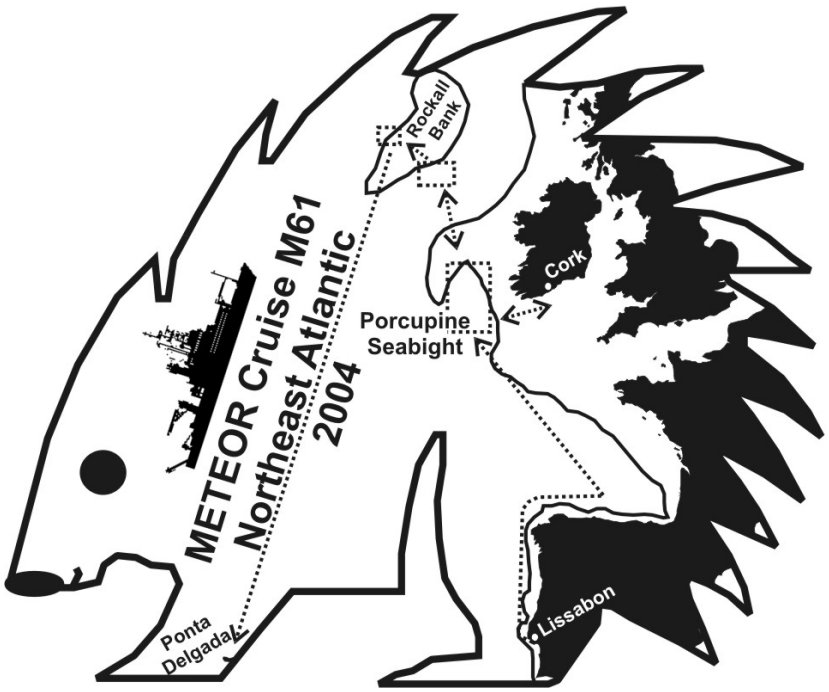
METEOR-Berichte 06-2

Northeast Atlantic 2004

Cruise No. 61

April 19 to June 6, 2004, Lisbon – Cork – Cork – Ponta Delgada



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Abstract

R/V METEOR Cruise No. 61 was divided into three different legs, which all focused on the NE-Atlantic to the west of Ireland from the Porcupine Seabight towards the Rockall Bank. Legs 1 and 3 concentrated on geo-biological studies on the carbonate mounds in this region, which are covered by a unique cold water coral fauna. Leg 2 dealt with seismic investigations in order to investigate the extension processes that led to the development of the Porcupine rift basin. The foci of the individual legs were on the following themes.

M61-1 was a multidisciplinary cruise addressing biological, paleo-geological and hydrographical scientific objectives in the carbonate mound provinces west of Ireland in the eastern Porcupine Seabight and on the Rockall Bank. The cruise started in Lisbon (Portugal) and ended in Cork (Ireland). M61-1 activities were embedded within the ESF-DFG MOUNDFORCE project of the EUROMARGINS Programme. Together with the succeeding M61-3 cruise, these Meteor activities document Germany´s strong scientific and logistic support for the success of this challenging programme. Investigations are also designed as a preparatory cruise for the EU-project HERMES (Hotspot Ecosystem Research on the Margins of European Seas; start April 2005). All institutions participating in M61-1 are partners in HERMES Work package 2 “Coral Reef and Carbonate Mound Systems”.

M 61-2 was directed at researching the earth’s crust in the vicinity of the Porcupine rift basin. During this leg, seismic research has been undertaken in the Porcupine Basin west of Ireland, an area that represents a natural laboratory for the investigation of extensional processes. Firstly, both sides of a rift basin occurring in close proximity to each other could have been studied here, allowing questions about the symmetry of extension to be addressed by several east-west profiles parallel to the direction of extension. Secondly, the amount of extension increases from north to south, so a series of east-west cross sections on different latitudes has provided information on crustal structure during variable extension. The spatial changes between these sections also represent the temporal development of the rift through continued extension. In order to achieve these research goals, a series of east-west oriented wide angle reflection profiles in the Porcupine Basin has been acquired. These profiles aid in the explanation of extensional processes and their development through continued extension. They also address insufficiently explained questions about the initiation of large scale magmatism and intrusion, the onset of mantle serpentinisation and the development of detachment faults.

M61-3 During this leg, the only recently discovered ‘carbonate mounds’ on the NW-European continental margin have been investigated, which represent unique geo- and ecosystems for European waters. The broad scientific interest that is directed at these mounds is reflected in three EU-projects, which until recently almost exclusively concentrated their efforts on the mounds, as well as the currently operating ESF-EUROMARGINS project MOUNDFORCE M 61-3 focused on the use of a ‘Remotely Operated Vehicle’ (ROV) for the investigation of the carbonate mounds. The primary tasks of Bremen’s QUEST ROV were a detailed characterization of individual mound structures, selective sample collection and the retrieval of sensor systems placed at the seafloor one year before. These ROV tasks have been supplemented by hydro-acoustic measurements and conventional sediment sampling in order to work - in close collaboration with M61-1 - on the main research focuses of the MOUNDFORCE project: (a) analysis of the environmental factors that drive the development of the ‘carbonate mounds’, (b)

surveying the benthic communities in dependence of changing environmental factors and (c) investigations to the stabilization and lithification of the mound sediments.

Zusammenfassung

Die METEOR Reise 61 umfasste drei Abschnitte, die sich auf das Seegebiet westlich von Irland von der Porcupine Seabight bis zur Rockall Bank konzentrierten. Im Mittelpunkt des ersten und des dritten Abschnittes standen dabei geo-biologische Untersuchungen an den „carbonate mounds“ in diesem Gebiet, die von einer einzigartigen Tiefwasserkorallenfauna bewachsen sind. Der zweite Abschnitt befasste sich mit seismischen Untersuchungen zu den Extensionsprozessen, die zur Entstehung des Porcupine Riftbeckens geführt haben. Die Schwerpunkte der einzelnen Fahrtabschnitte lagen dabei auf den folgenden Punkten.

M61-1 war eine multidisziplinäre Forschungsfahrt mit biologischen, paläo-geologischen und hydrographischen Fragestellungen in die “Carbonate Mound Province” westlich von Irland in das Gebiet der östlichen Porcupine Seabight und auf die Rockall Bank. Die Fahrt begann in Lissabon (Portugal) und endete in Cork (Irland). M61-1 ist Teil der Untersuchungen des ESF-DFG geförderten Vorhabens MOUNDFORCE des EUROMARGINS Programms. In Verbindung mit den nachfolgenden Aktivitäten auf M61-3 unterstreichen die auf M61-1 durchgeführten Untersuchungen Deutschlands starken wissenschaftlichen und logistischen Beitrag zum Erfolg dieses Vorhabens. Die auf M61-1 durchgeführten Untersuchungen sind ebenfalls bereits eine Vorstudie zum EU-Programm HERMES (Hotspot Ecosystem Research on the Margins of European Seas, Beginn April 2005). Die Institute, die an M61-1 beteiligt sind, sind alle Partner im HERMES Work Package 2 „Coral Reef and Carbonate Mound Systems“.

M 61-2 hatte sich zum Ziel gesetzt, die Struktur der Erdkruste im Bereich des Porcupine Riftbeckens zu untersuchen. Im Verlauf dieses Fahrtabschnittes sollten seismische Untersuchungen im Porcupine Becken westlich von Irland durchgeführt werden. Dieses Gebiet stellt ein natürliches Labor für die Untersuchung von Extensionsprozessen dar. Erstens kann man hier beide Seiten eines Riftbeckens in großer räumlicher Nähe untersuchen, so dass Fragen zur Symmetrie der Extension jeweils durch einzelne Ost-West-Profile parallel zur Dehnungsrichtung abgedeckt werden. Zweitens nimmt der axiale Dehnungsfaktor von Nord nach Süd zu, so dass eine Reihe ost-westlicher Querschnitte in verschiedenen Breiten Informationen über die Krustenstruktur bei unterschiedlicher Dehnung liefert. Die räumlichen Veränderungen zwischen diesen Sektionen bilden also eigentlich die zeitliche Entwicklung des Rifts bei fortschreitender Dehnung ab. Um diese Ziele zu erreichen, wurden im Porcupine Becken eine Reihe Ost-West verlaufender Weitwinkel-Reflexionsprofile aufgenommen. Diese Profile tragen dazu bei, die Symmetrie des Extensionsprozesses und seine Entwicklung bei fortschreitender Dehnung zu klären. Sie stellen auch einen Beitrag zu unzureichend geklärten Fragen wie den Beginn von Magmatismus und Intrusion in signifikantem Ausmaß, den Beginn der Mantelserpentinisierung und die Entwicklung von Detachment-Verwerfungen dar.

M 61-3 Während dieses Fahrtabschnittes wurden die erst vor wenigen Jahren entdecken „carbonate mounds“ am NW-Europäischen Kontinentalhang untersucht, die für Europäischen Gewässer einzigartige Geo- und Ökosysteme darstellen. Das große wissenschaftliche Interesse, das diesen Mounds entgegengebracht wird, spiegelt sich u.a. in drei EU-Projekten, die sich bis vor kurzem nahezu ausschließlich mit diesen Mounds befassten, und dem zur Zeit laufenden ESF-EUROMARGINS Projekt MOUNDFORCE wider. Im Mittelpunkt von M 61-3 stand die

Untersuchung dieser „carbonate mounds“ mit einem „Remotely Operated Vehicle“ (ROV). Die Hauptaufgaben des Bremer QUEST ROVs lagen dabei auf einer detaillierten Charakterisierung einzelner Moundstrukturen, der gezielten Probennahme und der Aufnahme von ein Jahr lang am Meeresboden deponierter Sensorpakete. Diese Arbeiten wurden durch hydroakustische Vermessungen und konventionelle Sedimentbeprobungen ergänzt, um in enger Zusammenarbeit mit M 61-1 die Hauptthemenbereiche im MOUNDFORCE Projekt zu bearbeiten: (a) Analyse der Umweltfaktoren, die die Entwicklung der „carbonate mounds“ steuern, (b) Erfassung der benthischen Lebensgemeinschaften in Abhängigkeit von sich ändernden Umweltfaktoren und (c) Untersuchungen zur Stabilisierung und Lithifizierung der Moundsedimente.

Research Objectives

R/V METEOR cruise No. 61 was dedicated to study different aspects of geology, geophysics, geobiology and paleoceanography in the Northeast Atlantic (Fig. I). It was divided into three individual legs (see Table I), each of these with its own scientific focus, which are described in detail below.

Table I: Legs and chief scientists of R/V METEOR cruise 61

Leg	Period	Ports	Chief Scientists
M61/1	19.04.2004 – 04.05.2004	Lisbon (Portugal) Cork (Ireland)	Dr. Olaf Pfannkuche
M61/2	08.05.2004 – 31.05.2004	Cork (Ireland) Cork (Ireland)	Prof. Dr. Tim Reston
M61/3	04.06.2004 – 21.06.2004	Cork (Ireland) Ponta Delgada (Portugal)	Dr. Volker Ratmeyer

Master: N. Jacobi (M61/1 – M61/3)

M61/1: Geo-Biological Investigations on Azooxanthellate Cold-Water Coral Reefs on the Carbonate Mounds Along the Celtic Continental Slope

Recent scientific exploration along the European ocean margin proofed the existence of a deep-water coral ecosystem belt stretching from northern Norway to NW Africa and extending into the Mediterranean Sea. Two colony forming stone coral species, *Lophelia pertusa* and *Madrepora oculata*, have the potential to construct impressive reef frameworks similar to those built up by their tropical cousins. They are essentially involved in the formation of the spectacular carbonate mounds off Ireland. Aside these structural aspects, deep-water coral ecosystems attract a yet unknown number of associated species that live permanently or temporarily there. Many of them are of economic importance. This important biological resource, however, is in many places severely exploited and under threat. Amongst a suite of human impacts to the deep coral ecosystems, demersal trawling creates by far the strongest destruction.

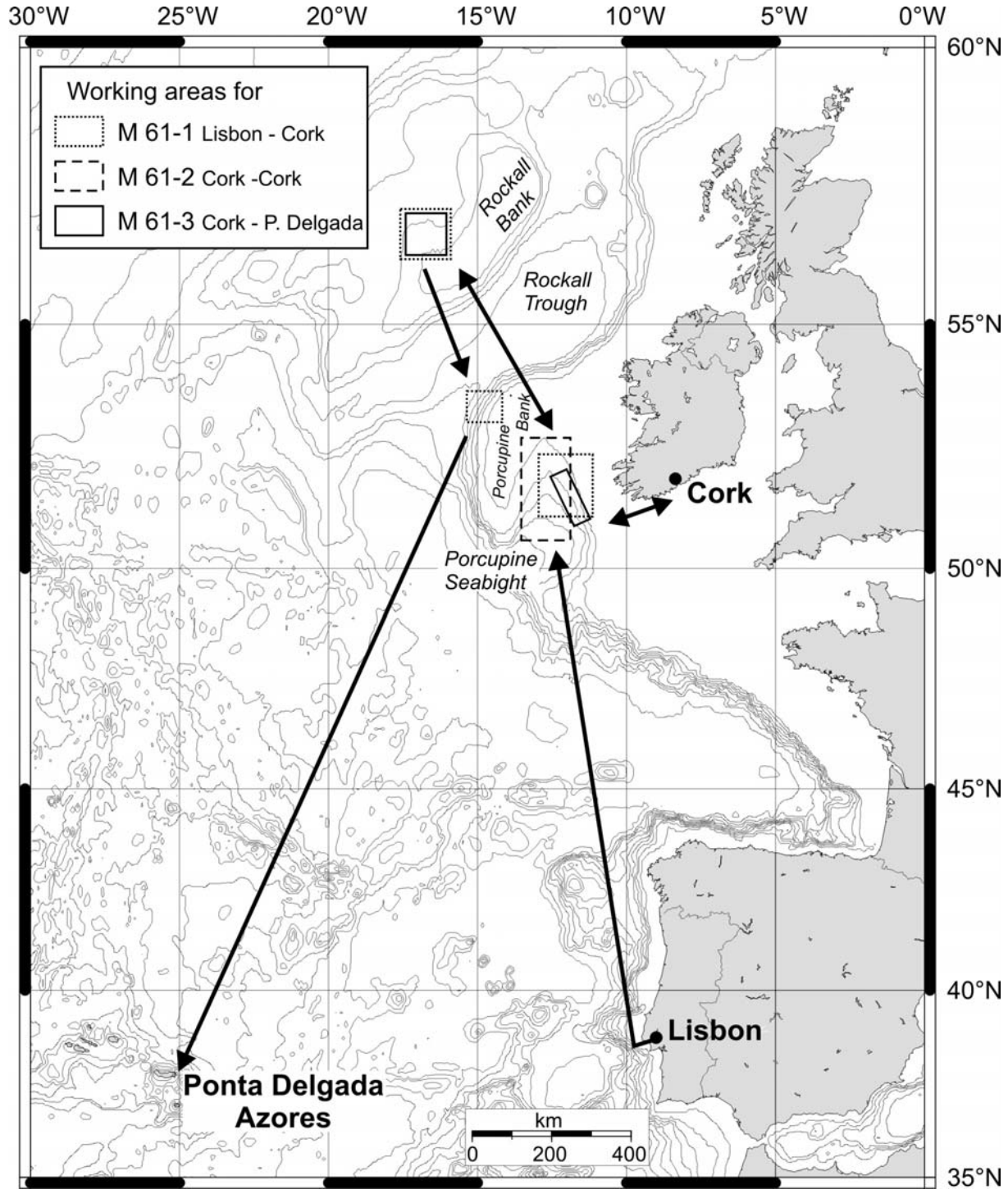

Fig. 1: Working areas of the individual legs of R/V METEOR cruise 61

We are just at the beginning to understand the functional role and the dynamics of the key species. Most intense occurrences are concentrated in areas where a complex seabed topography such as banks, ridges, seamounts, canyon systems and fjords exert a physical control on the deep current flow such as by the generation of topographically-guided filaments, current acceleration and density-driven convection. In this respect, the coral ecosystem acts as a benthic recorder of ocean circulation, nutrition and carbon flow. The distribution of deep-water coral/ carbonate

mound ecosystems at the Irish Atlantic frontier is applied to understand the structure, functioning and dynamics under the particular trophic system of the NADR (North Atlantic Drift)

The trophic state of the upper mixed ocean layer is seasonally eutrophic with significantly pulsed particle exports from the upper mixed layer in late spring and early autumn. Main questions addressed were: What is the influence of the NADR biogeochemical conditions on the biodiversity, functioning and dynamics of the coral/carbonate mound ecosystem thriving under this trophic situation at present and in the past? Global change and the reaction of marine ecosystems were addressed by investigating the change of biodiversity which occurred in deep-water coral ecosystems during the last glacial-interglacial cycle. While the now vigorously growing coral reefs in Scandinavian waters started to develop in a formerly glaciated environment just at the end of the Termination IB, the geological history of the coral-capped carbonate mounds off Ireland probably extends back over the past 2 Million years.

Coral-covered carbonate mounds of the Belgica Mound Province (BMP), north-eastern Porcupine Seabight and an unexplored area of the south-west Rockall Bank were the main targets of M61-1. The BMP consists of about 25 exposed and 20 buried carbonate mounds that structure the continental margin in a confined depth limit between 600 and 900 m. Exposed mounds arise 50 to 200m above the adjacent seabed, thus forming topographic obstacles in the local current regime. While the shallower mounds are covered by Early Holocene coral debris, flourishing coral ecosystems thrive along the summits and flanks of the deeper exposed mounds. Here dense thickets of colonial coral frameworks, produced by *L. pertusa*, *M. oculata*, and locally by stylasterids provide a complex 3-dimensional habitat for a species rich community of benthic and demersal organisms. According to geophysical interpretation of seismic data, mound growth begun in the Late Pliocene and was influenced by global change, i.e. the peaked Northern Hemisphere glacial-interglacial cycles.

M61/2: Changes in Structure of the Earth's Crust Associated With Progressive Extension of the Porcupine Rift Basin

The Porcupine Basin west of Ireland provides a natural laboratory for the study of extensional processes of the Earth's crust. First, due to the small extent of this rift basin, both sides of the basin can be investigated, allowing questions about the symmetry of the rifting process to be addressed by a sequence of east-west transects parallel to the direction of extension. Second, the axial stretching factor increases from north to south, so that a series of east-west cross-sections reveal the crustal structure at different stages of rifting. The spatial variation between these sections thus represents the temporal evolution of a rift with increasing amounts of extension.
The general aims of the project are thus:

- Determination of changes in crustal structure associated with progressive extension from a rift basin.
- Determination of the symmetry of the extension process by determining the crustal structure on both sides of the basin.

To achieve these general aims, the investigations during M61-2 concentrated on the following tasks:

(1) Determination of the crustal thickness and as a result of the actual stretching factor. Until now the stretching factor has only been estimated from subsidence patterns. However, additions of material with crustal density (e.g. intrusions or mantle serpentinisation) during extension

would mean that subsidence only gives a minimum estimate of the amount of extension. By determining the detailed structure of the crust, the true stretching factor can be determined and so refine models of the development of the Porcupine Basin.

(2) Determination at which stretching factor (if at all) voluminous magmatic intrusions (melting through pressure reduction) and/or serpentinisation of the mantle take place. This will allow existing models of melting and of mantle serpentinisation to be tested.

(3) Investigation of the P deep crustal reflection beneath the centre of the basin. P may be a detachment fault, but as it is represented by a strong reflection it also can represent a major seismic discontinuity of the same form.

(4) Investigation of the Porcupine Median Volcanic Ridge (PMVR) along the middle of the basin. It is quite possible that this structure is not magmatic in origin but rather is composed of serpentinites characterised by low seismic velocities. The nature of this ridge has important consequences for the tectonic evolution of the basin.

M61/3: Development of Carbonate Mounds on the Celtic Continental Margin

In the past years, the EU-projects ECOMOUND, GEOMOUND and ACES have revealed many new results concerning the large carbonate mound provinces at the NW-European continental margin. Through this it has been made clear that particular external environmental factors have a significant influence on the latest development of the mounds and on the cold water corals living on top of them. However, the investigation of the mound surfaces and their uppermost layers is still in its early days. There are many open questions that are dealt with in the scope of the ESF-EUROMARGINS project MOUNDFORCE. These are for example, which environmental factors are of definitive importance for the distribution of the corals, how the corals are distributed on individual carbonate mounds, how does the mound fauna develop under changing environmental conditions and, what stabilizes the steep flanks of the carbonate mounds.

The variable appearance of carbonate mounds in the individual mound provinces is an indication of varying cause-and-effect relationships. In order to study these various relationships, carbonate mounds from different provinces have been examined in the frame of the M61-3 cruise. For this reason four working areas have been investigated during leg M61-3: (1) the Galway Mound in the Belgica Mound Province, eastern Porcupine Seabight, (2) the Propeller Mound in the Hovland Mound Province, northern Porcupine Seabight, (3) the western Rockall Bank area, and (4) the northern Porcupine Bank area.

The work done concentrated on three major scientific questions:

Which factors control the development of the carbonate mounds?

Possible limiting environmental factors which are to be considered focus on the specific characteristics of the different water masses, as e.g. temperature, salinity and oxygen concentration, the structure of the water column (e.g. the development of a pycnocline), water-mass movements (currents, internal tides), and, of course, the food sources available for the corals. An important aspect here is the distribution of living corals on the carbonate mounds in relation to these parameters.

The main task during M61-3 regarding this thematic complex was the successful recovery of seven sensor packages (current meter, CTD) using the Bremen QUEST ROV. The sensor packages have been deployed on Galway Mound in 2003. These packages recorded detailed data

on the flow field around the particular mound. The data have been supplemented by CTD casts through the water column. A possible correlation between the flow field and the distribution of corals should be investigated by a detailed distribution analysis of the corals on the mounds using video transects obtained with the ROV. As a base for the reconstruction of paleo-flow fields, surface sediments have been collected with a box corer in order to correlate the grain size distribution in the surface sediments with the recent flow field. Based on such a groundtruthing, grain size distributions of older sediments can be used as proxy for paleo current intensities.

How do the associated faunas on the carbonate mounds develop under changing environmental conditions?

Videofootage from carbonate mounds reports highly diverse faunas of corals, sponges, crinoids and numerous other organism groups. Among these organisms the framework building coral *L. pertusa* takes a dominant role with regard to mound development. Long-term changes of these benthic ecosystems (e.g. the last glacial/interglacial change) are indicated by first data from glacial sediment sequences from the Celtic continental margin which probably lack any *L. pertusa*. On the base of sediment cores collected earlier from Propeller Mound investigated in Bremen, a model for the mound development has been established that describes the mound evolution from interstadial to glacial to interglacial stages. To what extend this model, developed for one particular mound, can be extrapolated to other structures in the Porcupine Seabight (e.g. Galway Mound) or to other areas of the Celtic Continental margin (e.g. Western Rockall Bank) is unknown at the moment. To answer this question, during M61-3 several gravity cores have been collected from different carbonate mounds.

What are the dominant stabilisation and lithification processes at the carbonate mounds?

The steep slopes of the carbonate mounds, often exceeding inclinations of 10%, raise the question if solely the incorporation of corals in the sediments is sufficient to stabilise the mostly fine-grained hemipelagic mud. During M61-3 some steep slope segments have been sampled with the QUEST ROV in order to tackle this question. In addition there is a great interest to investigate carbonate crusts and hard grounds, as those are probably also closely related to the growth history of the carbonate mounds. Also such carbonate crusts and hardgrounds have been successfully sampled with the ROV.

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