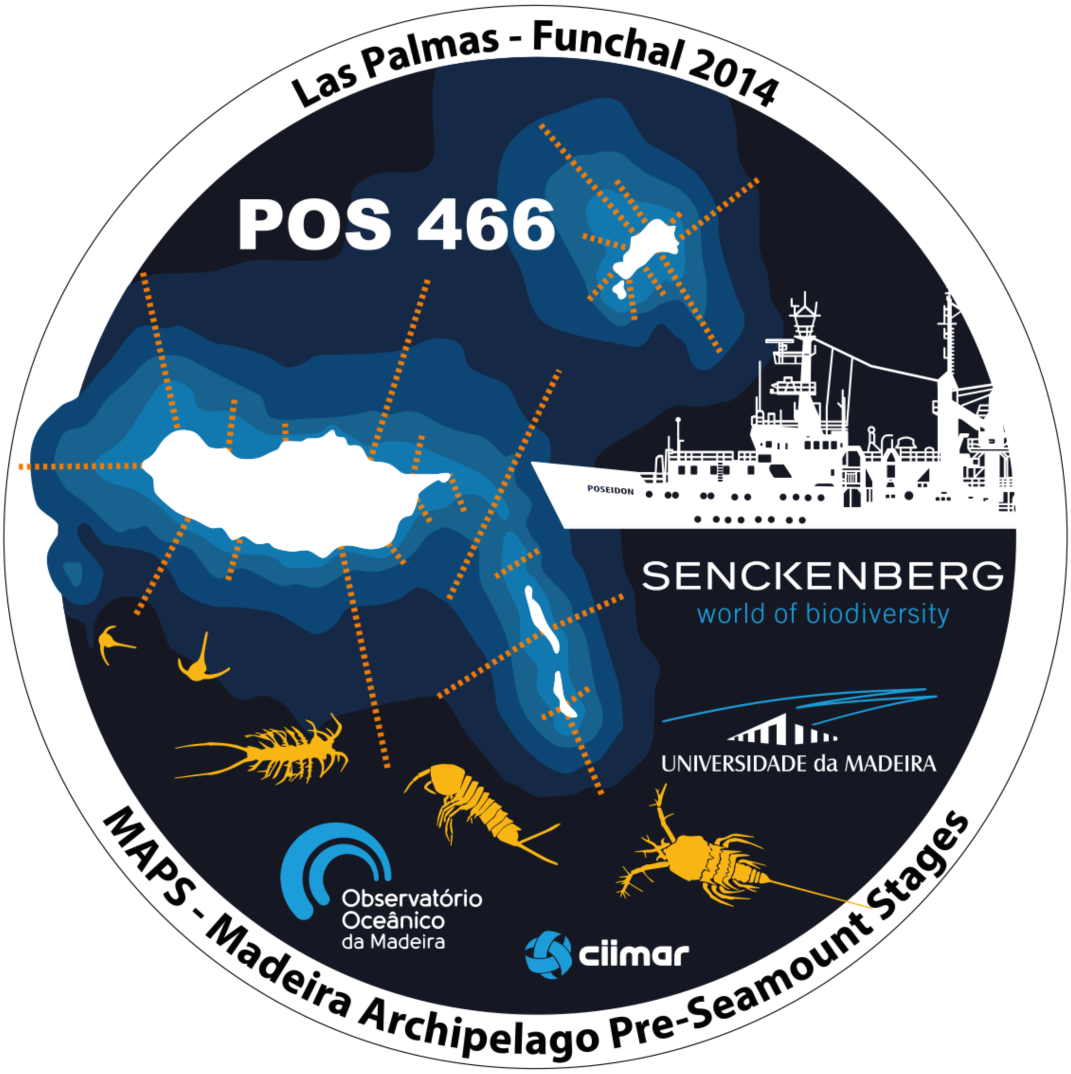
Research Cruise P466 of German Research Vessel POSEIDON

Cruise Report



Project title: ***M**adeira **A**rchipelago **P**re-seamount **S**tages, MAPS*

Project theme: Influence of terrestrial processes on marine sedimentary facies as well as meiobenthic and phytoplanktonic assemblages and dispersal in the pre-seamount stage: Quantitative sedimentologic and organismic comparison along the "Madeira Hot Spot Track"

Chief Scientist: Dr. Kai Horst George, Senckenberg am Meer, Abt. DZMB, Südstrand 44, D-26382 Wilhelmshaven, Germany; phone: +49 (0)4421 9475-110; Fax: +49 (0)4421 9475-111; e-mail: kgeorge@senckenberg.de

Summary

Background of the research project "***M**adeira **A**rchipelago **P**re-seamount **S**tages, MAPS*" and of POSEIDON cruise P466 is the question, whether submarine island-seamount-chains like the Madeira Hot Spot Track (MHST) that show the same origin but different ages, do reflect that age gradient faunistically. Moreover it shall be investigated if the meiofauna assemblages of seamount summits, respectively of the littoral of islands of the MHST form sub-populations of one overall meta-population, and if dispersal and/or isolation mechanisms may be recognizable along the MHST. That should help understanding if seamounts and islands function as staging posts, thus supporting the dispersal of marine meiobenthos, or if they in contrast act as isolated entities, rather benefitting the evolution of exclusive faunas with high percentage of endemism.

In that context, a second gradient beside the age gradient and referring to the influence of terrigenous input into the littoral and sublittoral along the chain of MHST may be of essential relevance. Whereas such input of organic and anorganic terrigenous material is high at Madeira, it is supposed to decrease considerably at Porto Santo compared with marine influence. At both seamounts Ampère and Seine the terrigenous signal diminishes down to an eolian dust input. The change from a lithoclastic-terrigenous-marked shelf sedimentation towards an autochthonous production of carbonates should be reflected in the composition of the phytoplankton community (particularly of the calcareous nanoplankton) as well as of the (meio)benthic associations of the corresponding islands and seamounts. The aimed census of the phytoplankton may enable detecting a possible influence of islands on the composition and structure of the respective species assemblages; moreover, it may allow comparing possible impacts on species composition caused by seamounts respectively islands. The Great Meteor Seamount that is located outside the MHST, and whose plateau meanwhile sunk below the photic zone, may be a good object for further comparison. MAPS is the first project considering the above mentioned aspects, and it may contribute remarkably for our comprehension of the role of seamounts for marine fauna, especially against the background of their pre-seamount stages, as exemplified by Madeira and Porto Santo.

1. Project Description (K.H. George, M. Kaufmann, A. Wehrmann)

The Madeira Archipelago is located in the subtropical north-eastern Atlantic (32.5°N, 17.0°W) and consists of the main island Madeira, the three small Desertas Islands in the south-east of Madeira and Porto Santo Island in the north-east (Fig. 1). All islands of the Archipelago form the youngest part of a volcanic chain of seamounts of increasing age that extends in north-eastern direction towards the coast of Portugal ("Madeira Hot Spot Track", MHST, Appendix 1, Fig. 1) (Geldmacher *et al.* 2006). Regarding benthologic, sedimentologic and phytoplanktonic research, two seamounts of the MHST, namely Seine and Ampère seamounts were sampled in the past years (P218, P322, P384, M42/3, M60/1 and M83/2). In addition, the Great Meteor Seamount and Sedlo Seamount, being located in the west and north-west of Madeira, respectively, were sampled (P397 and M60/1) aiming the comparison with those of the MHST as they reflect distinct stages in seamount evolution.

<u>Meiobenthology (K.H. George)</u>

Despite very special characteristics (very small organisms, no planktonic life stages, strict linkage to the sediment etc.) that are presumed to hamper the geographic dispersal in the oceans, the marine meiobenthos often shows a wide to an even cosmopolitan distribution, an intriguing phenomenon named "meiofauna paradox" by Giere (2009). In that context, the potential role of seamounts for meiobenthic dispersal was recognized in the 70ies of the past century (e.g. Thiel 1970, Emschermann 1971). Nonetheless, of approximately 232 seamounts that have been studied word-wide under biological aspects (Samadi *et al.* 2007), only 8 seamounts have so far been sampled with respect to the meiobenthos (George 2013), and detailed faunistic and taxonomic studies restrict to just 3 north-eastern Atlantic seamounts, namely Seine, Sedlo, and the Great Meteor Seamount (e.g. Bartsch 1973a, b, c, 2001, George & Schminke 2002, Bartsch 2003, Gad 2004, Gad & Schminke 2004, George 2004, Plum & George 2009, Büntzow 2011, Koller & George 2011).

The obtained results of a faunistic comparison of e.g. Copepoda Harpacticoida (Crustacea) remain somewhat conflicting: the Great Meteor Seamount for example seems to be inhabited by a high amount of exclusive species, a considerable portion of which showing affinities to deep-sea taxa (George & Schminke 2002, George 2004). On the other hand, Büntzow (2011) confirmed a number of 10 species shared by Seine and Sedlo seamounts, and the main part of harpacticoids he reported may be assigned to shallow-water groups. It has to be admitted, however, that all so far obtained data arose from few and qualitative sampling, presenting therefore a certain ambiguity. To sharpen and refine the achieved results, further sampling on adjacent seamounts has to be done, and sampling methods must be standardised. In recent cruises, this was done using a van Veen grab (BG) for sampling in sandy substrates, instead of optionally deploying sledges, box corers and multicorers. The analyses of the sampled material will contribute to elucidate questions as to the community structure, the faunistic composition, the species diversity, and the geographic distribution/potential endemism of different meiobenthic taxa, in particular of Harpacticoida.

The planning of a detailed quantitative evaluation of the corresponding meiobenthic material is in preparation. It may allow comparing harpacticoid assemblages of different Mediterranean seamounts with each other as well as with those of Sedlo and Seine seamounts. In order to include the Great Meteor Seamount into that broad faunistic and biogeographic comparison, that seamount was the object of research cruise P397 of RV POSEIDON in 2010. Using the BG for sampling, cruise P397 provided for the first time quantitative meiobenthic samples of that seamount. In the frame of a second project the potential role of the Great Meteor Seamount as “staging post” or isolated elevation for harpacticoid Copepoda shall be recognized, using the data of the above mentioned seamounts for detailed faunistic and taxonomic comparison. In the same context, during research cruise M 83/2 of RV METEOR in 2010, with Ampère Seamount a second chain link of the MHST (in addition to Seine seamount) was quantitatively sampled for meiofauna. In the end, it was planned from the beginning also to include eastern Atlantic islands into these comprehensive investigations, as many of the reported seamount species are closely related with shallow-water taxa (George & Schminke 2002, Bartsch 2003, Gad 2004, Büntzow 2011). Thus, an inclusion of (sub-) littoral species of neighbouring islands appears to be quite meaningful and important. In a first step, the littoral harpacticoid fauna of Madeira and Porto Santo as the youngest chain links of the MHST is studied in the frame of a third research project, aiming to provide taxonomic and quantitative faunistic data for further comparison with the seamount assemblages of Harpacticoida (Packmor 2013). To complete the data set down to water depths of approximately 300 m, cruise P466 sampled corresponding locations surrounding Madeira, Porto Santo, and the Desertas Islands. The obtained results will, in combination with the data of the littoral, provide detailed information of the Madeira Archipelago that is absolutely unprecedented for that region. Thus, cruise P466 together with a subsequent data analysis may allow a well-based inclusion of the Madeira Archipelago into the comprehensive comparison particularly of the harpacticoid fauna of the MHST and with neighbouring seamounts.

Sedimentology (A. Wehrmann)

In contrast to the Madeira Abyssal Plain (MAP) which was intensely studied under various sedimentological aspects, the database of the Madeira Archipelago Shelf (MAS) is restricted to the southern coast of Madeira Island based on a two-day survey in 2002 (Rodrigues *et al.* 2006, Oliveira *et al.* 2007). During that survey 75 sediment samples were taken in water depths down to 100m.

Sedimentation on the MAS is mainly controlled by (i) the hydrodynamic energy and (ii) the topography of the respective island, i.e., Madeira, Porto Santo and Desertas. The input of hydrodynamic energy is caused by the incoming swell from a northern sector (NW to NE) showing mean wave period of 7 sec and a significant wave height of 1.5 m. During storm surges (WNW to NW) wave period increases to 11 sec with significant wave height of 3 m.

Madeira

The age of Madeira Island was dated to 5.2 Ma. The island is build up by basaltic rocks forming steep cliffs and pyroclastic rocks marked by a more even topography. Due to the island height of 1862 m, the steep slope topography and the high precipitation rate the erosion potential is high as documented by the frequent occurrence of cliffs, landslides and rock falls. Quaternary sediments originate from erosive processes of the central parts of the island. At some places the terrestrial drainage system continues into the marine environment as submarine canyons deeply incising the narrow shelf. This canyons function as bypasses directly supporting the proximal abyssal plain with sediment material. Large subaquatic dunes with crest distances of more than 100 m oriented perpendicular to the canyon axis indicate basinward sediment transport within the canyons (Rodrigues *et al.* 2006).

The shelf of Madeira is very narrow, decreasing from 9 km in the west to 1.5 km in the east. The western shelf is characterized by a high-energy shore-parallel sediment transport. Main processes providing the shelf with sediment is cliff erosion and to a minor degree input of clastic material from the central part of the island by river discharge. On the lower energetic south-eastern shelf the sediment transport is in a coast normal direction supplied by the radial oriented drainage system reflecting the steep island topography. In the transitional part between the western and the south-eastern shelf the sediments derived from equal portions from coastal cliff erosion and fluvial input.

As controlled by the intense weathering and erosive processes the composition of the shelf sediments is dominated by volcanoclastic material. Heavy minerals contribute to more than 50% to the sediment, whereas the bioclastic components vary between 0.05 to 11%. The grain size distribution is controlled by the regional energy gradient. Rodrigues *et al.* (2006) and Oliveira *et al.* (2007) described coarse and well sorted sands on the high energetic western part of the shelf shifting to fine grained badly sorted sediments on the low energetic south-eastern shelf. Additionally, grain size is negatively correlated with water depth. The bioclastic material mainly derives from molluscs and echinoderms. Highest values of bioclastic material are found between 30 to 50 m and around 100m water depth.

Porto Santo

The island Porto Santo is also build up by volcanic rocks (basaltic to trachytic lava, pyroclastics and dikes) but in contrast to Madeira only shows a low topographic relief (max. height 517 m) with a marked peneplain at 50 to 90 m height. The vulcanic rocks are of young Tertiary age (14 to 11 Ma), as indicated by intercalation of Miocene reef carbonates (Lietz & Schwarzbach 1971). The Quaternary sedimentary cover is mainly composed of eolian transported carbonatic sands, fine- to coarse grained debris, soils and beach terraces. The eolian sediments are up to 50 m thick covering the pre-depositional paleorelief down to a level below present sea level. The medium sorted silts to coarse sands consist up to 97% of bioclastic components (coralline red algae, molluscs, echinoderms, foraminifers, bryozoans) and were deposited during the Würmian glacial by eolian reworking of the exposed Porto Santo shelf. The paleowind direction was NW as indicated by internal cross-bedding. The carbonate sands were intercalated by soils and debris. The soils have been dated by terrestrial gastropods (14C ages 21.570+-350 aBP and 13.480+-120 aBP). The recent beach deposits of the south-eastern coast of Porto Santo are formed by reworking processes of the eolian sands.

The shelf of Porto Santo covers an area of 200 km² and has a platform-like morphology. A marked terrace is at 50 to 60 m water depth.

The research on biosedimentary systems of seamounts started in 2010 during P397 cruise by an integrated study of benthic biology and sedimentology on the Great Meteor Seamount. Its summit region is marked by an extended plateau of 2132 km² in the disphotic zone covered by fine grained bioclastic carbonate deposits mainly produced in the pelagic zone above the plateau. In a second approach the Ampere Seamount was sampled during M83/2 cruise. In contrast to the Great Meteor Seamount the summit region of Ampère Seamount is in the photic zone, which is clearly documented in the sedimentary record by organism groups related to kelp forests. The sediments of the P397 and M83/2 cruises were analysed by two BSc theses at the University of Bremen (Hesemann 2013) and the University of Oldenburg (Spisla 2013) under the supervision of A. Wehrmann. F. Hesemann will continue his work on the carbonate factories of the Great Meteor Seamount with comparable studies in his MSc-thesis on the MAS sediments (cruise P466).

Phytoplanktology (M. Kaufmann)

Former descriptions give for the Madeira Archipelago the Canary current as the principal surface oceanographic feature. Newer investigations however indicate a higher relevance of the Azores current, with main surface flow from westerly directions (Caldeira *et al.* 2002, Caldeira & Sangrà 2012). Seasonally, in autumn and winter northern geostrophic currents dominate, in summer southern flow and in spring more westerly flow is observed (Caldeira & Sangrà 2012).

Biogeographically, Madeira is situated in the Northeast Atlantic Subtropical Gyre (East) – NAST-E with a clear oligotrophic character (Longhurst *et al.* 1995). The proxy for biomass and for primary productivity, the chlorophyll *a* content, often is lower than 1 mg m^{-3} for this region. The low existing productivity is mainly sustained by pico- and nanoplanktonic organisms with size ranges from 1 to about 20 µm (Uitz *et al.* 2006). Bigger size classes (>20 µm), like diatoms and dinoflagellates, can play a more important role only, when nutrient input from deep layers is guaranteed, for example during more intense winds in winter, mixing the surface layer, or during upwelling situations.

Seamounts and islands are historically considered as natural barriers in the main current pathways leading therefore to special geophysical and biological effects, compared to the surrounding open ocean (Hasegawa *et al.* 2004, Heywood *et al.* 1990, Roden & Taft 1985). Seamounts can build local phenomena such as Taylor columns, which can have impacts on the local seamount ecosystem (Mendonça *et al.* 2012, Morato *et al.* 2008, White *et al.* 2007). Islands' influence on biological production has long been recognized and investigated. Doty & Oguri (1956) postulated an 'island mass effect', which was confirmed and more precisely described as formation of eddies and frontal systems in the leeside of islands. Well-studied cases are the Islands of Hawaii (Jia *et al.* 2011 and literature cited therein), and the Canary Islands (Sangrà *et al.* 2009 and literature cited therein). Eddy formation often leads to upwelling and higher nutrient concentrations near the islands. This permits a higher primary production with implications for higher trophic levels (Coutis & Middleton 1999, Hasegawa *et al.* 2004).

In the particular case of the Madeira Archipelago only few studies do exist. *In situ* data collections were done during 5 expeditions of the National Portuguese Fisheries Research Institute between 1979 and 1982 aiming mainly fishery biology. These expeditions were made around the several islands of the archipelago, as well as at some seamounts in Madeira's EEZ (INIP 1980, 1982, 1984a, 1984b, 1984c). These data, together with satellite data, were later reanalysed by Caldeira *et al.* (2002) who confirmed the 'island mass effect' of Madeira, showing the formation of eddies at the western part. They also pointed out special features due to the specific bathymetry, e.g., the shallow connection between the eastern tip of Madeira Island and the nearby Desertas. This shallow connection may be responsible for upwelling in prevailing north-eastern currents, causing a local higher primary production. The authors specifically highlight the need of further *in situ* investigations at the western part of Madeira, at the north-western part of Porto Santo, the already mentioned area between Madeira and Desertas, as well as the area between Porto Santo and Madeira.

A recent modelling study (Caldeira & Sangrà 2012) widened the previous observations, pinpointing again the need for more detailed *in situ* data collection in the highlighted areas. In their model study, the authors have shown the importance of the small island shelf for formation of eddies under different conditions. For confirming these model studies, *in situ* observations are urgently needed. This will be achieved by the here presented investigation.

In 2006 and 2008, microphytoplankton communities were surveyed regularly in coastal waters off Madeira Island with identification of the most abundant diatoms and dinoflagellates. A field guide of these organisms is in preparation and preliminary results were recently presented at a scientific meeting (Kaufmann *et al.* 2012).

Nanoplankton was examined during a pilot study in 2004, which revealed a high biodiversity of coccolithophores in these waters (Kaufmann 2004a).

The samples obtained during cruise P466 will be analysed in close cooperation with Dr. Mona Hoppenrath, SaM, Wilhelmshaven, using her wide expertise in dinoflagellate and diatom taxonomy (Hoppenrath 2004, Hoppenrath *et al.* 2007, Hoppenrath 2009, Hoppenrath *et al.* 2009).

2. Objectives and narrative of the cruise (K.H. George, A. Wehrmann, M. Kaufmann)

The major goal of MAPS is the incorporation of new and innovative aspects into the study of seamount productivity and their potential role for the distribution of marine species and the establishment of particular benthic assemblages. One aspect affects seamounts and islands forming a chain of marine elevations presenting the same origin but showing an age gradient, like the chain links of the MHST do. A second aspect related to the first is the recognition and comparative evaluation of terrestrial and/or marine influences, namely the input of terrestrial organic input into marine environments (as occurring in Madeira and Desertas that form “pre-seamount” stages) and its decreasing impact on planktonic and benthic (here: meiobenthic) faunas with time (as supposed for Porto Santo, Ampère and Seine seamounts), culminating in old seamounts that even left the photic zone (like the Great Meteor Seamount), combined with its increasing displacement by marine factors. Against that general background, the further goals are explained below.

Cruise P466 of RV POSEIDON aimed an extensive sampling of the sublittoral meiobenthos and sediment (both 50-300m depth), as well as of phytoplankton (0-150m) in the Madeira Archipelago (Fig. 1). Moreover, several physical and chemical variables were measured throughout the water column down to 3000m depth. Altogether, 582 deployments were made at 108 stations distributed over 22 transects around the islands of Madeira, Porto Santo, and Desertas (Fig. 1 and Appendix 1: Station list).

<u>Meiobenthology (K.H. George)</u>

Cruise P466 to the Madeira Archipelago is embedded in a broad, long-term project aiming to clear whether seamounts adopt functions as staging posts for the dispersal of marine meiofauna, in particular of shallow-water species, or if seamounts rather act as “trapping stones” for species whose ancestors reached the submerged elevations by accident, leading to the evolution of distinct, exclusive and highly diverse communities with high rates of endemism. For that purpose, several adjacent north-eastern Atlantic seamounts and islands (see above) are included into an extensive evaluation that studies Copepoda Harpacticoida exemplarily. In that perspective, a special goal is proving whether the components of the MHST, i.e. Seine Seamount, Ampère Seamount, Madeira, and Porto Santo show similar harpacticoid assemblages. The following hypothesis H_0, which bases on the results presented by Büntzow (2011), is formulated:

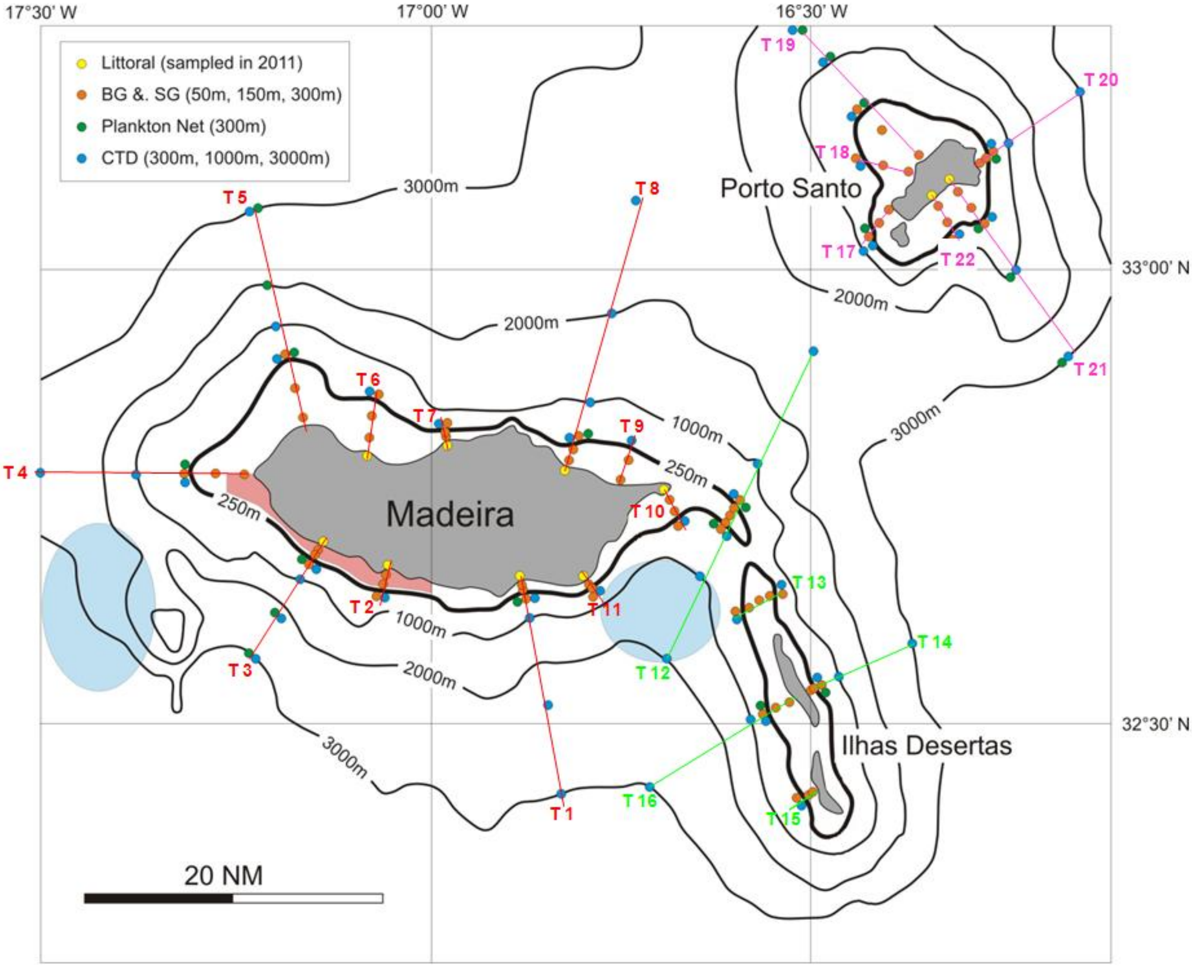


Figure 1: Map of Madeira, Porto Santo, and the Desertas Islands, showing the 22 transects that were sampled during P466 of RV POSEIDON in March, 2014. Pink area showing location were sediment data are available from; light blue areas showing particular interesting locations for planktonic sampling.

H_0: The harpacticoid assemblages of all studied chain links of the Madeira Hot Spot Track are similar with respect to the species composition and species diversity of at least their shallow-water components.

H_0 insinuates that Madeira, Porto Santo, Seine and Ampère constitute real staging posts in the sense of Rosen (1983); the named islands (= pre-seamounts) respectively the seamounts would then be located within a “critical dispersion distance” of the corresponding taxa (here: harpacticoid species), contributing therefore to an establishment of enduring sub-populations. These sub-populations together might even form meta-populations of the corresponding species (Cecca 2002) that comprised all elevations of the MHST. As the corresponding seamount summits lie in sublittoral water depths, in addition to the littoral material that has already been sampled at Madeira and Porto Santo, material from sublittoral locations of both islands (plus the Desertas) was needed for a founded comparison. Testing of H_0 shall be done based on morphologic characteristics, which is feasible without major problems in Harpacticoida. Conservation of the sampled material was nonetheless done using 5% Lugol (instead of 96% undenaturated ethanol or 37% formalin) to allow subsequent genetic analyses if considered necessary.

Sedimentology (A. Wehrmann)

Considering the geological evolution of seamounts, the Madeira Archipelago is of special interest in the understanding of their function to the dispersal of marine benthic organisms. As being the youngest parts of the MHST the Madeira Archipelago allows studying the different pre-seamount stages under similar regional climatic, hydrodynamic and oceanographic conditions. However, the islands differ strongly in how the environmental conditions on the shelf are controlled by terrestrial processes. This is most obvious when comparing Madeira Island with Porto Santo where the flattened topography of the emerged parts will have only a minor influence to the shelf conditions. Porto Santo therefore represents the last stage before the sedimentary system shift from terrestrial controlled (Madeira), over a mixed terrestrial/marine system (Porto Santo) to a marine system where sedimentation is than mainly controlled by autochthonous carbonate production of (photic/aphotic) benthic ecosystems and by primary production (Ampère Seamount, Great Meteor Seamount). The interdisciplinary approach of this survey will also give answers how the meiobenthic communities will response to this shift in the sedimentary systems.

On basis of the restricted sedimentary database the most essential focus of the cruise was:

1. What are the basic parameters of the surficial sediments on the MAS? It is postulated that the sediment composition of the islands' shelves differs significantly in their mineralogical composition. So far, only the south-western shelf of Madeira Island was surveyed once, whereas no data are available of the entire MAS. These data are strongly needed in the analysis of the meiobenthic data. The sediments will be analysed due to their basic parameters, i.e., grain size frequency distribution, TOC, $CaCO_3$ and mineral composition. The data will be converted into spatial distribution maps which will later be integrated into meiobenthic distribution data analysis.

As stated above, the sedimentary system of volcanic islands/seamounts shifts during their different evolutionary stages. From the Quaternary sedimentary record of Porto Santo it is known that the eolian deposits of Würmian age origin from reworked shelf material during glacial sea level lowstand. Due to their bioclastic composition (coralline red algae, molluscs, echinoderms, foraminifers, bryozoans) it is expected that carbonate production by benthic ecosystems was established during the uppermost Pleistocene. Modern examples of similar non-tropical carbonate factories are known from many shelf areas of warm to cold temperate regions. In this context the shelf of Porto Santo is investigated in detail under this topic as it represents the transitional stage in seamount evolution:

2. What are the characteristic elements of this transitional stage? And, which benthic communities/ecosystems are involved in autochthonous carbonate production?
3. What are the controlling factors? And, how can the different carbonate factories be classified?

The bioclastic components of the shelf sediments will be analysed down to a level which allows calculating to what extent different organism groups contribute to sediment production/source by their skeletal remains. Additionally, their trophic life modes will indicate how they are integrated into the regional, larger scaled oceanographic processes (e.g., seasonality, food webs, primary production, and nutrients availability).

Phytoplanktology (M. Kaufmann)

The main goals identified for cruise P466 and postulated hypotheses are as follows:

$H1_0$: There is no detectable influence of the islands on the abundance, composition and distribution of the phytoplankton community, especially there is no upwelling, which could enhance growth of microphytoplankton.

$H2_0$: There is no difference between near shore and off shore abundance and composition of the phytoplankton community, especially there are no differences in the prevailing pico- and nanoplankton communities close to the islands compared to off shore stations.

$H3_0$: There is no species diversity difference between the two microplankton groups (diatoms & dinoflagellates) compared to the nanoplankton coccolithophorids despite the difference in total abundances.

These three Null hypotheses will be tested by sampling phytoplankton communities with different methods at different stations around the islands: water samples from discrete depths in the upper layer (0-150 m) will be filtered onto glass fiber filters, these will be immediately shock frozen (preferably in liquid nitrogen) and stored at -80˚C until further analysis onshore. This will be done by scrutinising the phytopigments with HPLC (High pressure liquid chromatography). This method will allow the determination of the whole community composition of phytoplankton using characteristic markerpigments for the different taxonomic groups (Roy *et al.* 2011). Together with the physical data this will contribute to the understanding of the mechanisms involved in the physical-biological coupling around the islands.

In addition to the overall community composition, further methods will be applied to investigate the biodiversity (on genus and species level) of microplankton (emphasis on dinoflagellates and diatoms — net samples) and of smaller nano- (2-20µm, emphasis on coccolithophorids, see below) and picoplankton (<2 µm). Especially in oligotrophic regions, this small-sized phytoplankton plays a dominant role in primary production (Uitz *et al.* 2006). Microplankton composition will be studied by microscopical methods for which net-samples will be fixed and stored in the dark. Picoplankton composition and abundance will be studied by flow cytometry, which allows fast counting and optical analysis of individual particles (Dubelaar & Jonker 2000). For this, small water samples will be fixed and preserved onboard and stored at -80˚C for observation onshore.

The nanoplankton group, which consists primarily of the coccolithophores (Haptophyta, Prymnesiophyceae), will be studied in more detail using light and scanning electron microscopy. This group is of particular interest, as they are known to occur at high diversities particularly in oligotrophic regions of the oceans. They are adapted to live in deeper regions of the euphotic zone at limited light levels but already slightly increased nutrient levels above the nutricline (Winter & Siesser 1994). Due to their secretion of a calcareous skeleton, they are estimated to be responsible for about 50% of the precipitation of $CaCO_3$ in the oceans, playing thus a major role in the carbon flux from the upper ocean to the deep sea (Milliman 1993). Water samples will be filtered onto membranes, dried on air and stored in the dark at room temperature until further analysis in the laboratory.

The obtained results around the islands will be compared with previous results attained around seamounts to see if there are consistent differences or common patterns.

3. Scientific Participants, deployed gears

Ten participants formed the scientific staff; they are listed in Tab. 1. The following gears were deployed: van Veen grab (meiofauna; operation leader: Marco Bruhn), Shipek grab (sedimentology, meiofauna; operation leader: Dr Achim Wehrmann), plankton net (phytoplankton; operation leader: Dr Carmen Zinßmeister), underwater videocamera (operation leader: Maik Wilsenack). Water samples were taken using Niskin bottles mounted on a rosette (operation leader: Dr Manfred Kaufmann), which was additionally equipped with a CTD for measurement of temperature, conductivity, density (depth), oxygen, and fluorescence (operation leader: Dr Barbara Springer).

Table 1: List of scientific participants on POSEIDON cruise P466 to the Madeira Archipelago from March 2nd-18th, 2014.

No.	Name	Status	Institution	Research group
1	George, Dr Kai Horst, Mr	Scientist	SaM, Wilhelmshaven	Chief scientist
2	Albers, Lena, Mrs	Technician	SaM, Wilhelmshaven	Meiofauna
3	Bruhn, Marco, Mr	Technician	SaM, Wilhelmshaven	Meiofauna
4	Hesemann, Ferdinand, Mr	MSc-Student	SaM, Wilhelmshaven	Sedimentology
5	Kaufmann, Dr Manfred, Mr	Scientist	UMa, Funchal & Ciimar, Porto	Phytoplankton
6	Packmor, Jana, Mrs	Scientist	SaM, Wilhelmshaven	Meiofauna
7	Springer, Dr Barbara, Mrs	Scientist	SaM, Wilhelmshaven	CTD
8	Wehrmann, Dr Achim, Mr	Scientist	SaM, Wilhelmshaven	Sedimentology
9	Wilsenack, Maik, Mr	Technician	SaM, Wilhelmshaven	Underwater Video camera
10	Zinßmeister, Dr Carmen, Mrs	Scientist	SaM, Wilhelmshaven	Phytoplankton

4. Sampling results

Underwater video (M. Wilsenack, K.H. George)

The aim of deploying an underwater video system was to check the sediment conditions for subsequent sampling. This was of particular importance as the sampling concentrated on the islands' slopes that are steep and were therefore supposed to be characterized by quite different sediment types (sands, sandy mud, rocks, and mussel shells) and exposed to water currents of different strength. Ignoring those relevant physical variables would result in many failures of sampling, causing a significant loss of time coupled with a disproportional high amount of work. The insights provided by the deployment of the underwater video system allowed an optimization of gear deployment.

The video camera was deployed in water depths between 50 and 150 m water depth. The total number of camera deployments was 49, resulting in a total time of video filming of 16 hrs and 40 minutes. Table 2 summarizes the video deployments including date, corresponding transect, and water depths.

Table 2: Number of deployments (hauls) realized with the underwater video system.

Date	Transect No.	No. of hauls 50 m	No. of hauls 150 m	Alternative depths
05.03.2014	1	1	1	-
	2	1	1	-
06.03.2014	11	1	1	-
	12	1	2	-
07.03.2014	17	1	1	-
	18	1	1	-
08.03.2014	19	2 (60 m)	1	1 (70 m)
09.03.2014	20	1	1	-
10.03.2014	21	1	1	-
	22	1	1	-
11.03.2014	16	1	1	-
	15	1	1	-
12.03.2014	13	-	2	1 (80 m)
13.03.2014	14	1	1	-
	09	1	1	-
14.03.2014	08	2	1	-
	07	2	2	-
15.03.2014	05	2	-	-
	06	1	1	-
16.03.2014	03	1	1	-
	04	1	1	-

Meiofauna sampled with the van Veen grab (K.H. George, L. Albers, M. Bruhn, J. Packmor)

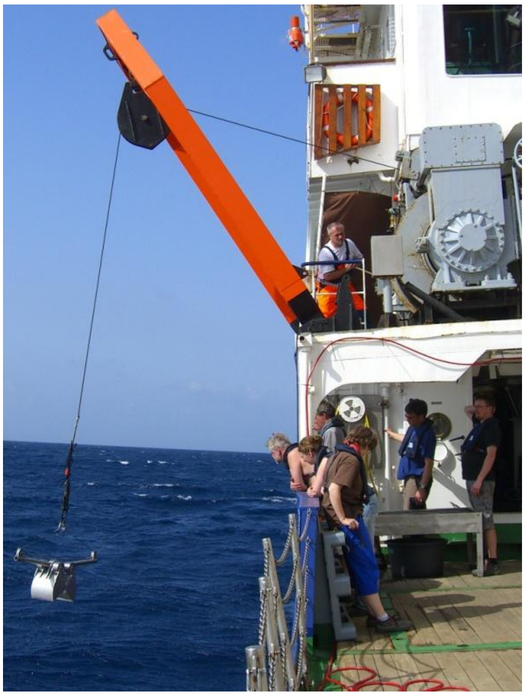


Figure 2: Deployment of the van Veen grab during P466. Photo: C. Zinßmeister.

Most seamounts present sediments consisting of rather medium-sized sands, and also the littoral areas in Madeira and Porto Santo sampled in previous years resemble such substrate. Thus, sampling with the normally best suited gear for sampling meiobenthos, the multiple corer (MUC) was inappropriate during cruise P466, as it fails in medium to coarse sandy sediments. Consequently, the van Veen grab (BG) was deployed (Fig. 2), as done before in other occasions (Great Meteor Seamount, Ampère Seamount). The used BG covers an area of $0.1m^2$, and as all stations were sampled with the same gear, the meiofauna sampling may be considered as quantitative.

At each station, at least 3 BG deployments were undertaken, and considered as 3 replicates for each station. However, due to different conditions (e.g. steep slopes, strong bottom currents, high waves and therefore strong rolling of the vessel) some hauls failed, so not all BG hauls were successful; when the conditions were too bad for deployment of the BG, or when the first hauls failed (providing only water; BG not closed), then the Shipek grab was used as alternative. Altogether, 205 BG deployments were done.

The obtained sediment was immediately sieved onboard. The sieved fraction was subsequently fixed with 7.0% Lugol solution.

As meiobenthic organisms are very small, lying between 0.032 and 1.0 mm body length, it was impossible to check onboard which taxa are present in the sampling material; that has to be done as soon as the material returns to the labs of the research institute Senckenberg am Meer (Wilhelmshaven, Germany). However, we expect a highly diverse and abundant meiofauna, whose major components may be Nematoda and Harpacticoida. Due to the sediment, for the latter we expect rather interstitial families like e.g. Ameirinae [part.], Canuellidae, Ectinosomatidae [part.], Leptastacidae, and Paramesochridae. However, as some sediments included muddy or even clayish fractions, also burrowing Harpacticoida like e.g. Cletodidae, Diosaccinae, and Zosimeidae may be found, as these taxa were already reported from several littoral areas at Madeira and/or Porto Santo (Packmor, unpublished).

Sediment sampled with the Shipek grab (A. Wehrmann, F. Hesemann)

For sampling of the sediment surface a Shipek Grab was applied, allowing a nearly undisturbed recovery of the sediment surface down to a depth of 6–7 cm. As a small-scale spatial variation in sediment composition has to be expected 3 grabs were taken at the majority of the stations. In total sediment samples were taken at 69 Stations (with 190 substations) around the Madeira Archipelago shelf. Water depth ranged between 48 m and 347 m. 175 substations were successfully sampled, in 5 times the grab did not release, in 10 times it hit hard grounds lacking sedimentary coverage. Each sample was split, as one half is designated for grain size analyses and quantitative component analyses, the other half is sampled superficially for TOC analysis. All subsamples were dried at 50°C immediately after sampling. Larger living organisms (algae, coral, polychaetes, and crustaceans) were fixed in ethanol (70%). For POM analysis the sediment will be heated at 450°C for 6 hours.

As postulated by our working hypothesis the terrestrial signal in sediment composition is clearly recognizable, especially at most of the shallow nearshore stations of Madeira Island and the Desertas. There, sediments are dominated by coarse to gravelly heavy mineral (e.g. magnesite) sands which originate from erosion of volcanic rocks. Strong hydrodynamic (wave) impact at the steep shore cliffs separates mineral particles of lesser density from heavy minerals. The dark sands are inhabited by the tube building polychaete *Ditrupa* sp. Towards deeper waters the content of lithoclastic material decrease whereas the amount of bioclastic sediment components increase. Generally, grain size composition of shelf sediments is very heterogenous ranging from dark grey mud to coarse bioclastic gravel. Additionally, the bioclastic sediments show a broad variety of components reflecting numerous different subhabitats/-environments. The biogenic composition of the sediments can be assigned to distinct groups of benthic organisms, i.e., bryozoans, foraminifera (e.g. *Miniacina miniacea*), barnacles, gastropods, bivalves, echinoderms (sea urchins & brittle stars), tube-building polychaetes, calcareous red algae (*Lithothamnium* rhodoliths) and corals. The bioclastic sediments can be classified as authochthonous to par-autochthonous showing a strong spatial relation to their so called ‘carbonate factories’, like bryozoans thickets.

The sediments of the Madeira Archipelago shelf differ strongly to those known from seamounts of the wider region (Great Meteor Seamount, Ampere Seamount). This is in general accordance to our working hypothesis. So far, a significant pelagic signature, as represented by pteropods and globigerinid foraminifers, is missing in the sediments. On the other side, the pre-seamount stage provides a more divers suite of habitats functioning as biosedimentary systems.

The sediment survey of POS 466 has not considered the shallowest sedimentary environments (< 50 m water depth) which are mainly deposited at sheltered sites where hydrodynamic energy regime is low. Further surveys should focus on these sites to fill the gap from the 50 m line towards the shore. Of special interest are the large rhodolith pavements southeast of Porto Santo (pers. comm. M. Kaufmann) and the dissected rocky platform northeast of Porto Santo. The sediments sampled during POS 466 have strongly broadened the knowledge of shelf sediments (and their respective sources) from the Madeira Archipelago.

<u>CTD profiles (B. Springer, M. Kaufmann)</u>

A total of 49 CTD stations for hydrographical analyses and water sampling for phytoplankton and nutrients, ranging from 0 m depth to 3000 m around the islands (Madeira, Porto Santo, Ilhas Desertas), were collected during 12 days (05.03.–17.03.2014) on cruise P466.

A Seabird CTD (SBE911 plus), mounted on a Seabird SBE32 carousel equipped with 12 Niskin bottles (10 l each), was used for all hydrographic samples. The profiler was equipped with two sensors for each parameter, i.e. for temperature, conductivity and oxygen. Additionally two fluorescence sensors (Dr. Haardt BackScat II, Turner Cyclops-7^{TM}) were attached for measurements of the chlorophyll-*a* signal.

All sensors were calibrated a few months before the cruise. The raw CTD data will be pre-processed following the recommended procedure for the SBE 911plus, using the SBE-Data-Processing software (e.g McTaggart *et al.* 2010).

The pre-processing steps includes conversion from raw binary data to engineering units in ASCII format, separation of the downcast from the upcast profiles, low pass filtering of the pressure channel to reduce high frequency noise, correction from pressure inversion caused by ship motion, derivation of correct salinity and bin averaging of the downcast profile into 1 dbar pressure intervals.

The pre-processed data will be converted to SeaDataNet ODV format for data quality control (DQC) using the ODV software (Schlitzer, R. 2013, http://odv.awi.de).

The ship mounted Seabird SBE21 thermosalinograph logged the temperature, conductivity, and fluorescence (Wetlabs ECO FLRT) in 4 m water depth continuously during the cruise, except for a 24 hrs. interval for fixing the pump.

In addition to the CTD casts and during the whole cruise the flow field down to 800–900 m depth was measured by a ship mounted 75 kHz Acoustic Doppler Current Profiler (ADCP), RDI Ocean Surveyor.

Most profiles showed a well-mixed surface layer extending from 0 to about 250 m (Fig. 2). In this layer the temperature was around 17ºC, salinity around 36.5 PSU and dissolved oxygen above 240 µmol/l. The fluorescence signal was slightly higher around 30–40 m depth, but maintaining uniform levels down to over 200 m before decreasing towards zero.

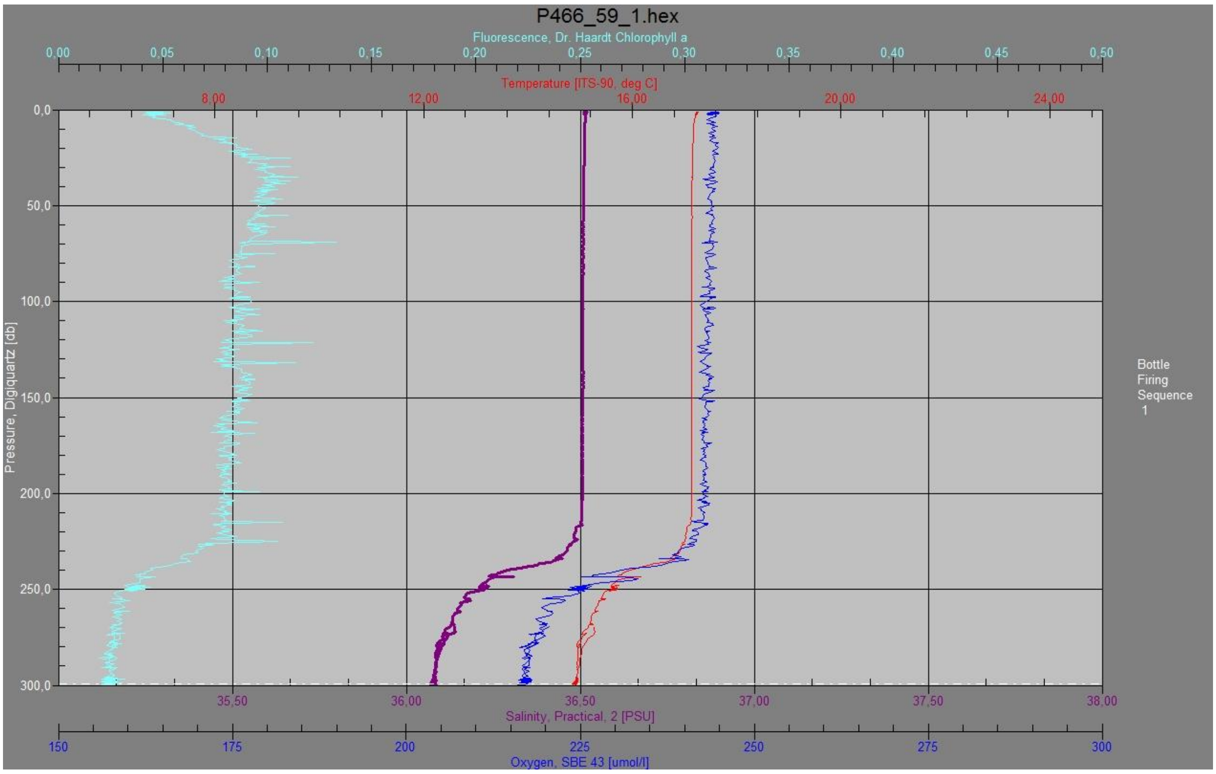


Figure 3: CTD profile at station 59 showing homogenous mixed water layer down to about 250 m. (temperature = red, salinity = violet, oxygen = dark blue, fluorescence = light blue).

The deeper water layers showed the typical profile for this area, with the shallow, well mixed layer described above, followed by a strong thermocline until 600–800 m, an increase at about 1,000 m, indicating water masses of Mediterranean origin, followed again by decreasing temperature until about 2–3ºC at the maximum measured depth of 3,000 m (Fig. 3). Dissolved oxygen attained minimum values at about 800 m increasing thereafter until the maximum measured depths with values comparable to surface values.

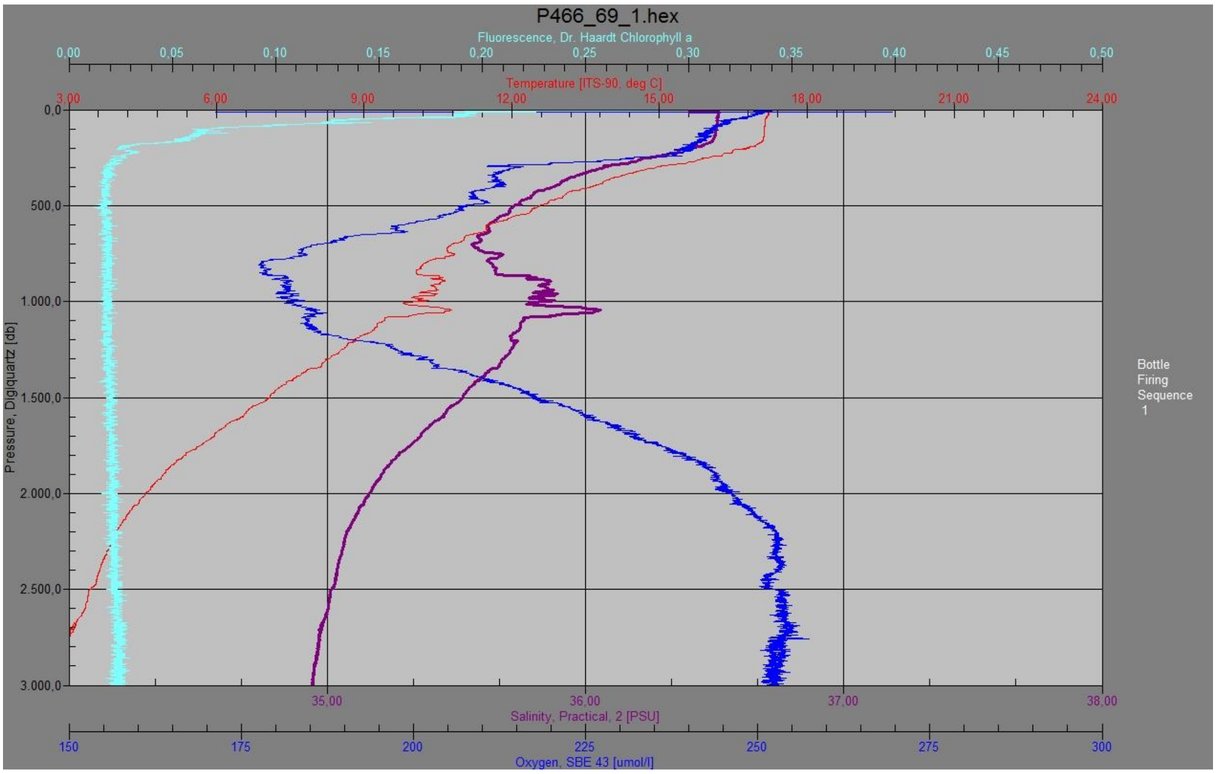


Figure 4: CTD profile at station 69 showing homogenous mixed water layer down to about 250 m, strong clines until about 600–800 m, the Mediterranean Outflow water at about 1,000 m and decreasing values of temperature, salinity until maximum measured depth (3,000m). (temperature = red, salinity = violet, oxygen = dark blue, fluorescence = light blue).

<u>Water sampling with Niskin bottles (M. Kaufmann, B. Springer)</u>

From the total of 49 CTD stations, water samples were taken at 47 of them. At the two remaining stations only hydrographic profiles were obtained. Using CTD and fluorescence profiles the sampling depths were determined individually for each station during downcast. In general four depths were sampled for different purposes: phytopigment determination (HPLC), identification and enumeration of coccolithophores (nanophytoplankton), identification and enumeration of picophytoplankton, DNA determination and identification and enumeration of microphytoplankton (Utermöhl) (Tab. 3).

Table 3: Number of samples and volumes filtered for each phytoplankton group.

	HPLC	Coccolithophores	Picoplankton	DNA	Nutrients	Utermöhl enumeration	total
no. samples	180	180	202	45	180	50	837
Vol. filtered (l)	511.9	517.0	-	125.4	-	-	1154.3

For nutrient determination a volume between 50 and 200 ml was sampled directly from the Niskin bottles immediately after each haul, as well as about 200 ml for microphytoplankton determination. The remaining volume was transferred to 10 l folding cans and transported to the onboard lab for filtering. For picophytoplankton determination 3.2 ml of water sample from each depth were transferred into cryovials and fixed with 0.2 ml of a 20% Paraformaldehyde solution. After fixation the samples were frozen at -30ºC and will be analysed by flow cytometry. For phytopigment analysis by HPLC, between 2.5–4.0 l of water sample from each depth was filtered with low vacuum suction (~200 mbar) onto glass fibre filters (GF/F, 25 mm diameter, ~0.7 µm nominal pore size) and immediately frozen at -30ºC. For DNA analysis between 2.5-4.0 l of water sample from only one depth at each station was filtered with low vacuum suction (~200 mbar) onto glass fibre filters (GF/F, 25 mm diameter, ~0.7 µm nominal pore size) and immediately frozen at -30ºC. For nanophytoplankton analysis, between 2.5-4.0 l of water sample from each depth was filtered with low vacuum suction (~200 mbar) onto polycarbonate membranes (Nuclepore, 47 mm diameter, 0.4 µm nominal pore size), dried at 40ºC in plastic Petri dishes and sealed thereafter with Parafilm™.

During filtration for phytopigment analysis first impressions indicated no presence of a Deep Chlorophyll Maximum typical for summer situations in oligotrophic regions. The filters presented almost the same intensity of green colour at depths from 20 until almost 120 m (Fig. 5) supporting the impression of a well-mixed winter surface layer also observed at the CTD profiles.

Figure 5: Green colour of GF/F filter after filtration of 3.0 l of water sample from the mixed surface layer.

Plankton sampling with the Plankton net (C. Zinßmeister)

Figure 6: Vertical plankton, 55µm mesh size. Photo: C. Zinßmeister.

Water samples using vertical plankton net with 55µm mesh size (Fig. 6) has been used to investigate relative abundance and composition of the microphytoplankton community around Madeira and associated islands. These samples contain plankton from near coast water (depth at station: 150–300 m) and offshore water (depth at station: up to 3,000 m). Vertical plankton net lowering has been 150 m of wire length with winch speed down of 0.2–0.5 m/s and winch speed up of 0.2–0.3 m/s. Vertical hauls have been taken following the stations of the cruise schedule P466 (Fig. 1). In total 21 samples of the water column between surface and about 150 m water depth have been taken at 13 transects. Based on windy weather conditions one vertical water sample couldn’t be taken at transect T12 and an additional sample from transect T5 has been collected (Tab. 4). In addition tab seawater has been filtrated through 20 and 100 µm mesh size sieves.

Each sample has been fixed with Lugol in two to three 500ml plastic bottles shared for the lab of Manfred Kaufmann, Funchal, Madeira and Mona Hoppenrath, Wilhelmshaven, Germany.

Table 4: List of vertical plankton net stations at transects on POSEIDON cruise P466 to the Madeira Archipelago.

Transect	Station	Date	Depth at station [m]
T1	POS466/036-1	06.03.2014	311,5
T2	POS466/042-2	06.03.2014	286,5
T17	POS466/052-1	07.03.2014	247,1
T19	POS466/057-2	08.03.2014	2102,3
T19	POS466/058-1	08.03.2014	1022,9
T19	POS466/059-2	08.03.2014	343
T20	POS466/066-2	09.03.2014	320,6
T20	POS466/069-2	09.03.2014	3222,5
T20	POS466/070-1	09.03.2014	1040,8
T20	POS466/071-2	10.03.2014	245,2
T16	POS466/083-2	11.03.2014	312,3
T14	POS466/093-2	12.03.2014	310,6
T8	POS466/105-2	14.03.2014	298,7
T5	POS466/112-2	14.03.2014	2920,2
T5	POS466/113-1	15.03.2014	2001,5
T5	POS466/114-1	15.03.2014	991
T5	POS466/119-2	15.03.2014	200,4
T4	POS466/127-2	16.03.2014	245,4
T3	POS466/130-2	16.03.2014	292
T3	POS466/132-2	16.03.2014	1958,3
T3	POS466/133-1	16.03.2014	2998,5

5. References

Bartsch, I. 1973a. Halacaridae (Acari) von der Josephinebank und der Großen Meteorbank aus dem östlichen Nordatlantik. I. Die Halacaridae aus den Schleppnetzproben. „Meteor“ Forschungs-Ergebnisse D 13: 37–46.

Bartsch, I. 1973b. Halacaridae (Acari) von der Josephinebank und der Großen Meteorbank aus dem östlichen Nordatlantik. II. Die Halacaridae aus den Bodengreiferproben. „Meteor“ Forschungs-Ergebnisse D 15: 51–78.

Bartsch, I. 1973c. *Copidognathus raekor*, eine neue Halacaridae (Acari) von der Großen Meteorbank. „Meteor“ Forschungs-Ergebnisse D 16: 65–68.

Bartsch, I. 2001. A new halacarid genus (Acari: Halacaridae: Halacarinae) from the Great Meteor Seamount, Eastern North Atlantic. Specis Diversity 6: 117–125.

Bartsch, I. 2003. Lohmannellinae (Halacaridae: Acari) from the Great Meteor Seamount (northeastern Atlantic). Description of new species and reflections on the origin of the seamount fauna. Mitteilungen des hamburger zoologischen Museums und Instituts 100: 101–117.

Büntzow, M. 2011. Vergleichende gemeinschaftsanalytische und taxonomische Untersuchungen der Harpacticoidenfauna der Seeberge “Sedlo” und “Seine” (nördlicher Mittelatlantik). Doctoral thesis, pp. 1-128. Carl-von-Ossietzky-Universität, Oldenburg, Germany.

Caldeira, R. M. A. & Sangrà, P. 2012. Complex geophysical wake flows. Madeira Archipelago case study. Ocean Dynamics, DOI 10.1007/s10236-012-0528-6.

Caldeira, R. M. A., Groom, S., Miller, P., Pilgrim, D. & Nezlin, N. P. 2002. Sea-surface signatures of the island mass effect phenomena around Madeira Island, Northeast Atlantic. Remote Sensing of Environment, 80: 336–360.

Cecca, F. 2002. Paleobiogeography of marine fossil invertebrates. Taylor & Francis, London.

Coutis, P. F. & Middleton, J. H. 1999. Flow-topography interaction in the vicinity of an isolated, deep ocean island. Deep-Sea Research I, 46: 1633–1652.

Doty, M. S. & Oguri, M. 1956. The island mass effect. J. Cons. perm. int. Explor. Mer, 22: 33–37.

Dubelaar, G.B.J. & Jonker, R.R. 2000. Flow cytometry as a tool for the study of phytoplankton. Scientia Marina 64: 135–156.

Emschermann, P. 1971. *Loxomespilon perezi* - ein Entoproctenfund im Mittelatlantik. Überlegungen zur Benthosbesiedlung der Großen Meteorbank. Marine Biology 9: 51–62.

Gad, G. 2004. Diversity and assumed Origin of the Epsilonematidae (Nematoda) of the plateau of the Great Meteor Seamount. Archive of Fishery and Marine Research 5 (1-3): 30–42.

Gad, G. & H.K. Schminke 2004. How important are seamounts for the dispersal of interstitial meiofauna? Archive of Fishery and Marine Research 51: 43–54.

Geldmacher, J., K. Hoernle, A. Klügel, P.V.D. Bogaard, F. Wombacher & B. Berning 2006. Origin and geochemical evolution of the Madeira-Tore Rise (eastern North Atlantic). Journal of Geophysical Research 111: B09206, doi: 10.1029/2005JB003931.

George, K.H. 2004. Description of two new species of *Bodinia*, a new genus incertae sedis in Argestidae Por, 1986 (Copepoda, Harpacticoida), with reflections on argestid colonization of the Great Meteor Seamount plateau. Organisms, Diversity & Evolution 4: 241–254.

George, K.H. 2013. Faunistic research on metazoan meiofauna from seamounts—a review. Meiofauna Marina 2: 1–32.

George, K.H. & H.K. Schminke 2002. Harpacticoida (Crustacea, Copepoda) of the Great Meteor Seamount, with first conclusions as to the origin of the plateau fauna. Marine Biology 141: 887–895.

Giere, O. 2009. Meiobenthology. The microscopic motile fauna of aquatic sediments. Springer Verlag Berlin, Germany.

Hasegawa, D., Yamazaki, H., Lueck, R. G. & Seuront, L. 2004. How islands stir and fertilize the upper ocean. Geophysical Research Letters, 31: L16303, doi: 10.1029/2004GL020143.

Hesemann, F. 2013. Genese der bioklastischen Sediment der Großen Meteorbank (Atlantik). BSc Thesis University of Bremen, 45 pp.

Heywood, K. J., Barton, E. D. & Simpson, J. H. 1990. The effects of flow disturbance by an oceanic island. Journal of Marine Research 48: 55–73.

Hoppenrath, M. 2004. A revised checklist of planktonic diatoms and dinoflagellates from Helgoland (North Sea, German Bight). Helgoland Marine Research 58: 243–251.

Hoppenrath, M. 2009. Marine Planktonic Diatoms. In: R. Röttger, Knight, R. & Foissner, W. (eds.). A course in protozoology. Shaker Verlag, Aachen: 14–26.

Hoppenrath, M., Beszteri, B., Drebes, G., Halliger, H., Janisch, S., Van Beusekom, J. E. E. & Wiltshire, K. H. 2007. *Thalassiosira* species (Bacillariophyceae, Thalassiosirales) in the waters around the islands of Helgoland (German Bight) and Sylt (Northfrisian Wadden Sea) – a first approach to assessing diversity. European Journal of Phycology 42: 271–288.

Hoppenrath, M., Elbrächter, M. & Drebes, G. 2009. Marine Phytoplankton. Selected microphytoplankton species from the North Sea around Helgoland and Sylt. Kleine Senckenberg-Reihe, 49: 1–264.

INIP 1980. Programa de apoio às pescas na Madeira — I. Cruzeiro de reconhecimento de pesca e oceanografia 020080779. Relatórios Técnicos e Administrativos do INIP, 3. INIP, Lisboa: 1–141.

INIP 1982. Programa de apoio às pescas na Madeira — II. Cruzeiro de reconhecimento de pesca e oceanografia 020170680. Cruzeiro de reconhecimento de pesca e oceanografia 020241180. Relatórios INIP, 11. Relatórios do INIP, Lisboa: 1–220.

INIP 1984a. Programa de apoio às pescas na Madeira — V. Cruzeiro de reconhecimento de pesca e oceanografia 020451182. Relatórios INIP, 37. INIP, Lisboa: 1–124.

INIP 1984b. Programa de apoio às pescas na Madeira — III. Cruzeiro de reconhecimento de pesca e oceanografia 020330981. Relatórios INIP, 22. INIP, Lisboa: 1–132.

INIP 1984c. Programa de apoio às pescas na Madeira — IV. Cruzeiro de reconhecimento de pesca e oceanografia 020390582. Relatórios INIP, 25. INIP, Lisboa: 1–125.

Jia, Y., Calil, P. H. R., Chassignet, E. P., Metzger, E. J., Potemra, J. T., Richards, K. J. & Wallcraft, A. J. 2011. Generation of mesoscale eddies in the lee of the Hawaiian Islands. Journal of Geophysical Research, 116: C11009, doi:10.1029/2011JC007305.

Kaufmann, M. 2004a. Der Einfluss von Seamounts auf die klein- und mesoskalige Verteilung des Phytoplanktons im zentralen, subtropischen Nordostatlantik, PhD thesis, Christian-Albrechts-Universität, Kiel, Germany.

Kaufmann, M., Santos, F., Maranhão, M. 2012. On the coastal microphytoplankton of Madeira Island with some historical notes in: Sequeira, M. M. 2012 Floramac2012 – Scientific program – Abstract book – Excursion guide, 5-8 September, Funchal, Portugal.

Koller, S. & K. H. George 2011. Description of a new species of *Zosime* Boeck, 1872 (Copepoda: Harpacticoida: Zosimeidae) from the Great Meteor Seamount, representing one of the few eurybathic Harpacticoida among the distinct plateau and deep-sea assemblages. Meiofauna Marina 19: 109–126.

Lietz, J. & Schwarzbach, M. 1971. Quartäre Sedimente auf der Atlantik-Insel Porto Santo (Madeira-Archipel) und ihre paläoklimatische Deutung. Eiszeitalter und Gegenwart 22: 89–109.

Longhurst, A., Sathyendranath, S., Platt, T. & Caverhill, C. 1995. An estimate of global primary production in the ocean from satellite radiometer data. Journal of Plankton Research 17: 1245–1271.

McTaggart, K. E., Johnson, G. C., Johnson, M. C., Delahoyde, F. M. & Swift, J. H. 2010. Notes on CTD/O2 data aquisition and processing using Sea-Bird hardware and software (as available). IOCCP Report No. 14, ICPO Publication Series No. 134: 1–10.

Mendonça, A., Arístegui, J., Vilas, J. C., Montero, M. F., Ojeda, A., Espino, M. & Martins, A. 2012. Is There a Seamount Effect on Microbial Community Structure and Biomass? The Case Study of Seine and Sedlo Seamounts (Northeast Atlantic). PLoS ONE, 7: e29526.

Milliman, J.D. 1993. Production and accumulation of calcium carbonate in the ocean: Budget of a nonsteady state. Global Biogeochemical Cycles 7: 927–957.

Morato, T., Varkey, D. A., Damaso, C., Machete, M., Santos, M., Prieto, R., Pitcher, T. J. & Santos, R. S. 2008. Evidence of a seamount effect on aggregating visitors. Marine Ecology Progress Series, 357: 23–32.

Oliveira, A., Palma, C., Valenca, M. & Rodrigues, A. 2007. Madeira Island — SW coastal sediments geochemistry. Thalassas, 23(2): 9–16.

Packmor, J. 2013. Rhizotrichidae Por, 1986 (Copepoda: Harpacticoida) of Madeira and Porto Santo: description of two new species of the genus *Tryphoema* Monard, 1926. Marine Biodiversity 43: 341–361.

Plum, C. & K.H. George 2009. The paramesochrid fauna of the Great Meteor Seamount including the description of a new species of *Scottopsyllus* (*Intermedopsyllus*) Kunz (Copepoda: Harpacticoida: Paramesochridae). Marine Biodiversity 39: 265–289.

Roden, G. I. & Taft, B., A. 1985. Effect of Emperor Seamounts on the mesoscale thermoheline structure during the summer of 1982. Journal of Geophysical Research, 90: 839–855.

Rodrigues, A., Oliveira, A., Fonseca, R., Taborda, R., Cascalho, J.P. 2006. Sedimentary dynamics of the southern shelf of Madeira (Portugal). Journal of Coastal Research, SI 39: 454–458.

Rosen, B. 1983. Reef island staging posts and Noah's arks. Reef encounter 1: 5–6.

Roy, S., Llewellyn, C.A., Egeland, E.S., Johnson, G. 2011. Phytoplankton Pigments. Characterization, Chemotaxonomy and Applications in Oceanography. Cambridge University Press, Cambridge.

Samadi, S., T. Schlacher & B. Richer de Forges 2007. Seamount Benthos. In: Pitcher, T.J., T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan & R.S. Santos (eds.). Seamounts: Ecology, Fisheries & Conservation. Blackwell Publishing, Oxford: 119–140.

Sangrà, P., Pascual, A., Rodríguez-Santana, Á., Machín, F., Mason, E., Mcwilliams, J. C., Pelegrí, J. L., Dong, C., Rubio, A., Arístegui, J., Marrero-Díaz, Á., Hernández-Guerra, A., Martínez-Marrero, A. & Auladell, M. 2009. The Canary Eddy Corridor: A major pathway for long-lived eddies in the subtropical North Atlantic. Deep Sea Research I, 56: 2100–2114.

Spisla, C. 2013. Die biosedimentären Systeme des Ampère-Seamount, Nordost Atlantik. BSc Thesis University of Oldenburg, 66 pp.

Thiel, H. 1970. Bericht über die Benthosuntersuchungen während der „Atlantischen Kuppenfahrten 1967" von F.S. „Meteor". „Meteor" Forschungs-Ergebnisse D 7: 23–42.

Uitz, J., Claustre, H., Morel, A. & Hooker, S. B. 2006. Vertical distribution of phytoplankton communities in open ocean: An assessment based on surface chlorophyll. Journal of Geophysical Research, 111: C08005, doi:10.1029/2005JC003207.

White, M., Bashmachnikov, I., Arístegui, J., Martins, A. 2007. Physical processes and seamount productivity. In: Pitcher, T.J., Morato, T., Hart, P.J.B., Clark, M.R., Haggan, N. Santos, R.S. (eds.). Seamounts: Ecology, Fisheries & Conservation. Blackwell Publishing, Oxford, UK: 63–84.

Winter, A., Siesser, W.G. 1994. Coccolithophores. Cambridge University Press, Cambridge.

RV POSEIDON. Photo: Dr. Achim Wehrmann, Senckenberg am Meer Wilhelmshaven.