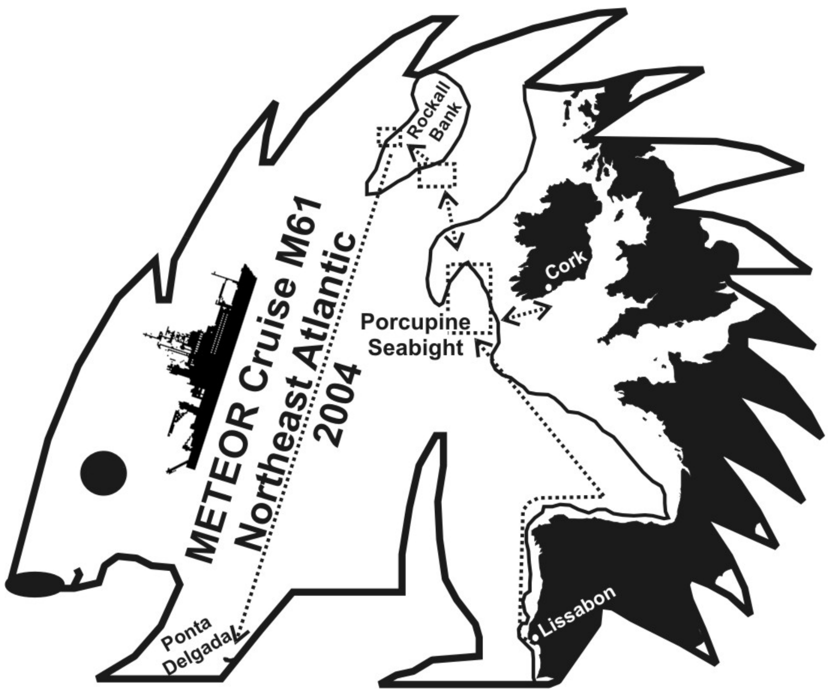
METEOR-Berichte

Northeast Atlantic 2004

Cruise No. M61

April 19 to June 6, 2004,
Lisbon (Portugal) – Ponta Delgada (Azores)



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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.

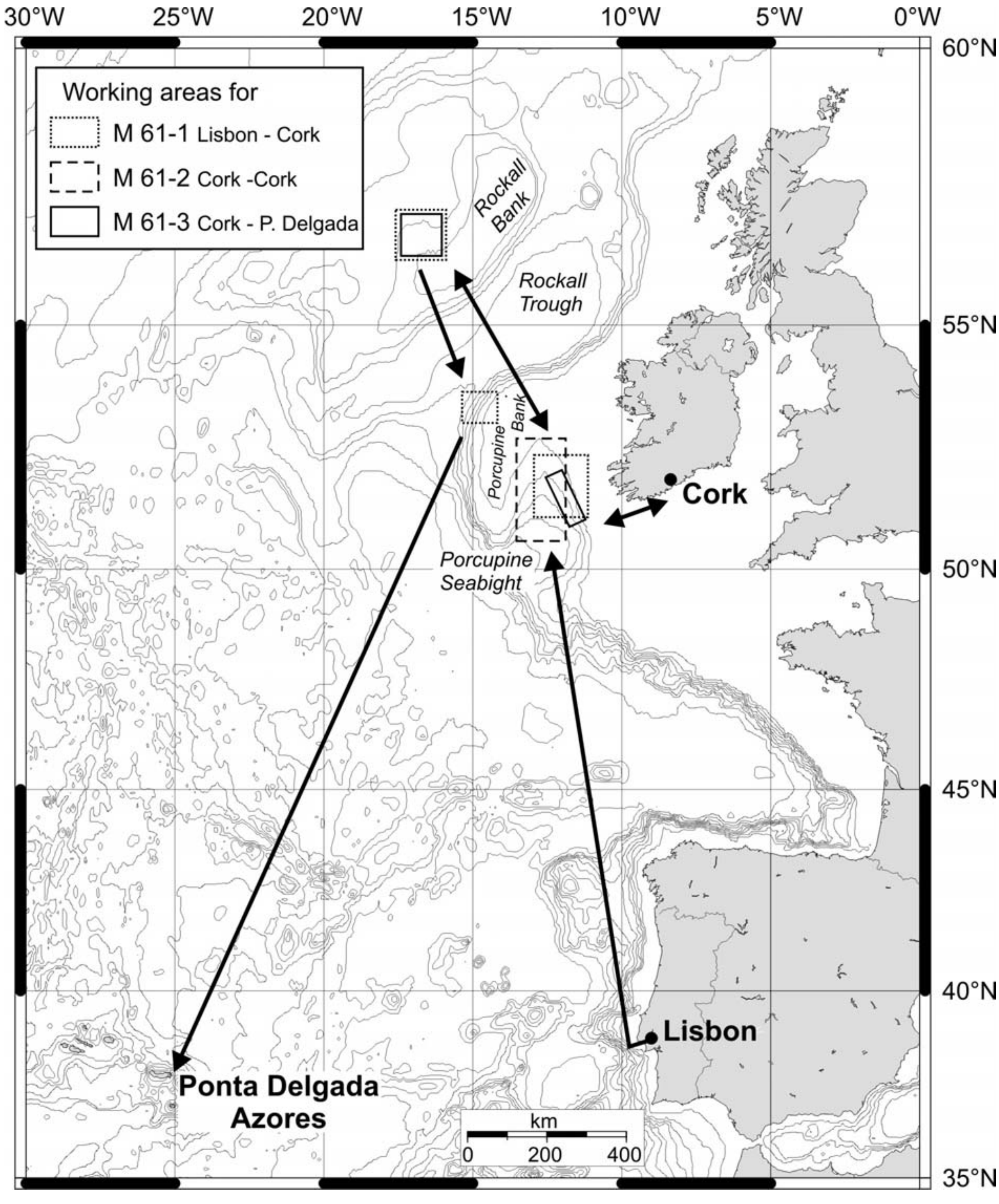


Fig. 1: Working areas of the individual legs of R/V METEOR cruise 61

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.

Acknowledgements

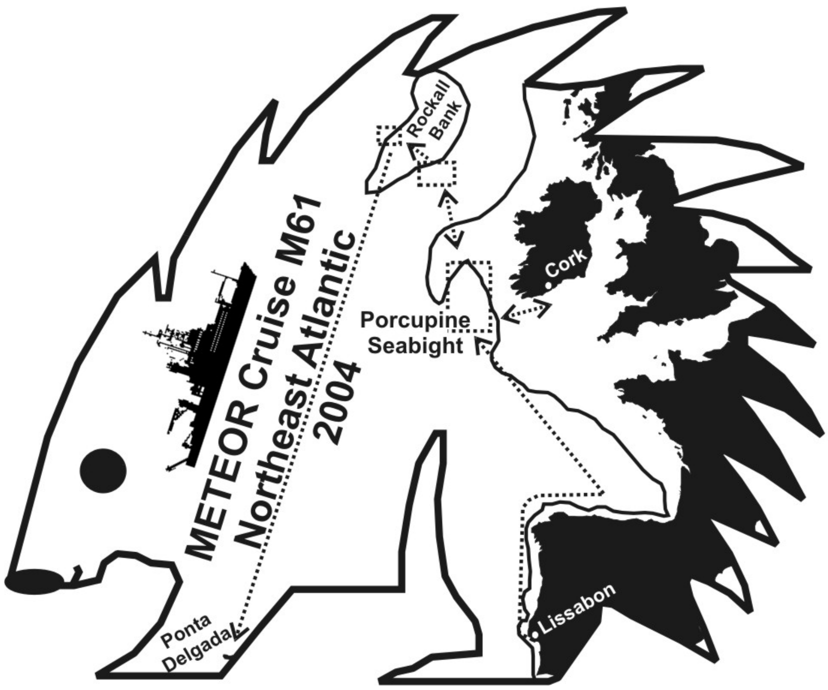
We gratefully acknowledge the friendly and professional cooperation and efficient technical assistance of Captain N. Jakobi, his officers and crew, who substantially contributed to the overall scientific success of R/V METEOR cruise No. 61. We benefited greatly from the support provided by our colleagues from the Geological Survey of Ireland, who made substantial bathymetric and side scan sonar information accessible for us. We also appreciate the most valuable help of the Leitstelle METEOR in Hamburg. The work done was funded by the Deutsche Forschungsgemeinschaft.

METEOR-Berichte 06-2

Northeast Atlantic 2004

Cruise No. 61, Leg 1

April 19 to May 4, 2004, Lisbon – Cork



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

Pfannkuche O., Bannert, B., Beck, T., Beuck, L., Dullo, W.-C., Flögel, S., Freiwald, A., Gass, S., Gektidis, M., Heger, A., Jamieson, A., Kavanagh, F., King, N., Kuhanec, B., Linke, P., Martin, B., Neulinger, S., Noe, S., Queisser, W., Rüggeberg, A., Ruseler, S., Schiemer, I., Schmidt, S., Schönfeld, J., Taviani, M., Türk, M., Vertino, A., Wigham, B.

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1.1 Participants

Tab. 1.1 List of Participants on Leg M61-1 and Abbreviations

	Name	Discipline	Institute
1.	Pfannkuche, Olaf, Dr.	chief scientist, seafloor observation	IFM-GEOMAR
2.	Bannert, Bernhard	video techniques	Oktopus
3.	Beck, Tim	benthic ecology	IPAL
4.	Beuck, Lydia	image analysis	IPAL
5.	Dullo, Wolf-Christian, Prof. Dr.	paleo-oceanography	IFM-GEOMAR
6.	Flögel, Sascha, Dr.	hydrography	IFM-GEOMAR
7.	Freiwald, Andre, Prof. Dr.	paleo-oceanography	IPAL
8.	Gass, Susan	benthic ecology	SAMS
9.	Gektidis, Marcos, Dr.	scientif. docum./publ. outreach	IPAL
10.	Heger, Amy	sea floor observatories	OceanLab
11.	Jamieson, Alan, Dr.	seafloor observatories	OceanLab
12.	Kavanagh, Fiona	benthic taxonomy	NUIG
13.	King, Nicola	sea floor observatories	OceanLab
14.	Kuhanec, Bettina	scientif. docum./publ. outreach	IPAL
15.	Linke, Peter, Dr.	seafloor observatories	IFM-GEOMAR
16.	Martin, Bettina, Dr.	planktology	IHF
17.	Neulinger, Sven	microbiology	IFM_GEOMAR
18.	Noe, Sybille, Dr.	paleo-oceanography	IFM-GEOMAR
19.	Queisser, Wolfgang	gear technology	IFM-GEOMAR
20.	Rüggeberg, Andres Dr.	paleo-oceanography	IFM-GEOMAR
21.	Ruseler, Silke	planktology	IHF
22.	Schiemer, Isabell	student paleo-oceanography	IPAL
23.	Schmidt, Steffi	paleo-oceanography	IFM-GEOMAR
24.	Schönfeld, Joachim, Dr.	paleo-oceanography	IFM-GEOMAR
25.	Taviani, Marco, Dr.	paleontology	Uni Bologna
26.	Türk, Mathias	electronics	IFM-GEOMAR
27.	Vertino, Agostina, Dr.	benthic taxonomy	IPAL
28.	Wigham, Ben, Dr.	sea floor observatories	OceanLab

Participating Institutions

IFM-GEOMAR:	Leibniz-Institut für Meereswissenschaften, an der Univ. Kiel, Germany
IHF	Inst. für Hydrobiologie und Fischereiwissenschaft, Univ. Hamburg, Germany
IPAL	Institut für Paläontologie, Univ. Erlangen, Germany
OceanLab	Ocean Laboratory, Univ. of Aberdeen, Newburgh, UK
Oktopus	Oktopus GmbH, Hohenweststedt, Kiel, Germany
SAMS:	Scottish Association for Marine Sciences, Oban, UK
NUIG	National Univ. of Ireland Galway, Martin Ryan Institute, Galway, Irleland
Uni Bologna	Univ. Bologna

1.2 Research Program

The following objectives were addressed during M61-1:

- Water mass distribution and characteristics in the carbonate mound province

Carbonate mounds occur in a dynamic slope environment impacted by a strong tidal-driven hydrodynamic regime. CTD measurements during cruise M61-1 determined the small scale spatial variability of water masses in the carbonate mound and deep water coral realm. A series of high-resolution CTD profiles across Galway Mound and Thérèse Mound (Belgica Mound Province - BMP) and across Kiel Mount (Rockall Bank) has been carried out. Water close to the seafloor, was sampled with the Rosette water sampler combined with the CTD to study stable isotope composition in the benthic boundary layer,

- Longterm benthic boundary layer (BBL) processes in a living coral environment.

A long-term observatory (GEOMAR Modular Lander) instrumented by IFM-GEOMAR and SAMS was deployed on Galway Mound until mid of August (recovery Poseidon Cruise 316) to monitor the near seabed current-, CTD-regime and particle dynamics in a living coral ecosystem and to take time lapse stereo-photos of benthic activity (IFM-GEOMAR). SAMS estimated near-bed particle dynamics by integrating optical instruments and a data logger into the GEOMAR lander

- Short term sea floor observations of BBL processes

The work of the OceanLab group focused around the use of the ISIT camera that has been mounted on another GEOMAR Modular Lander. The ISIT lander used a very sensitive ISIT camera (rated to 6000m) to record bioluminescence events. Another scientific objective was to deploy the bait carrying Oceanlab ROBIO lander to get some time-lapse still images of the nekton and megabenthos community associated with *Lophelia*.

- Zooplankton distribution at carbonate mounds

Planktological studies dealt with the question if deep-water corals, which are potential predators for zooplankton, may have a direct impact on the composition and abundance of zooplankton. The study focused on the vertical distribution of meso-zooplankton over the carbonate mounds and outside their influence. Two layers were of special interest: the deep scattering layer with its vertically migrating organisms, and the near-bottom layer, which is of great importance for exchange processes between the water column and the sea floor.

- Mapping of biological habitats and sedimentary facies

Selected mounds were mapped with OFOS (Ocean floor observation system) to detect patterns of biological zones and sedimentary features, megafauna distribution and human impact to the coral ecosystem through ongoing trawling activities. The already existing ROV (Remotely Operated Vehicle) documentations of previous cruises showed that each mound province exhibits specific habitat patterns so that unifying models explaining ecological functioning of corals and mound formation are not yet conclusive. The OFOS systems provided substantial new data to understand the site-specific patterns such as diverse colonization patterns predominantly by a comparison between thriving coral mounds vs. dying coral mounds using statistical image analysis of underwater video documentations. Sediment samples collected will contribute to the identification of species richness and their role within the ecosystem.

- Paleo-environmental reconstruction of carbonate mounds

So far, few data exist that help to understand the ancient history of carbonate mounds and their biota. Box- and gravity coring on selected mounds and off-mound areas was carried out to analyse the role of corals in mound formation and the general understanding of deposited sedimentary sequences and their accumulation rates during the glacial-interglacial transition. Recent discoveries of cemented carbonate strata or crusts answered why the often steep-inclined slopes of the mound do not collapse or become eroded with time. Despite the ambient cool water and great depths, precipitation of carbonate crusts or hard grounds is a common process even in the NE-Atlantic, but the questions of what drives carbonate diagenesis and when does it happen are still unresolved. So far, only few hard ground samples exist because of inadequate sampling gear. On M61-1 the operation of the hydraulic TV-grab provided the unique opportunity to collect carbonate hard grounds and crusts.

1.3 Narrative of the cruise

Sunday 18.4. 2004 - The vanguard of the scientific party boarded R/V METEOR at 9.00h and started with the unloading of three containers. The main scientific party arrived in the course of the afternoon. The rest of day was spent with the distribution of equipment to the laboratories and with technical installations of sampling gear.
Monday 19.4.2004 - R/V METEOR left Lisbon harbour at 10.30h with a group of 28 scientists. From the mouth of the Tejo River we took a northern course along the west coast of the Iberian Peninsula. We encountered a heavy swell of appr. 8 m from the North West. The day was spent with the preparation of the laboratories, the construction of sampling gear and a plenary scientific meeting. Weather conditions remained unchanged.
Tuesday 20.4.2004 - In the evening, we reached the Cap Finistere region and started our crossing of the Bay of Biscay. Gear preparations especially the rigging of the lander systems continued.
Wednesday 21.4.2004 - We continued our crossing of the Bay of Biscay. The swell changed the direction to west and caused an unpleasant rolling of the ship. Gear preparation continued.
Thursday 22.4.2004 - We arrived at our first station at 51° 10´N, 11° 40´W in the southern Belgica Mound province in the afternoon. Station work started with the deployment of the ROBIO Lander (Stat. 202). After the test drive of a few winches to test a new EPROM we left the locality and steamed 17nm to the north to survey two mounds west and southeast of Therese Mound with the OFOS system (Stat. 203-204). So far, both mounds had not been investigated. We named them Castor and Pollux Mounds. Both were covered by rich thickets of corals. We started the night with a highly resolved longitudinal CTD/Ro transect across Galway and Little Galway Mound (Stat205-214).
Friday 23.4.2004 - We finished the longitudinal CTD/Ro transect in the morning. Next was a series of Van Veen Grab casts (Stat. 215-218) in the vicinity of the Therese Mound including the Castor and Pollux Mounds. The early afternoon was spent with the deployment of the BCL-Lander on Galway Mound (Stat. 219). Afterwards R/V METEOR headed south to the ROBIO-deployment site (Stat. 220). The lander was successfully recovered and had worked well. We then steamed back to the area south of Galway Mound to sample sediments with a box grab (Stat.221-226).
Saturday 24.4.2004 - Box grab sampling ended in the morning and was followed by a highly resolved latitudinal CTD/Ro transect across Galway Mound (Stat. 227-233). The first MOCNESS net was towed across Galway Mound in the afternoon (Stat. 234). Unfortunately, one of the nets touched the bottom of the mound plateau but retrieved a rich collection from a coral thicket envi-

ronment. In the late afternoon we retrieved the BC-Lander (Stat. 235). The rest of the day and part of the following night was again dedicated to two MOCNESS transects (Stat.236-237).

Sunday 25.4.2004 - Another series of 6 van Veen grabs was taken north and east of Galway Mound (Stat. 238-243) followed by another MOCNESS haul (Stat. 244). In the afternoon we deployed the DOS-lander (Stat. 245) instrumented with a wide range of equipment and experimental trays on the top plateau of Galway Mound. This lander was moored for 110 days and will be retrieved with R/V POSEIDON around 10.8.2004. Next came another deployment of the ROBIO Lander (Stat. 246) west of Galway Mound. The rest of the day was spent with two OFOS transects across an hitherto unexplored mound at 51°29N, 11° 42,30´W´ which was named Erik Mound and at an escarpment along the 660m contour further to the south (Stat. 247-248).

Monday 26.4.2004 - The night until mid morning was dedicated to another CTD/Ro survey (Stat. 249-256). Next we deployed the BC-Lander (Stat. 257) and retrieved the ROBIO lander (Stat. 258). A CTD in the afternoon had to be cancelled for technical reasons and was replaced by a van Veen grab reference sample at the DOS deployment site (Stat. 259). The TV-grab was employed on the escarpment surveyed the day before to retrieve exposed carbonates (Stat. 260). Although the gear fell over during sampling procedure we were able to sample sufficient material. Two MOCNESS transects were driven during the late evening and the first half of the night (Stat. 262-262).

Tuesday 27.4.2004 - The second half of the night and the early morning was spent with van Veen grab sampling (Stat. 263-266) followed by two MOCNESS hauls until early afternoon (Stat. 267-268). In the course of the afternoon and early evening we retrieved the BC-Lander (Stat. 269) and succeeded to retrieve two 2.70m and 4.05m long gravity cores on Pollux Mound (Stat. 270-271). The night was spent with a box grab sampling survey with 6 successful deployments (Stat. 272-277).

Wednesday 28.4.2004 - The early morning was spent with another CTD/Ro survey (278-280). We then switched over to gravity coring which gained a successful core of 5.12 m and one empty core (Stat. 281-282). After a successful multiple corer haul and a final CTD/Ro cast (Stat. 283) we finished our station work at the Belgica Mound Province in the afternoon and headed in north-west direction towards the second working area at the south-western flank of the vast Rockall Bank.

Thursday 29.4.2004 - We continued our steaming to the Rockall area. Strong head winds reduced our cruising speed significantly to about 7-8kn.

Friday 30.4.2004 - We arrived at our second working area at 56° 40´N, 17° 34´W in the morning. First target was a volcanic structure that pierced through the gently dipping margin of the Rockall Bank. After a mapping survey with HYDROSWEEP (Stat. 284) and the deployment of the BC-Lander and the ROBIO-lander (Stat. 285-286) we selected two transects for the OFOS across the newly chartered mount (Stat. 287-288). The rough summit of the volcanic structure, that we call now "**Kiel Mount**", was covered by mostly fossil coral thickets. We documented a number of lithified carbonate sediments or hardgrounds. Larger drop stones were colonised by huge sea fans or black corals. The mid-slope of Kiel Mount is patchily plastered with carbonate crusts that show prominent dissolution features and often are out washed beneath the crust. Sediment filled dissolution cracks were abundantly inhabited by sea pens.

Saturday 1.5.2004 - We spent the night with two highly resolved CTD/Ro transects across Kiel Mount (Stat. 289-297). The BC-Lander and the ROBIO-lander were retrieved in the morning

(Stat298-299). This was followed by TV-grab sampling of carbonate crusts on top of Kiel Mount (Stat.300-301). The afternoon was dedicated to another multibeam survey further upslope south-east of Kiel Mount (Stat. 302). The survey revealed a multitude of interesting features. Because of the limited time, we could only survey one area with the OFOS (Stat. 303) until mid night. This site was dominated by an elongated carbonate mound, which was partly covered with dense *Lophelia pertusa* thickets that were hitherto not reported for the western part of Rockall Bank. The new mound was named "**Franken Mound**".

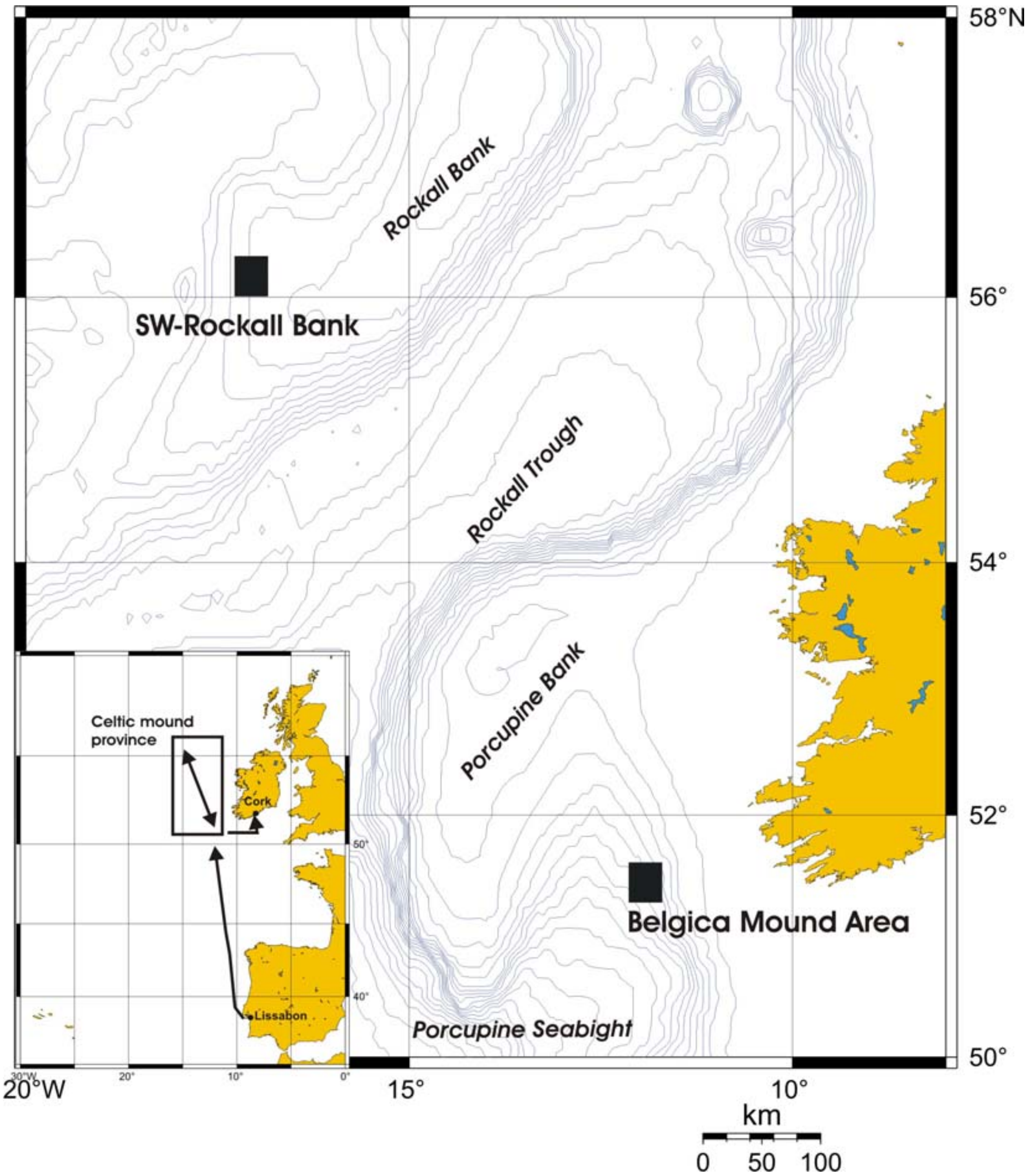


Fig. 1.1: Cruise tracks and working areas of Leg M61-1

Sunday 2.5.2004 - The rest of the night was dedicated to first bottom sampling in the newly surveyed sites. A series of van Veen grabs were deployed on Kiel Mount (Stat. 304-309). This was followed by box grab sampling and a gravity corer cast (Stat. 310-313). A CTD/Ro follwed at the Franken Mound (Stat. 314). The rest of the day was spent with van Veen grab sampling on Franken Mound, which was only of moderate success since the weather conditions quickly deteriorated from mid-day on reaching Beaufort 8. We left the station shortly before midnight and steamed back to the Porcupine Seabight area.

Monday 3.5.2004 - We continued our transit with strong gale (Beaufort 8-9) from northwest. A planned Station on Porcupine Bank had to be cancelled because of the rough sea state, which prevented gear deployments. We therefore continued our passage to Cork.

Tuesday 4.5.2004 - We continued our transit. In the meantime, winds had increased to 10 Beaufort with gusts of 12 Beaufort. In the evening R/V METEOR docked at the container dock of Cork Harbour thus finished our journey.

1.4 Preliminary Results

1.4.1 High Resolution Physical Oceanography in Relation to Mound Topography

(Dullo, W.-C., Flögel, S. and Rüggeberg, A.)

The major objective of CTD measurements during cruise M61-1 was to determine the small scale spatial variability of water masses around the carbonate mounds and deep water corals. Therefore, we conducted several series of high-resolution CTD profiles across Galway Mound and Thérèse Mound (BMP) and across Kiel Mount west of the Rockall Bank.

Another objective was to study the stable isotope composition of dissolved inorganic carbon in the water close to the seafloor, on which the benthic organisms partly rely when building their skeletons. The stable isotope composition of the bottom water will be used to calibrate temperature reconstructions using the isotope composition of the aragonite skeletons of living *Lophelia pertusa* specimens, collected within the close neighbourhood of the CTD/Ro deployments.

The Conductivity-Temperature-Depth (CTD) profiler used for investigations of the water column was a Seabird “SBE 9 plus” underwater unit and a Seabird “SBE 11 plus” deck unit. Additionally, it was equipped with a dissolved oxygen sensor and a Seabird bottle release unit including a rosette water sampler with 10l Niskin bottles. For the analysis and interpretation of the measurements, the downcast raw data were processed with “SBE Data Processing” software. For the visualisation of the data we used “Ocean Data View (mp-Version 2.0)”. The system operated reliably with the exception of station #314 where we encountered some problems with the bottle release unit and the data transfer cable onboard R/V METEOR which resulted in the loss of CTD-data below 320 m at this station due to a storage error.

A total of 40 CTD profiles has been measured in the Belgica Mound Province (Fig. 1.2–1.5) and at the western margin of Rockall Plateau (Fig. 1.6–1.8). Bottom water samples have been taken at all locations and continuous sampling throughout the water column was performed at three locations (Station #233, #283/2, #294/2).

The waters above the investigated mounds were sampled as closely as possible. We-operated seventeen CTD’s across Galway Mound (N-S and E-W transects), eight CTD’s across Thérèse Mound (N-S transect) and nine CTD’s across Kiel Mount (N-S and E-W transects). In addition, three CTD profiles (#278, #279, #280/1-2) were measured for microbiological studies (S. Neulinger), including bottom water samples for molecular biological analysis.

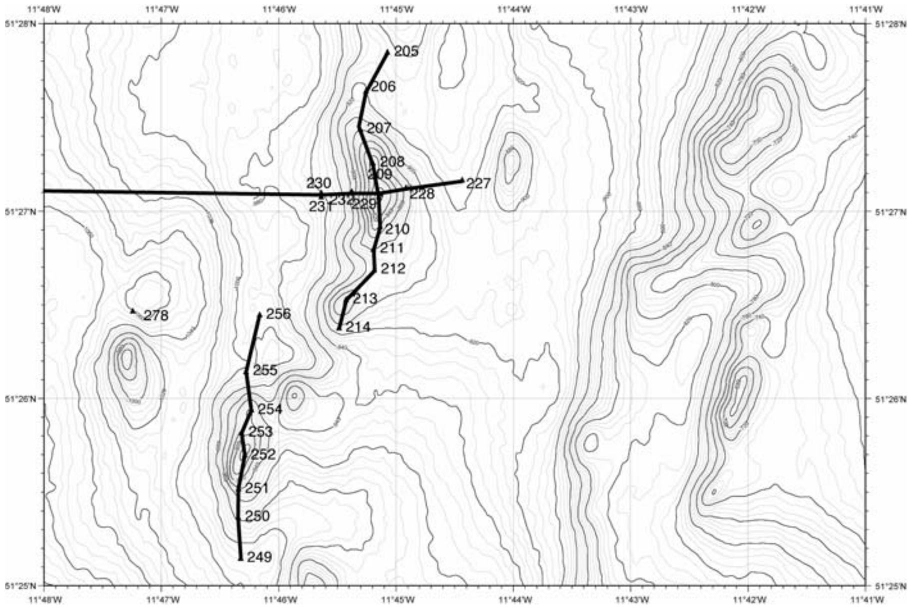


Fig. 1.2: Station map of CTD measurements in the Belgica Mound Province, SE Porcupine Seabight. Indicated are WE-, NS-transects across Galway Mound and NS-transect across Thérèse Mound (see Fig. 1.2 and 1.3).

Belgica Mound Province

The distribution of water masses is si-milar in all profiles. Temperature, sali-nity and dissolved oxygen show maxi-mum values at the surface and decrease continuously with depth (Figs. 1.3 and 1.4). A warm surface layer of 40 to 50 m depth was not established in April and May 2004 as compared to August results of R/V POSEIDON cruise 265**.** The near-surface temperature differen-ce between spring (M61-1) and sum-mer (POS 265) amounts on average 5°C. At around 650 m water depth, the oxygen content decreases rapidly to a minimum value at 1000 m, while salinity increases by 0.2 PSU.

Fig. 1.5 shows the N/S-relation of selected profiles typical for this area. The North Atlantic Central Water (NACW) exhibited a linear, uniform distribution down to a salinity mini-mum at around 700 m. The influence of the Mediterranean Outflow Water (MOW) is depicted in the slight salinity increase with maximum values of 35.6 ‰ at 1000 m water depth. This water mass is less characteristic in temperature, but shows a low oxygen content of 3.7 ml/l.

The arrangement of the CTD pro-files followed the almost S-N oriented current regime and perpendicular to it (Fig. 1.3 and 1.4). The E-W temperature profiles show a clear differentiation in a downslope and up-slope orientation (Fig. 1.3). The mounds obviously form a barrier which obstructs a mixing of the upslope and downslope bottom waters. A distinct pattern emerges in the distribution of dissolved oxygen in the bottom waters. The oxygen content between 850 and 950 m depth is higher by 0.1 to 0.2 ml/l to the north of Galway Mound than south of it. The N-S oxygen difference is considered as a significant feature. Such difference is not seen on the perpendicular E-W transect. If the effective bottom water flow is in southward direction, this pattern seems to reveal enhanced oxygen consumption at or around the top of Galway Mound. The conclusion is corroborated by the high density of the deep-water corals on top of Galway Mound that may effect locally enhanced oxygen consumption. A similar pattern is not recognized around Thérèse Mound, however.

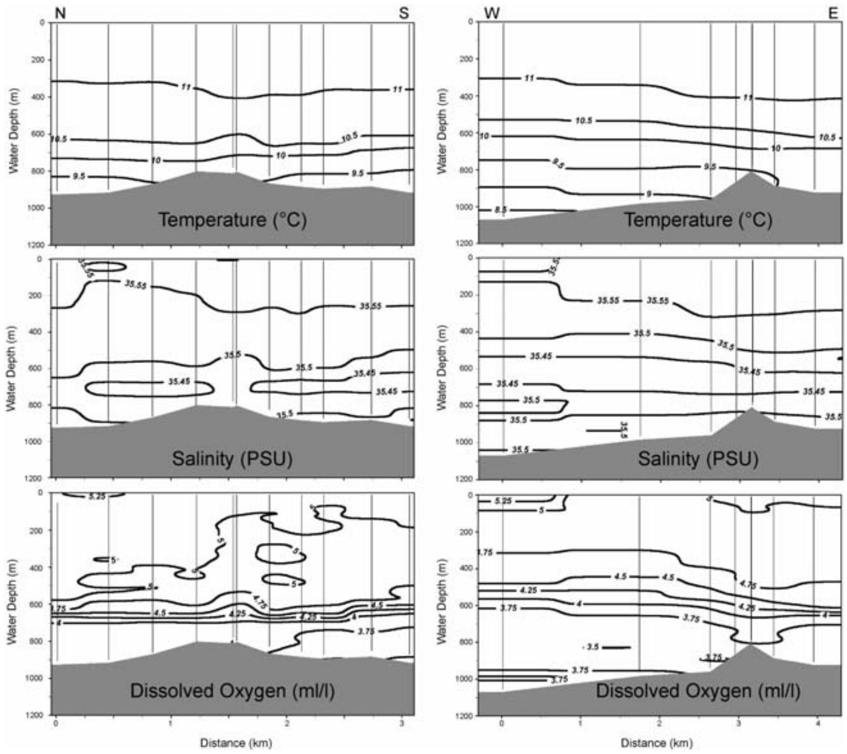


Fig. 1.3: EW- and NS-profiles of temperature, salinity and dissolved oxygen across Galway Mound (see transect in figure 1). MOW appears below 700 m water depth as indicated by increasing salinity and decreasing oxygen content, influencing the coral ecosystem on top of the mound.

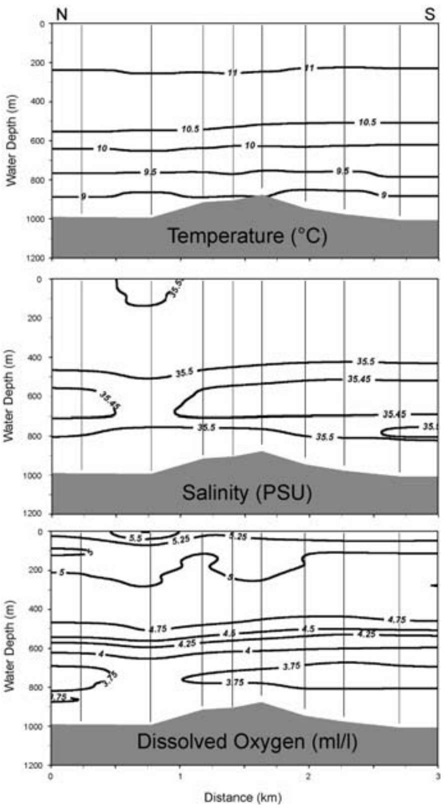


Fig. 1.4: NS-profiles of temperature, salinity and dissolved oxygen across Thérèse Mound (see transect in Fig. 1.2).

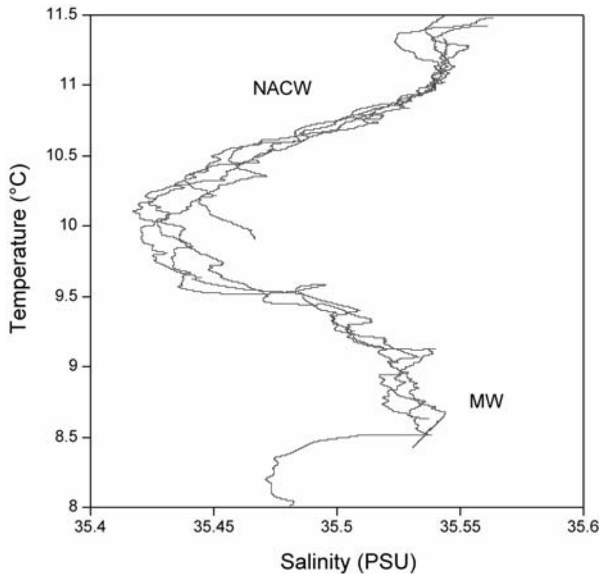


Fig. 1.5: TS-plot of selected profiles typical for the Belgica Mound Province.

W Rockall Bank

Two transects with 9 profiles were recorded west of Rockall Bank; one transect running N-S, the other in E-W direction across Kiel Mount (Fig. 1.6). The profiles of temperature, salinity and dissolved oxygen show a different distribution compared to the Belgica Mound Area. All parameters have maximum values at the surface and decrease continuously with increasing depth (Fig. 1.7). An increase in salinity is not well pronounced in water depths below 800 m suggesting an insignificant MOW advection to this area. However, the dissolved oxygen shows minimum values of 4.35 ml/l around 800 m water depth.

Figure 1.8 shows the T/S-relation of a selected profile typical for this area. The NACW exhibited a uniform distribution down to a salinity minimum at around 700 m. An influence of the MOW, if at all, is suggested in the slight increase of the salinity (35.6 units) and the oxygen minimum between 800 and 1000 m water depth.

All parameters along the E-W transect show a well-stratified water mass. Only dissolved oxygen increases below 1000 m water depth similar to the situation in the Belgica Mound Province. The N-S running oxygen section depicts much lower values south of Kiel Mount (4.15 ml/l) than in the north of the mount (4.75 ml/l). Again, such difference is not seen on the perpendicular, E-W transect (Fig. 1.7). High oxygen contents at 1200 m water depths at the northern and western foot of Kiel Mount indicate together with the OFOS-observation of current ripples on the sea floor the advection of well-ventilated Norwegian Sea Overflow Water from the North. Therefore, the N-S oxygenation difference points to substantial oxygen consumption on the southern rise of Kiel Mount. Whether this pattern is due to enhanced respiration of a denser coral thicket on the leeward side, or simply reflects a quiet zone of sluggish circulation behind Kiel Mount needs to be further investigated.

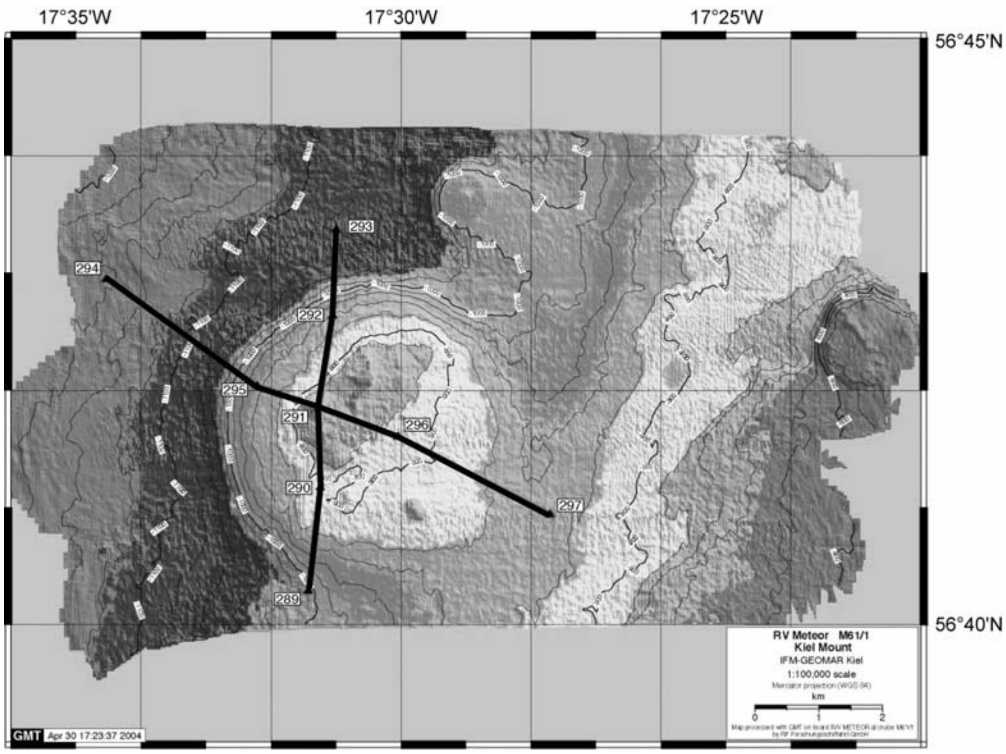


Fig. 1.6: Station map of CTD measurements at the western margin of Rockall Plateau. Indicated are WE- and NS-transects across Kiel Mount (see Fig. 1.7 and 1.8).

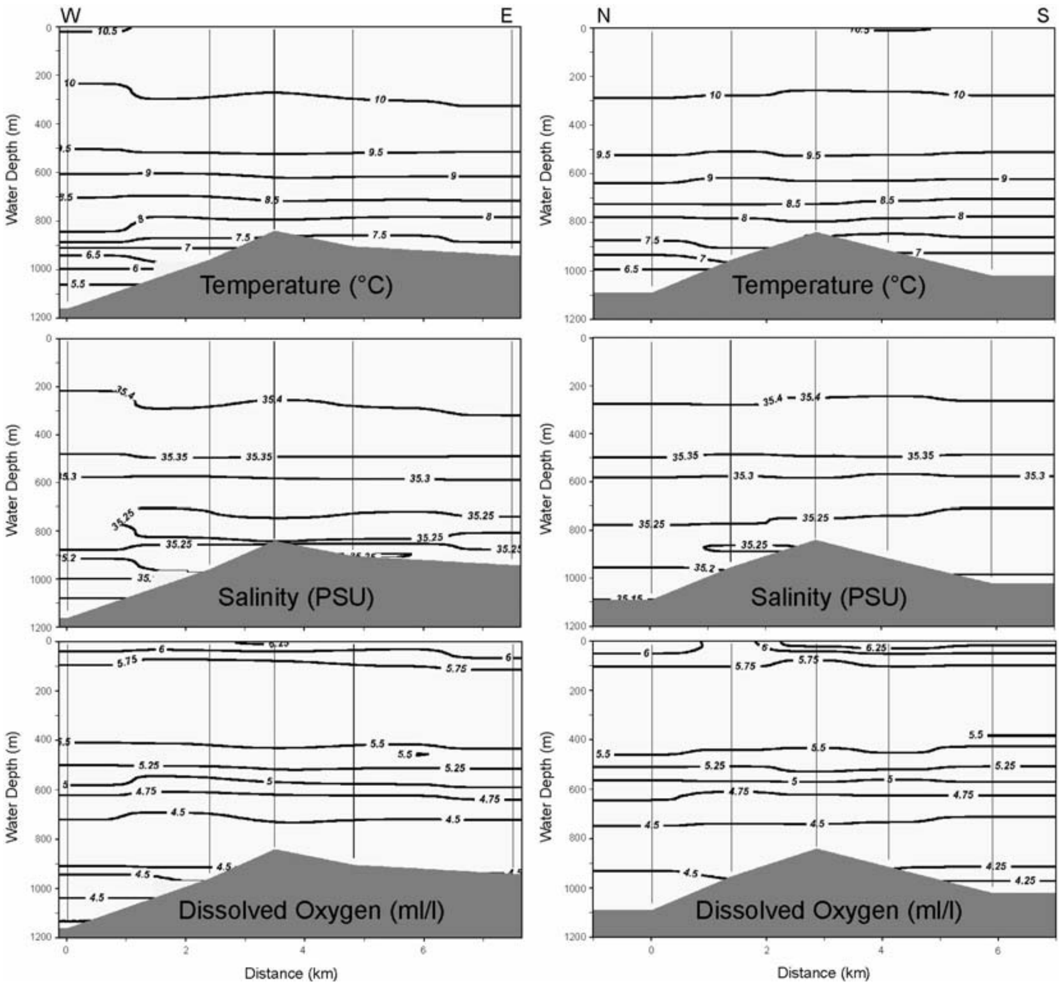


Fig. 1.7: EW- and NS-profiles of temperature, salinity and dissolved oxygen across Kiel Mount (see transect in Fig. 1.6).

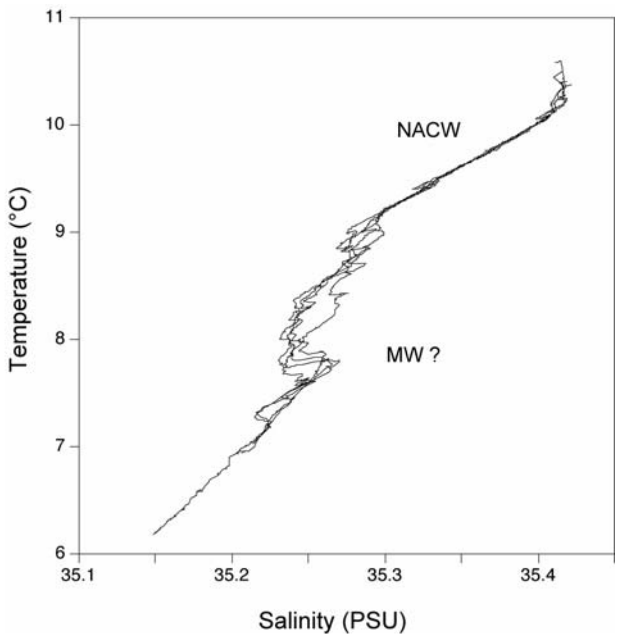


Fig. 1.8: TS-plot of several profiles typical for the Kiel Mount area.

1.4.2 The Role of Microbes in Slope Stabilisation on Deep-Sea Carbonate Mounds

(Neulinger, S.)

Microbes are 'key players' in mound-building processes. Indeed, prokaryotic organisms play this role since the Archaean era, and the mounds of the Porcupine Basin and Rockall Trough seem to be only the latest and long missed link of microbial carbonate formation through the ages. Many carbonate mounds in the above-mentioned provinces have rather steep-inclined flanks as compared to the slope of the continental margin in the surrounding area. The resistance of these mound flanks against slides and erosion is mainly ascribed to cemented carbonate strata or crusts on their surface. Though the formation of such carbonates is common even in the cold and deep waters of the NE Atlantic, the mechanisms and environmental factors that control this diagenetic process are currently unknown. Research experience from other settings gave rise to the hypothesis that the formation of the carbonate crusts in the Porcupine Basin and Rockall Trough is mediated by microbial activity.

In order to pursue this hypothesis of microbial calcification, several types of bottom samples were collected from on- and off-mound locations in the Porcupine Seabight, at the Porcupine abyssal plain, and at the SE-Rockall Bank for microbiological analysis: (1) soft sediment with box corer, multiple corer, and TV-grab, (2) coral debris and fossil carbonates with TV-grab, and (3) bottom water samples taken from the multiple corer and the CTD/Rosette. The substrate samples were either deep-frozen immediately for subsequent recovery of DNA and bacterial cultivation, or treated with paraformaldehyde solution to prepare them for fluorescence *in-situ* hybridization (FISH). Water samples were filtered through 0.2µm membrane filters to retain bacterial cells. The filters were conserved for DNA extraction and FISH in the same way as the substrate samples.

It was not possible to recover recent carbonate strata from mound flanks with the employed sampling gears. Actual samples of recent carbonate formations were to be collected with the ROV on leg M61-3. Thus, the samples collected on leg M61-1 served as references in genetic analysis and cultivation experiments.

1.4.3 OFOS-Surveys in the Belgica Mound Province and Western Rockall Bank: First Results

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

Ground-thruthing operations were carried out with the IFM-GEOMAR OFOS-camera sledge during M61-1. This visual inspection of cold-water coral environments in the bathyal zone addresses various scientific and socio-economic themes that are centred around sedimentary geology, benthic biology, and mapping of biological resources. The latter aspect has become a major matter of concern on many political agendas that are related to the protection of cold-water coral ecosystems and to mitigate unsustainable human fishing activities (Freiwald et al. 2004).

The OFOS scientific objectives were:

- To describe the sedimentary environment of carbonate mounds and the adjacent seabed (facies analysis).

- To map the benthic habitats and species distribution of the megafauna (these data will be further analysed for detailed thematic maps demonstrating biological diversity, biomass, carbonate production, coral densities, etc.).
- To document demersal fish and other exploitable organisms of economic importance.
- To document and to quantify human activities in cold-water coral ecosystems (e.g., trawling impact, lost fishing gear, scientific sampling, etc.)

OFOS surveys were carried out in the Belgica Mound Province (BMP) and a poorly explored sector at the deeper western Rockall Bank (WRB) margin totalling in 7 photo-transects with 980 underwater colour slides of which 961 are of excellent quality (98%). The film used was a KODAK Ektachrome 400 (27 DIN) colour slide. The downward looking camera system was adjusted with its optics, illumination and bottom weight distance indicator to 1.50 m above the seabed. An image taken at 1.50 m above the seabed shows an area of c. 1.10 by 1.75 m, or c. 1.925m^2. In addition, three equally spaced laser dots (50 cm) form a discrete triangle for scaling of objects. The online video camera mounted on the OFOS sledge provided black & white images due to the ship's-owned coaxial cable that did not allow transmission of a colour generated video signal. Onboard data-storage of the video documentation happened in three different ways: (1) continuous recording on VHS-tapes, (2) selected recording on a digital mini-DV tapes, and (3) a digital recording system linked up with the ADELIE video-tracking and protocol software package. The navigational maps used for the OFOS dives in the BMP based upon a multibeam map data set generated by RV Polarstern in 2000 (Beyer et al., 2003). This data set was kindly passed over by the Alfred Wegener Institute, Bremerhaven, to the OFOS planning team of M61-1. Navigation in the poorly explored WRB area was facilitated through data exchange with the Geological Survey of Ireland (GSI), who mapped the entire WRB during the past two years. The high resolution maps of two target areas in the WRB area were produced with R/V METEOR's HYDROSWEEP and PARASOUND systems.

1.4.3.1 OFOS-Dives in the Belgica Mound Province (BMP)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

Previous multidisciplinary research cruises to BMP proved the existence of 64 mounds of which about 20 are buried by sediment drift (De Mol et al. 2002). The BMP mounds cluster in two ridges at 700 and 900 m depth of a major contourite channel (Van Rooij et al. 2003). The M61-1 OFOS dives were concentrated on mounds that were not explored before (Fig. 1.9). These are two mounds belonging to the deeper mound ridge: Castor and Pollux, and one mound located in an intermediate position between the deeper and shallower ridge: Erik Mound. One buried mound, Joe‘s Nose, was documented as an example from the shallow mound ridge.

1.4.3.1.1 Castor Mound: OFOS Dive 1 (M61-1-203)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

The Castor Mound is the deepest and westernmost mound in the northern BMP. It is located south of a pronounced gulley feature that continues upslope where it intersects between the Galway Mound and the Therese Mound. The mound has an ovoid shape measuring c. 1000 m in NS-direction. The summit is positioned in the northern part of the mound, thus resulting in an asymmetric topography with a steeper northern slope and a less inclined southern slope.

The c. 1200 m-long Castor Mound survey started in a gulley due north of the mound at c. 1067 m depth. With a southerly heading, OFOS was towed over the steeper northern slope and passed the summit of Castor at c. 950 m. It went further down along the southern slope. The dive ended at 1025 m depth. Five major facies were recognised along the dive track (see Fig. 1.10):

Facies A Rippled sand with low-relief coral ridges

Facies A is only developed along the base of the southern flank from 1025 – 1015 m depth. Mobile sand sheets are intensely rippled by the strong tidal currents. The ripple troughs are filled with pteropod tests. The ripple marks are deflected around sparsely occurring coral frameworks or coral rubble accumulations. The mobile sand sheets show no signs of 'Lebensspuren', or semi-infaunal organisms, thus indicating a highly dynamic environment. Benthic life concentrates on the almost dead coral colonies or rubble, which is arranged in contour-parallel ridges with low relief (> 30 cm). The lateral distance between the ridges varies between 6 and 15 m. Large antipatharian colonies *(Parantipathes* sp.) are rooted within the coral framework.

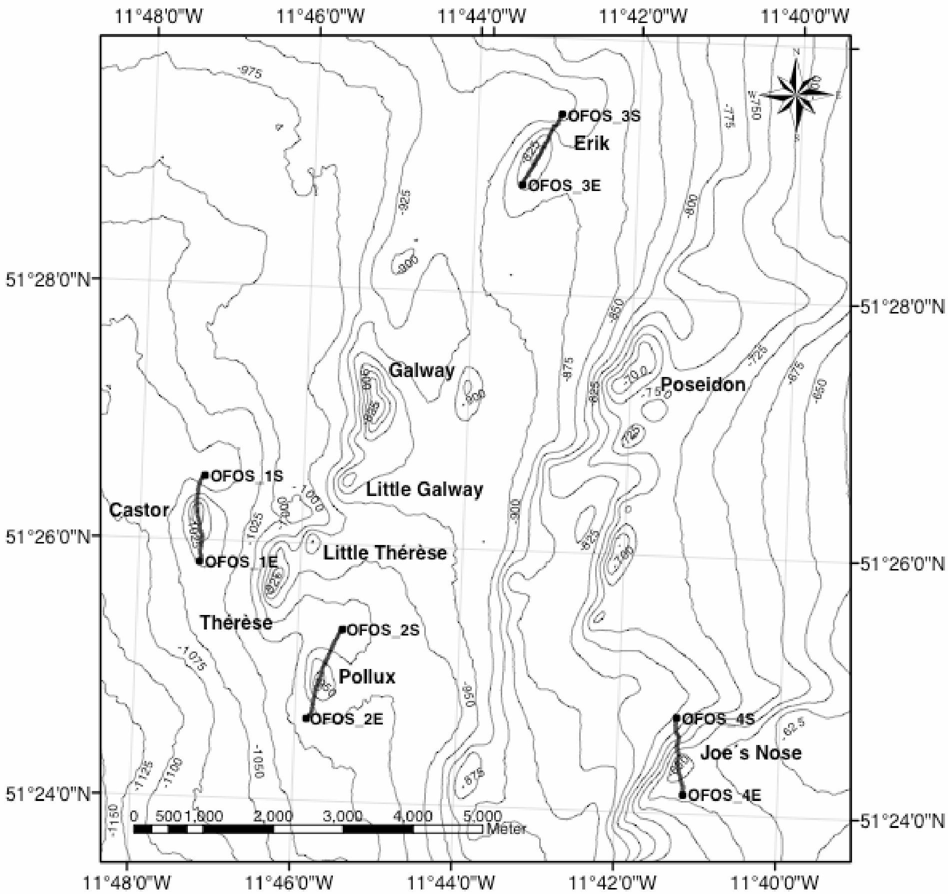


Fig. 1.9: Overview of the four OFOS dives in the BMP area.

Facies B Rippled sand with high-relief coral ridges

Facies B is similar to facies A but the size and height of the coral ridges turned from low to a high relief, up to 1 m thick. The ridge shows an almost complete cover of live and dead coral colonies *(Madrepora oculata, Lophelia pertusa),* anthipatharians, actinians and hexactinellid sponges. The coral colonies extended over ridges and therefore, the mobile sand sheet areas become smaller upslope. Facies B is developed along the southern slope from 1015 – 1003 m but is the dominating facies along most of the southern slope from 1036 – 950 m near the summit.

Facies C Coral thickets

Facies C is a continuation of facies B but the ridged topography becomes gradually hidden under an almost complete cover of coral colonies. The thickness of the coral cover is variable from a few centimetres to almost 1 m. Living corals grow upon dead and often degraded colonies. This facies, which is only present at the middle southern slope (1003 – 988 m), shows some faunal peculiarities. Dense clusters of gorgonian colonies *(Acanthogorgia armata*) are only found here (Fig. 1.11). Dead coral framework is intensely colonised by a red coloured hormatiid anemones which have been found so far only in the Pelagia Mound Province, western Porcupine Bank margin (Fig. 1.11). The false boarfish *Neocyttus helgae* was frequently observed among the corals. During previous ROV inspections in the BMP and Rockall Trough mound provinces this

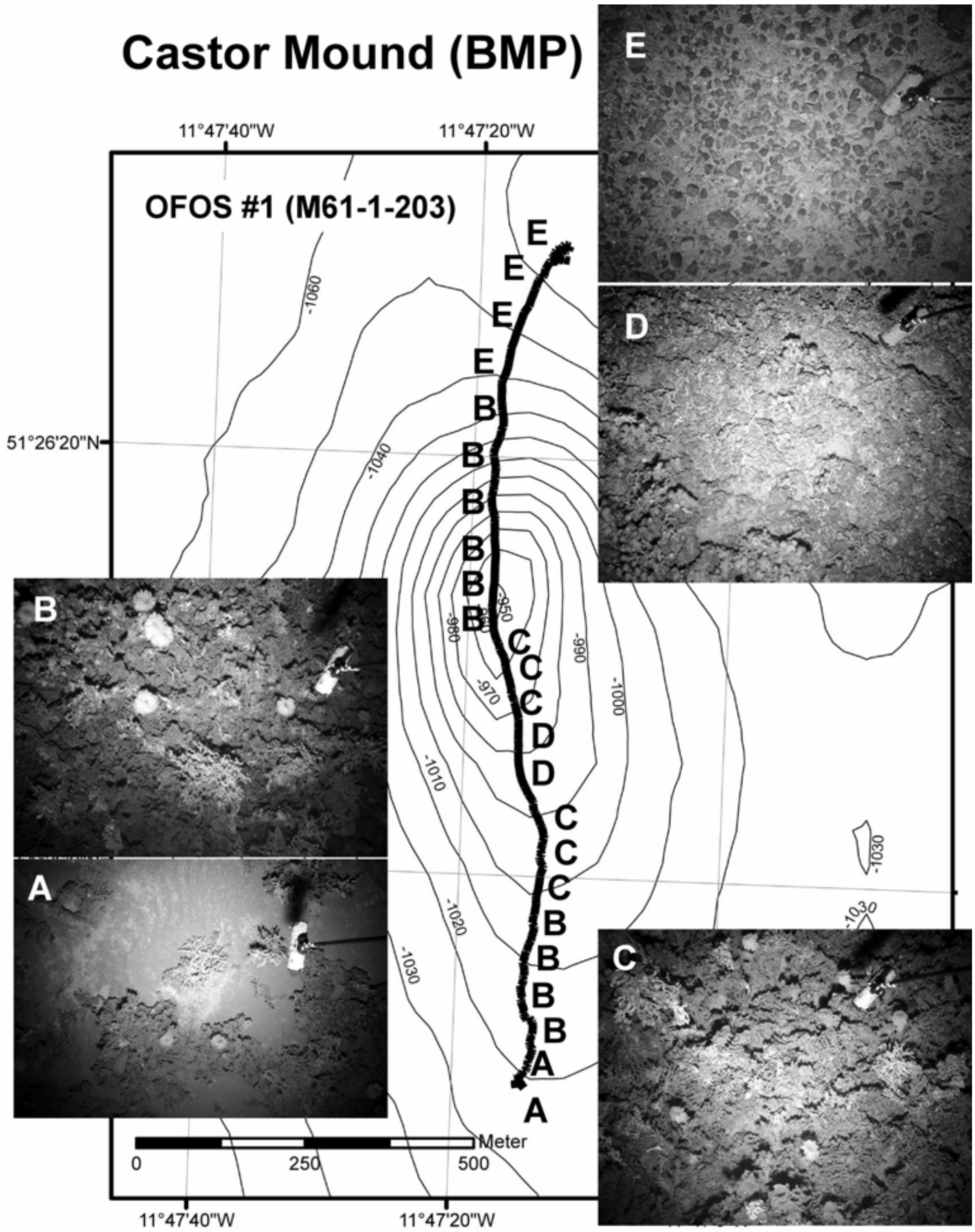


Fig. 1.10: Facies interpretation of OFOS-Dive #1 over Castor Mound in the BMP:
A = Rippled sand with low-relief coral ridges; B = Rippled sand with high-relief coral ridges; C = Coral thickets; D = Coral rubble, E = Dropstone pavements with dispersed corals. The ground weight with a length of 20 cm can serve as a scale bar.

fish has been observed on mounds, which are affected by strong currents (Freiwald, pers. observation). This coral thicket occurrence is the richest one mapped with OFOS during M61-1 in the BMP area.

Facies D Coral rubble

Near the summit of the upper southern slope, facies D, a coral rubble area is developed at 988 – 950 m depth. The corals are strongly fragmented and broken. The red coloured hormatiid anemone still occurs abundantly within this subhabitat. It is difficult to explain the existence of a large coral rubble facies near the crest of a mound. Generally, this area is known to harbour the densest live coral occurrences elsewhere in the BMP. Although very speculative at this point, it is tempting to conclude that this area was affected by fishing gear a while ago, that flattened the coral thicket completely.

Fig. 1.11: Gorgonian forest consisting of *Acanthogorgia armata* in the coral thicket facies (above). Dense accumulation of a red-coloured hormatiid anemones (arrows) in the coral thicket and coral rubble facies at the southern slope (below). The ground weight with a length of 20 cm can serve as a scale bar.

Facies E Dropstone pavements with dispersed corals

Facies E can be related to the gulley feature that is developed at the northern end of Castor Mound. It is documented from 1038 to at least 1037 m depth and consists of dropstone pavements and occasionally, dead coral framework or rubble. The dropstones are polymict in composition and comprise granites, black shales, and limestones both rounded and angular in shape and from pebble to boulder sizes. They are colonised by a discrete fauna consisting of brachiopods, encrusting holothurians *(Psolus squamatus)* and stylasterids *(Pliobothrus symmetricus).*

1.4.3.1.2 Pollux Mound: OFOS Dive 2 (M61-1-204)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

The Pollux Mound also belongs to the deeper mound ridge in the BMP but is slightly shallower than Castor Mound (see Fig. 1.9). It is ovoid in shape with a 1000 m-long long axis in NNW-SSE orientation. The base is at 990 m and the centrally positioned summit is at 908 m water depth. The steepest flank occurs at the western side and the least inclined flank is oriented to the southeast. During the 1000 m-long OFOS dive, starting in the NE of the mound and, after crossing the summit, ending on the SW-flank, four major facies have been found (Fig. 1.12).

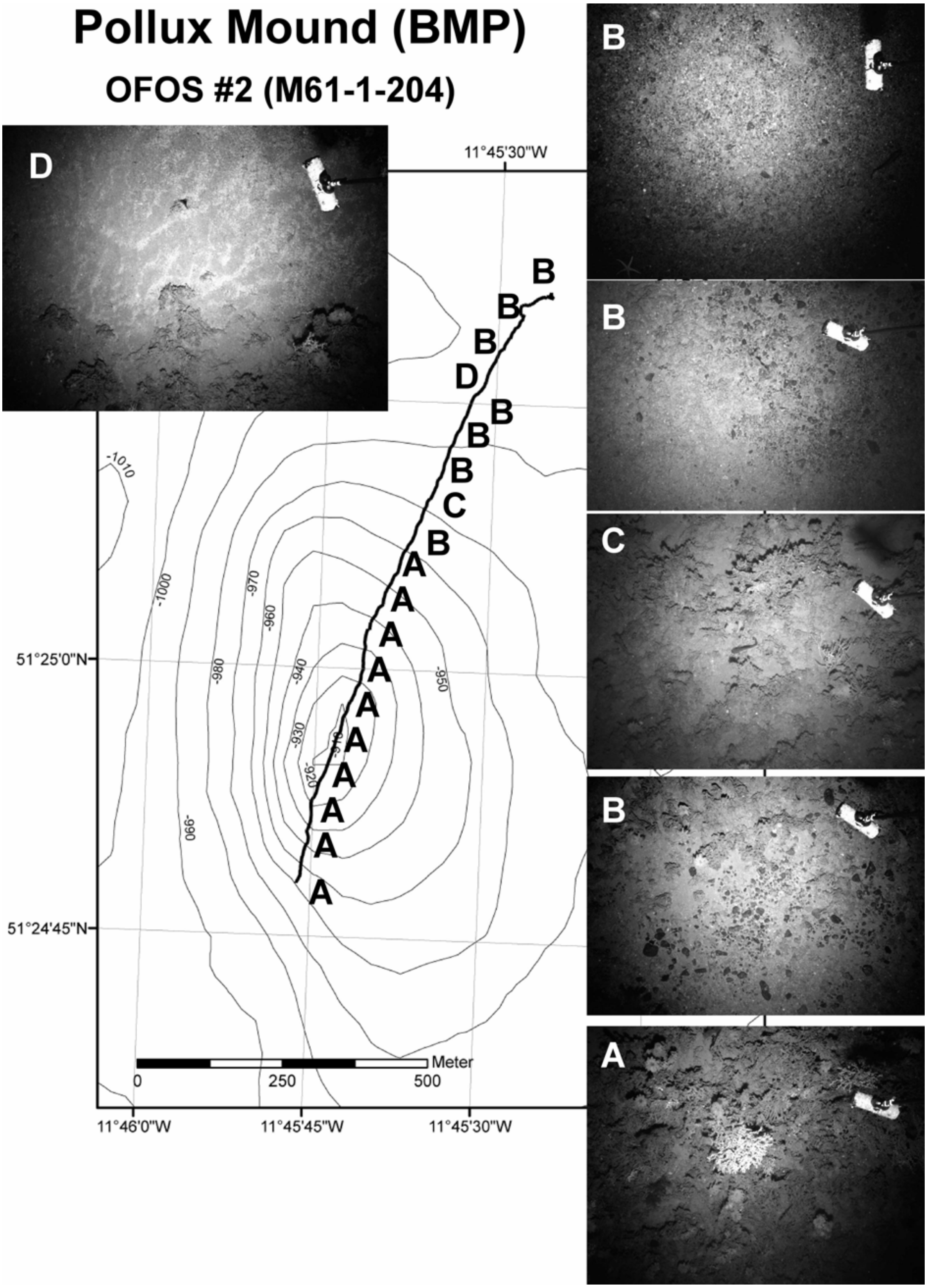


Fig. 1.12: Facies interpretation of OFOS-Dive #2 over Pollux Mound in the BMP:

A = Sand with high-relief coral thicket ridges; B = Dropstone pavements, rippled sand sheets; C = Coral rubble; D = Rippled sand sheets with low-relief coral ridges. The ground weight with a length of 20 cm can serve as a scale bar.

Facies A Sand with high-relief coral thicket ridges

Along the OFOS-track, almost the entire mound surface on both sides of the summit is characterised by the same facies type. Sandy areas interrupted by high-relief ridges, which are overgrown by (mostly dead) coral colonies, are developed from c. 960 to 908 m depth on both flanks mapped. Living corals occur much less in quantity than on Castor Mound. *Aphrocallistes bocagei,* antipatharians and the purple octocoral *Anthothela grandiflora* grow abundantly within the coral thickets. Two lost nets were found in this coral environment.

Facies B Dropstone pavements, rippled sand sheets

This facies is confined to the deeper northeastern slope (>965 m) and becomes steadily prominent towards the gulley. The sedimentary environment is quite heterogenous as it changes within short distances from dropstone pavements to mobile, rippled sand sheets and dispersed coral rubble. Nearly no living colonial corals were documented here. Dead coral frameworks and coral rubble areas show a random distribution. Larger dropstones often are colonised by *Parantipathes* sp. In the gulley, the small stylasterid *Pliobothrus symmetricus* dropstones is frequently attached to the mostly pebble and cobble-sized dropstones. A large lost net was found in the central part of the gulley.

Facies C Coral rubble

A larger coherent coral rubble area was noted only on the northeastern slope at 968 – 975 m. Locally, degraded and partly sediment-covered coral thickets were mapped. Live colonial corals occur very rare (1 per m^2 to a maximum) and are less than 20 cm high, thus indicating occasional larval settlement. *Aphrocallistes bocagei* and antipatharians were encountered at greater quantities within this environment.

Facies D Rippled sand sheets with low-relief coral ridges

Facies D forms a gradual downslope continuation of facies C. Rippled sand sheets migrate between low-relief coral thicket and rubble ridges.

Apparently, the facies differentiation on Pollux Mound itself is much less diverse compared to Castor Mound. The coral thickets are less dense and a higher ratio of dead vs. life corals can be noted for the Pollux Mound. Also the red-coloured hormatiid anemones are lacking on Pollux.

1.4.3.1.3 Erik Mound: OFOS Dive 3 (M61-1-247)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

Erik Mound is the northernmost structure studied in the BMP and is situated in an intermediate position between the deeper and almost buried mounds of the shallower upslope ridge. The shape is highly ovoid with almost symmetric contour lines. Only the northeastern slope is somewhat steeper than the opposing southwestern slope. The western flank starts at 900 m, whereas the eastern flank is shallower, with 870 m respectively (see Fig. 1.9). The NE-SW-striking long axis of Erik Mound measures 1300 m. The OFOS-dive #3 followed this orientation, starting at 904 m in the northeast and ending after 950 m at 845 m. Only three major facies types were discerned from the photographic documentation (see Fig. 1.13).

Facies A Coral rubble with sand cover

Facies A dominates the entire upper slope and summit area on Erik Mound with no further major differentiation from 855 m to the summit at 818 m. Coral thickets are very rare and relatively small-scaled in lateral extension. Only isolated living *Lophelia* and *Madrepora* colonies were observed. The coral rubble cover is very thin so that the muddy and sandy background sediment becomes visible. *Aphrocallistes* and antipatharians occur in much lesser abundance compared to the previously discussed deeper mounds. Larger muddy sand areas are inhabited by *Cerianthus* sp. A small exposure of facies A occurs downslope in the northeast between 870 and 882 m, where the coral rubble is associated to rippled sand sheets.

Facies B Coral rubble with dropstones

Facies B was detected only along the northeastern slope from 845 – 870 m. Coral rubble is associated with dropstone-rich seabed. Larger dropstone boulders are colonised by barnacles.

Facies C Dropstone pavements

From 880 m downslope, a dropstone pavement facies is developed in the northeastern off-mound area. Stylasterids *(P. symmetricus),* brachiopods and barnacles contribute to the carbonate sedimentation in this erosional environment.

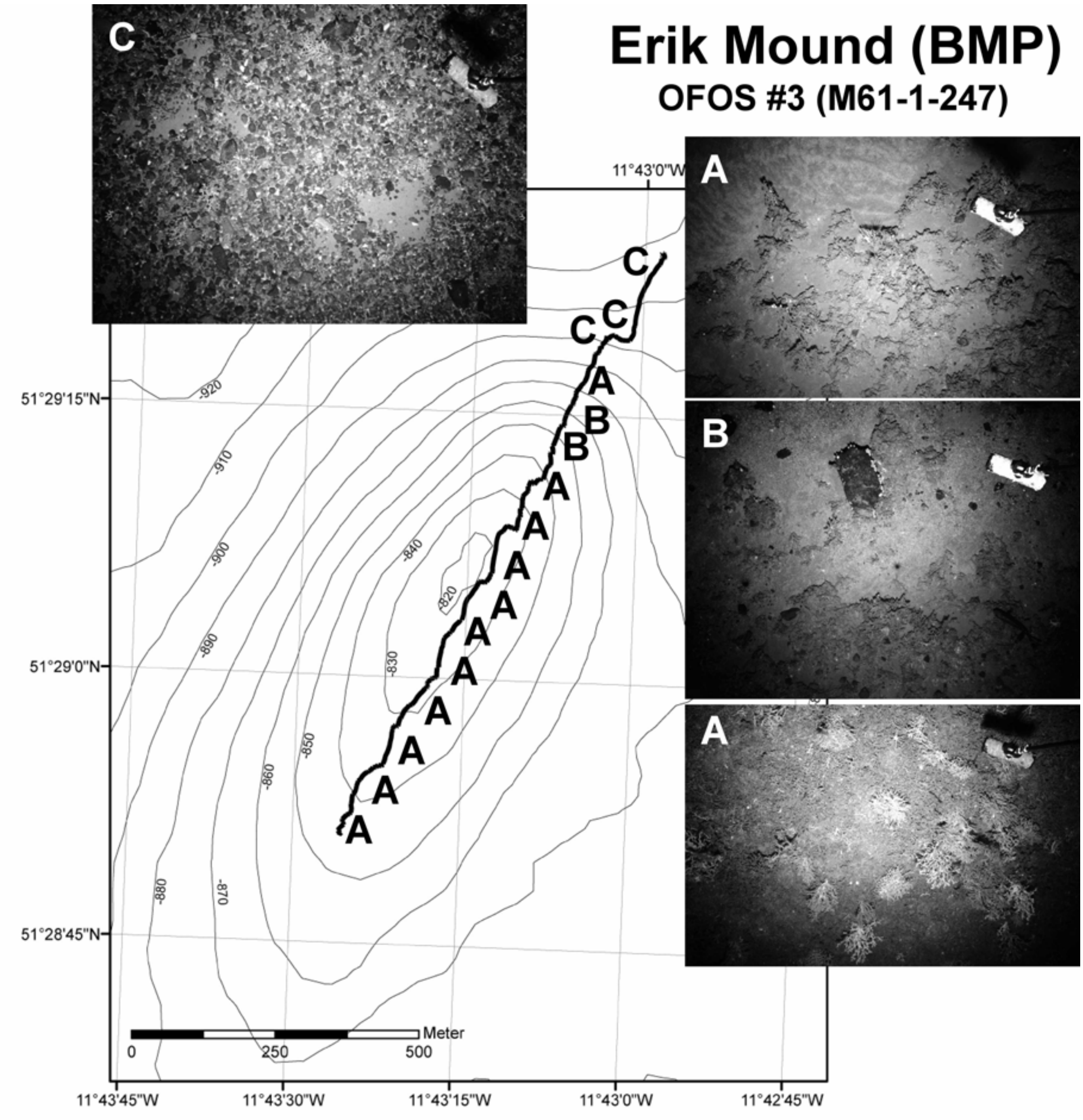


Fig. 1.13: Facies interpretation of OFOS-Dive #3 over Erik Moind in the BMP: A = Coral rubble with sand cover;B = Coral rubble with dropstones; C = Dropstone pavements. The ground weight with a length of 20 cm can serve as a scale bar.

1.4.3.1.4 Joe´s Nose: OFOS Dive 4 (M61-1-248)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

Joe's Nose marks a prominent c. 140 m-high escarpment within the otherwise gently inclined sedimentary drift packages of the western Irish margin (see Fig. 1.9). The reason for the existence of this remarkable structure is a buried carbonate mound and the very steep westerly-faced slope marks its former flank. This nose was inspected visually using the VICTOR 6000 ROV during the R/V POLARSTERN Cruise ARK-XIX/3a in 2003. According to the results, lithified carbonates of unknown origin and composition are cropping out on top of this structure at 632 m depth. The TV-Grab (M61-1-260) from this area yielded some pieces of a bathyal coral limestone. OFOS dive #4 started at 770 m in the northern gulley and headed south over the top plateau. This plateau, on which the OFOS-track ended at 668 m, gently dips SSE-ward. Five major facies were reflect the morphological complexity of this 1100 m-long transect (Fig. 1.14).

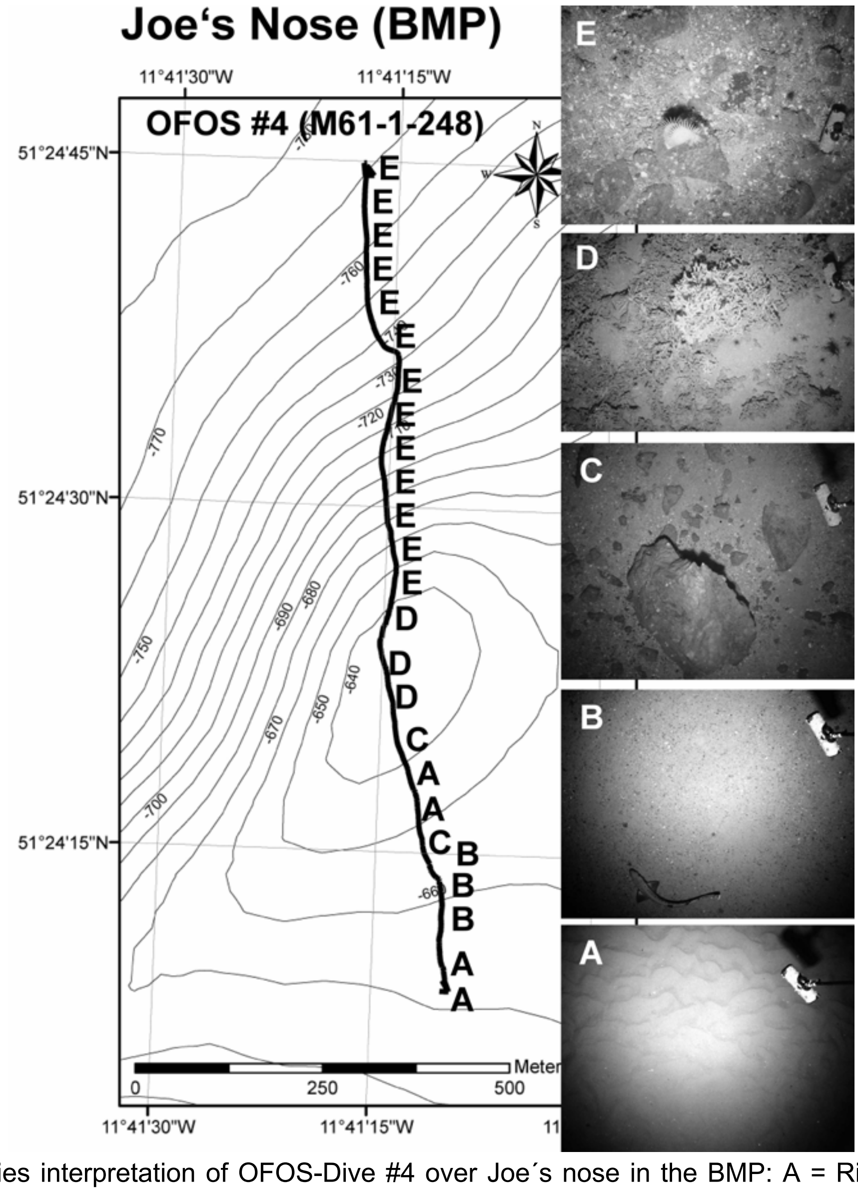


Fig. 1.14: Facies interpretation of OFOS-Dive #4 over Joe´s nose in the BMP: A = Rippled sand; B = Dropstone-littered sand; C = Barnacle plate-rich sands with dropstones; D = Coral rubble and thickets; E = Dropstones with barnacle plates and coral rubble. The ground weight with a length of 20 cm can serve as a scale bar.

Facies A Rippled sand

Facies A was documented two times on the gently dipping plateau of Joe‘s Nose: one area some distance away from the top at 665 – 668 m and one area closer to the top at 642 – 650 m. The muddy sands are accentuated by sinuous ripple marks, and occasionally, sand waves occur.

Facies B Dropstone-littered sand

Facies B consists of an even coarse sand sheet, rich in pebble-sized dropstones. Dropstone boulders are scattered throughout this environment. The boulders are surrounded by haloes of cobble-sized dropstones and shell hash. Demersal fish and sharks were frequently encountered, such as *Galeus melastomus, Helicolenus* sp. and *Lepidion eques*. The epibenthos is rather scarce, except for some cerianthids. Mobile epibenthos is dominated by decapods *(Paromola cuvieri).*

Facies C Barnacle plate-rich sands with dropstones

Facies C was encountered near the top of the plateau at 655 – 650 m and 642 – 636 m. Due to the presence of larger dropstones, the coarse sandy seabed is covered by barnacle plates, which had been fallen down after the death of the barnacles occupying the dropstone surfaces (Fig. 1.15). Most likely the barnacles belong to *Bathylasma cf. hirsutum*, a widespread bathyal element in the NE Atlantic (Gage, 1986).

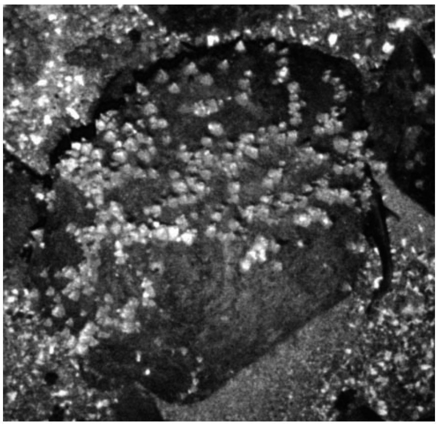


Fig. 1.15: A dropstone boulder from the plateau of Joe’s Nose (Facies C), plastered with *Bathylasma* cf. *hirsutum* at 640 m depth.

Facies D Coral rubble and thickets

The top of Joe’s Nose at 632 to 635 m is the place where coral thickets and coral rubble occurs. The coral thickets consist of almost dead but still exposed coral frameworks with few live *Madrepora oculata* colonies. The underlying hardsubstrate is an outcropping Pleistocene bathyal limestone, that forms stratified outcrops especially at the top of the steeply inclined escarpment. Few lost nets were encountered in this area.

Facies E Dropstones with barnacle plates and coral rubble

The entire northern slope of Joe’s Nose is characterised by facies E from 630 – 770 m. The slope is plastered by dropstones of all size classes and is littered with barnacle plates and locally, with coral rubble. Strong currents prevent settling of fine-grained sediments, thus sustaining this filter-feeding community. The anemone *Phelliactis hertwegii* was frequently observed on larger dropstones.

To conclude, there is an apparent decrease of living coral percentages from the deep Castor Mound to Joe’s Nose. However, in the recent past, ecological conditions must have been better to sustain coral thickets even in these shallower areas. The gulleys act as conduits for tidally amplificated currents and therefore, no sedimentation except barnacle plates and brachiopods, has occurred since the deposition of the dropstones.

1.4.3.2 OFOS-Dives at the Western Rockall Bank (WRB)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

During M61-1 a new coral province was studied at the deeper margin of the WRB. Previous information on promising topographic features as candidates for coral ecosystems were provided through the seabed mapping programme of the entire Irish exclusive economic zone by the Geological Survey of Ireland. Limited time and gale warning allowed only a 2.5 days reconnaissance that, however, yielded numerous surprising results that were broadened during the succeeding M61-3 cruise. The global databank of *Lophelia pertusa* and *Madrepora oculata* by Freiwald et al. (2004) shows no occurrences known to science prior to M61-1. However, existing knowledge of the ecological demands and the water mass properties in this new area, made it very much likely to discover new coral ecosystems.

The first seabed feature analysed was a conical submarine volcanic cone at 1100 to 900 m depth that we named as Kiel Mount (Fig. 1.16). Volcanic structures in this particular area are poorly studied but are probably of Paleogene age. The Kiel Mount was mapped with two OFOS transects which covered the plateau-like summit as well as the northern and southern slopes.

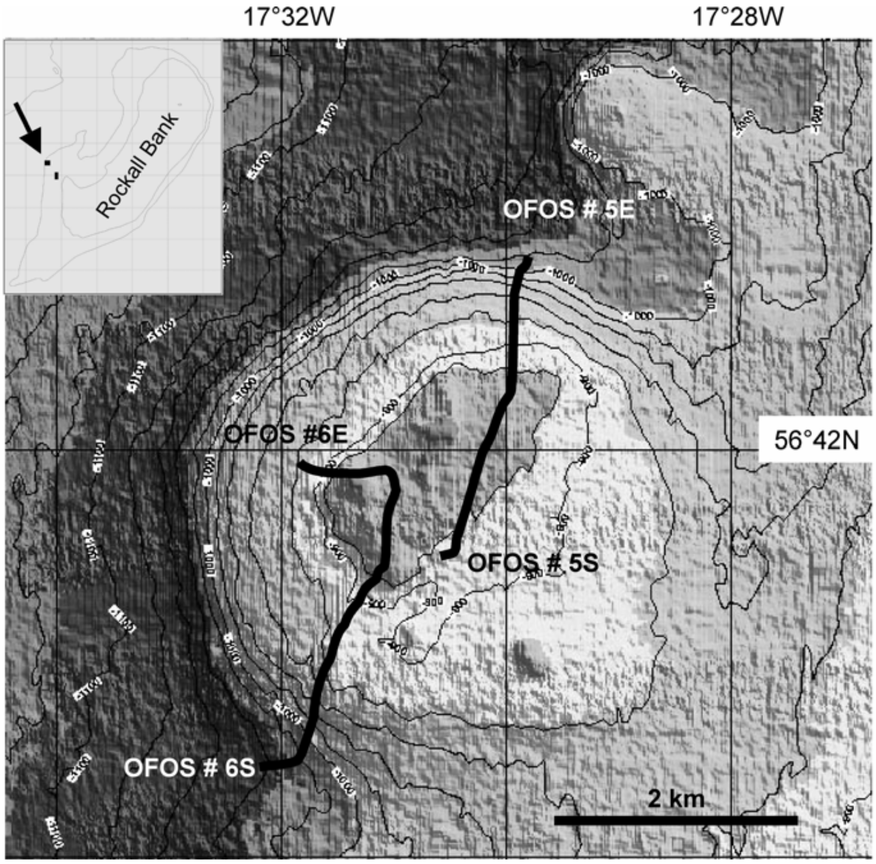


Fig. 1.16 The bathymetry of the Kiel Mount volcanic cone at the WRB (see arrow in the inserted map of the Rockall Bank for overview) was generated with the ship-based Hydrosweep. The tracks of the two OFOS dives are indicated.

1.4.3.2.1 Kiel Mount: OFOS Dive 5 (M61-1-287)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

OFOS Dive # 5 started in the deep gulley north of Kiel Mount at 1067 m and ended after 2.4 km on the central part of the summit at 902 m. Seven different facies types were encountered on this transect (Fig. 1.17):

Facies A Sand with pebbles and boulders

Facies A is restricted to the gulley in the north at 1067 – 1050 m. The sediment is a winnowed lag of a mixture of volcanoclastics and dropstones with thin veneers of sand sheets in between. Boulders are densely colonised by antipatharians, isidiid corals, encrusting holothurians *(Psolus* sp.) and large fossil stylasterid colonies *(Stylaster* sp.). Rarely, small colonies of live *Madrepora oculata* and the red-colour variety of *Paragorgia arborea* occur. The presence of the false boarfish *Neocyttus helgae* indicates a strong current regime.

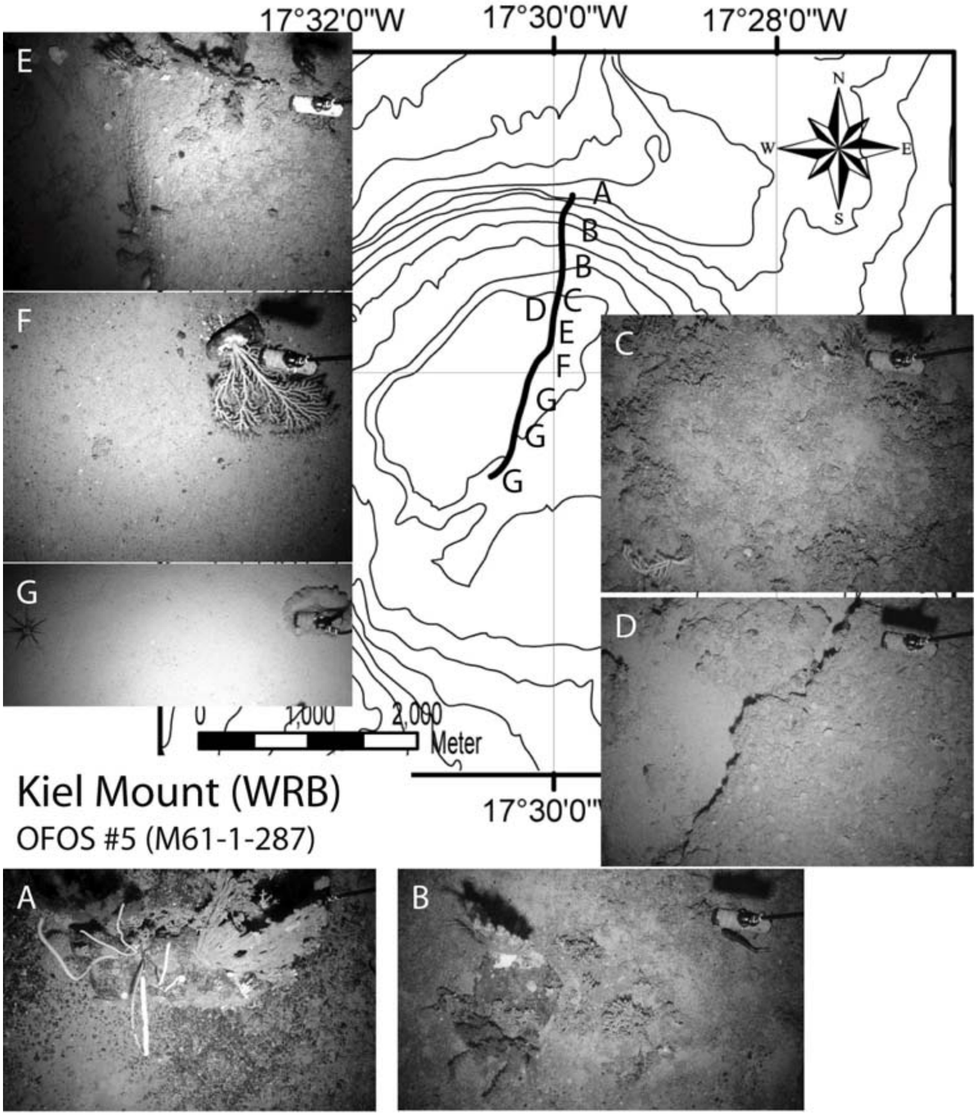


Fig. 1.17: Facies interpretation of OFOS-Dive #5 over Kiel Mount in the WRB area: A = Sand with pebbles and boulders; B = Coral rubble with pebbles and boulders; C = Coral rubble with muddy sand; D = Crusts and coral rubble; E = Basalt ridge; F = Pebbly sand; G = Bioturbated muddy sand. The ground weight with a length of 20 cm can serve as a scale bar.

Facies B Coral rubble with pebbles and boulders

Facies B continues upslope of facies A up to about 900 m. The pebbly and bouldery substrate is increasingly paved with coral rubble *(L. pertusa, M. oculata).* Live *M. oculata, Acanthogorgia armata* and the white colour variety of *P. arborea* became more abundant. *Molva dypterygia* was frequently observed resting on the coral rubble.

Facies C Coral rubble with muddy sand

Facies C was detected only on the outer rim of the summit from 900 to 850 m, where coral rubble is admixed with muddy sand.

Facies D Crusts and coral rubble

At about 850 m, underwashed crusts of unknown origin (basaltic or carbonate source rocks?) became a prominent feature on the summit of Kiel Mount. These crust substrate provides a habitat for a variety of cnidarians such as *P. arborea* (red colour variety), isidiid corals, *Parantipathes sp*., whip corals and *M. oculata*. The crusts are littered with coral rubble of thickly calcified *L. pertusa* and *M. oculata*. Crinoids clinged on almost all cnidarian colonies. Again, *N. helgae* indicates a vigorous current regime.

Facies E Basalt ridge

Basalt outcrops are prominent on the highest areas of the summit shallower than 850 m on Kiel Mount. This substrate is rich in cnidarian colonies except for scleractinians and sponges such as *Phakellia* sp.

Facies F Pebbly sand

Facies F followed the basalt ridges towards the central part of the summit and is characterised by pebbly sand and occasional large basalt and/or dropstone boulders. The sand substrate is frequently inhabited by reddish colonies of *Pennatula* sp., whereas on the boulders live *M. oculata, P. arborea,* isidiid corals, antipatharians and the stylasterid *Pliobothrus symmetricus* are very common.

Facies G Bioturbated muddy sand

The wide central plateau of the summit is covered by bioturbated muddy sand rich in ‘Lebensspuren’. The soft substrate is inhabited by the echiurid *Bonellia viridis*, cerianthids, the actinian *Bolocera tuediae,* echinoids and the holothurian *Benthogyne* sp.

1.4.3.2.2 Kiel Mount: OFOS Dive 6 (M61-1-288)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

The second OFOS dive on Kiel Mount covered the southern flank at 1060 m, crossed another rough basalt outcrop terrain at 833 m and turned west to descend at the upper western slope down to 928 m. Five different facies can be differentiated (Fig. 1.18)

Facies A Coral rubble, sand and dropstones

Facies A was encountered specifically at the upper slopes of Kiel Mount and on a small area on the summit plateau. The sediment is made of a mixture of coral rubble, coarse sand and dropstones at various degrees. The sand sheets are inhabited by *Pennatula* sp., *Capnella*-like alcyonarians, *Benthogyne* sp. (holothurian) and echinoids. Dropstone boulders are colonised by *P. arborea* (white colourmorph), isidiid corals, *Parantipathes* sp. and demosponges such as *Phakellia* sp.

Facies B Bioturbated sand

Facies B occurs preferably on the summit as a lateral variation of facies A but without coral rubble and much fewer dropstones. The sand is rich in 'Lebensspuren' and cerianthids.

Facies C Basalt outcrop with thin sand veneers

Basalt crops out on the summit and frequently along the upper slope of Kiel Mount. Very often, a thin veneer of sand is deposited on the basalt basement. In larger depressions, sand infills prevail an attractive substrate for ophiuroid aggregations. The basalts are colonised by antipatharians, *P. arborea* (red colourmorph) and numerous sponges.

Facies D Coral rubble with crusts

Facies D is characterised by underwashed crusts of either basaltic or carbonate origin and was detected on a sharp edged exposure at the upper southern slope. The crusts are locally littered with coral rubble and are intensely colonised by various antipatharian species, demosponges, crinoids and ophiuroids. This area was very rich in different fish species, such as *Neocyttus helgae, Nezumia equalis, Lepidion eques* and *Trachyscorpia cristulata.*

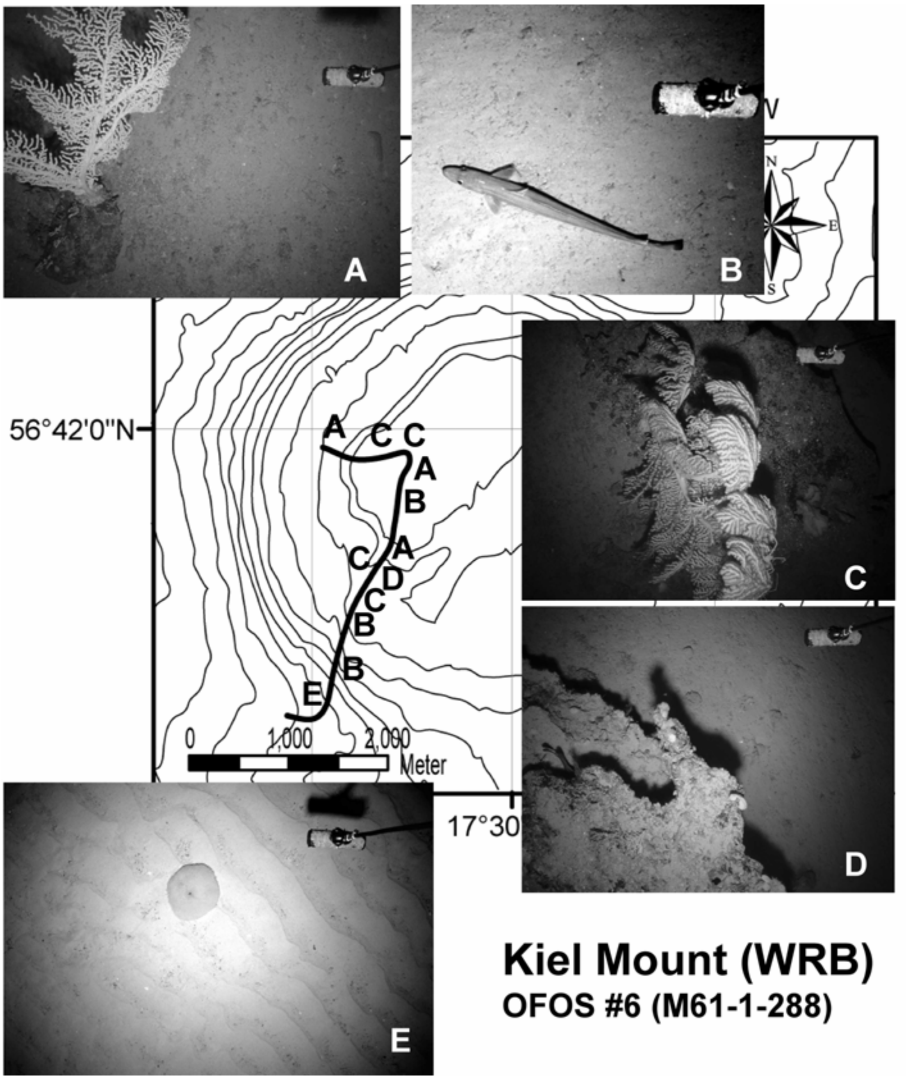


Fig. 1.18: Facies interpretation of OFOS-Dive #6 over Kiel Mount in the WRP area: A = Coral rubble, sand and dropstones; B = Bioturbated sand; C = Basalt outcrop with thin sand veneers; D = Coral rubble with crusts; E = Rippled sand. The ground weight with a length of 20 cm can serve as a scale bar.

Facies E Rippled sand

Facies E occurs along the deep and gently inclined foot of the southern slope. The rippled sand is sparsely inhabited with echinoids and hermit crabs.

To conclude, Kiel Mount is not very rich in live scleractinians but extremely rich in antipatharians, gorgonians, and sponges. We have never encountered so plenty of fish and holothurians on the sand bottoms. No signs of lost fishing gear argue for this observation.

1.4.3.2.3 Franken Mound: OFOS Dive 7 (M61-1-303)

(Freiwald, A., Beuck, L., Linke, P., Pfannkuche, O., Bannert, B.)

Franken Mound is a sedimentary structure 15 nm southeast of Kiel Mount but is situated in a mid-slope position of the WRB (Fig. 1.19). The shape is rather unusual compared to the coral-covered carbonate mounds in the BMP, which are marked by elongated and ovoid circumferences. Franken Mound has an irregular curved shape with the convex side pointing upslope to the east and an irregular surface topography with lots of smaller summits and depressions. The entire structure measures c. 2.5 km in length, with a base at around 700 m to the west and 660 m to the upslope east. The shallowest summit is at 627m. Due to a gale, we were not able to recover any seabed sample from Franken Mound and therefore, the facies description is based upon the interpretation of OFOS-dive #7 only. Three major facies were encountered during the 2 km-long OFOS transect which crosses the mound feature two times (Fig. 1.20).

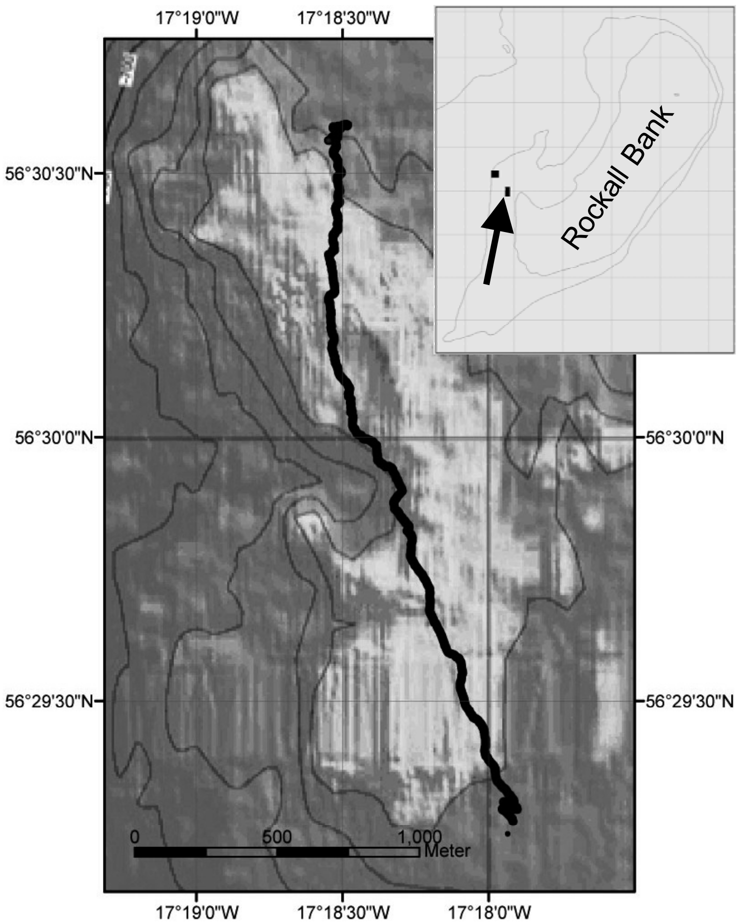


Fig. 1.19: Bathymetry of Franken Mound (WRB, for overview see inserted map (arrow)) and the OFOS dive #7 from south to north).

Facies A Muddy sand

Facies A is typically found off-mound in a variety of subfacies in water depths deeper than 660 m. Most distally the muddy sand plains are structured by current-ripple marks. Muddy sand without ripple marks is highly bioturbated. Closer to the mound, pebble-sized dropstones and boulders become more abundant. These boulders are colonised by antipatharians and encrusting holothurians *(Psolus* sp.). Benthic life is rich. There is plenty of cidaroid echinoids, holothurians, decapods *(Paromola cuvieri, Chaecon affinis)* and fish such as *Helicolenus* sp.

Facies B Barren carbonate limestone

The basement of Franken Mound is difficult to evaluate without seabed samples, but the weathering profile and bedding planes visible on some OFOS images point to a limestone origin. If correct, the limestone consists of massive sedimentary units or deci-to-centimetre-thick layers. Some underwashed carbonate crusts occur as well and they show signs of dissolution patterns (probably dissolution of aragonite fossils during diagenesis?). The basement crops out on all steep flanks within the inner mound area and provided hardsubstrate for a diverse epibenthic fauna, including scleractinians, gorgonians, antipatharians and demosponges. Several colonies of the octocoral *Anthomastus* sp. and bushy hydroids have been identified on the crustground.

Facies C Coral thicket/rubble

The coral thickets on Franken Mound are the largest one found during the entire M61-1 cruise. The thickness often exceeds 1 m and is attached to subvertical basement outcrops or plain carbonate crusts. The framework is primarily made by *L. pertusa* and to a lesser degree by *M. oculata.* Rarely, living *Stylaster* sp. and *Aprhrocallistes bocagei* were documented. The dead coral framework often is densely colonised by a yet not identified actinian and by *Phelliactis hertwegii*. Lost fishing gear was found several times entangled within the corals.

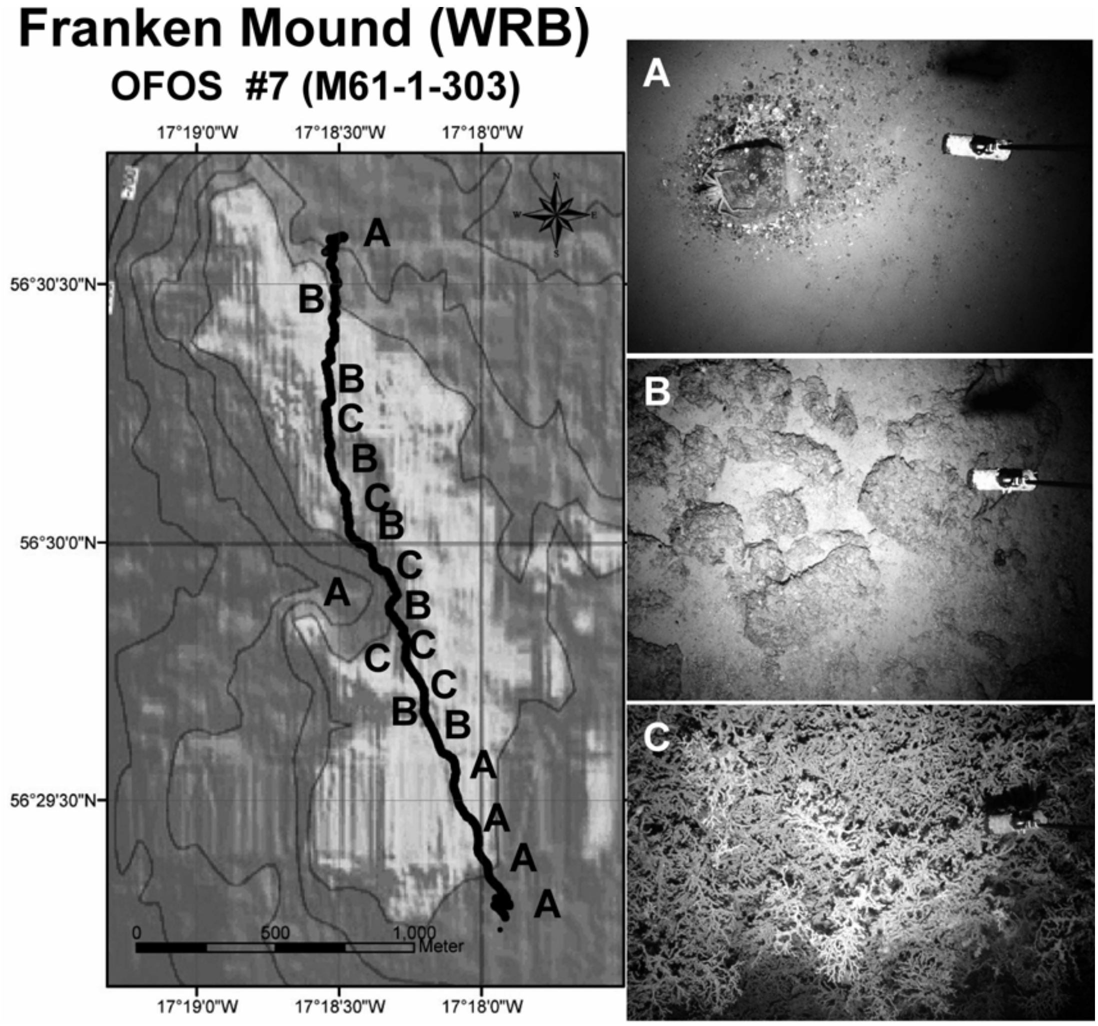


Fig. 1.20: Facies interpretation of OFOS-Dive #7 over Franken Mound in the WRP area: A = Muddy sand; B = Barren carbonate limestone; C = Coral thicket/rubble. The ground weight with a length of 20 cm can serve as a scale bar.

To conclude, in the WRB we found the most intense scleractinian coral growth shallower than 700 m depth (Franken Mound) whereas in deeper waters, corals are mostly dead (Kiel Mount). This situation is contrary to coral growth depth patterns found in the BMP. The sponge community found on Kiel Mount is similar to those living in the Logachev Mound Province, southwestern Rockall Trough. Signs of fishing activity are much lesser in the WRB area compared to the BMP, which is littered with lost fishing gear. Our relatively short reconnaissance in the WRB opened the door for further exploration of a new coral province in the North Atlantic.

1.4.4 Composition and Distribution of Zooplankton Above Coral-Covered Carbonate Mounds at the Belgica Mound Province

(Martin, B, Ruseler, S.)

Deep-water corals are potential predators for zooplankton. This study aims to detect their impact on the fauna in the water column above and near the coral-covered mounds. In this context it is of special interest to analyse the faunal composition of the bottom-near layers as well as the structure and dynamics of the diurnaly migrating zooplankton of the deep scattering layer above the upper slopes and the summits of mounds. Furthermore, if spawning of corals and associated fauna takes place in spring, surface near layers could host eggs and larvae of these organisms.

Pelagic metazoans were collected above the slopes and the summit of Galway Mound.Standard devices for the quantitative collection of zooplankton was a 1 m^2- MOCNESS (Wiebe et al.,. 1985) equipped with 9 nets of 0.333 mm mesh size. The net can be opened and closed sequentially and is equipped with an integrated CTD. All data are transmitted to an onboard computer. The water column was traversed by stratified oblique tows and bottom-near horizontal hauls (Tab. 1.1 and 1.2). The filtered volume is calculated by a flowmeter.

To investigate diel vertical migrations of the zooplankton hauls were carried out during day and night. To detect the depths and dynamics of the deep scattering layers the data of a 33kHz echo sounder were recorded during the stations. The fresh material was preserved in 4% formaldehyde in seawater. One haul was frozen at –80°C and will be send to Prof. G.A. Wolff, Earth & Ocean Sciences Department Liverpool, for biochemical analysis

Tab. 1.1: MOCNESS –haul data (a.b. = above bottom, w.c. = water column)

station #	date	time	position begin Lat. °N	long. °W	position end latitude °N	long. °W	water depth m	haul #	catch depth m	remarks
234	22.04.04	day	51°29.88	11°42.05	51°22.71	11°48.94	845-1016	1	1-80 m a.b.	a.b.
236	22.04.04	night	51°29.67	11°45.58	51°22.65	11°45.58	870-986	2	10-120 m a.b.	a.b.
237	23.04.04	night	51°30.35	11°45.05	51°25.14	11°45.42	890-982	3	800-0	2 nets a.b., rest w.c.
244	23.04.04	day	51°29.47	11°45.06	51°24.93	11°45.38	942-973	4	350-0	w.c.
245	24.04.04	night	51°24.93	11°45.08	51°30.99	11°45.05	790-971	5	840-0	2 nets a.b., rest w.c.
245	24.04.04	night	51°25.18	11°45.08	51°31.14	11°45.05	800-970	6	850-0	2 nets a.b., rest w.c.
245	25.04.04	day	51°25.05	11°45.03	51°30.08	11°45.15	790-970	7	750-0	2 nets a.b., rest w.c.
245	25.04.04	day	51°25.23	11°45.09	51°30.96	11°45.13	807-971	8	750-0	2 nets a.b., rest w.c.

First qualitative studies showed relatively high abundances of fish- and evertebrate larvae in all samples, one of the latter occured in masses. Wether these are larvae of corals has to be further analysed. Several specimens of Pipefishes (Family Syngnathidae) were caught in the upper 50m

during Haul 2, 3, 7. In the bottom-near layers (net 2 and 3 of haul 2, 6, 7, 8) fish-larvae, decapods as well as medusae were found in greater numbers. In addition adult polychaets were caught at 120 m above bottom at haul 2. At the first tow two of the nets touched the bottom and were filled with corals including associated fauna.
At the south-north tracks the gear reached the bottom-near layers in 800m by paying out about 1100 meters of wire whereas during the north-south tracks up to 2000 meters of wire were needed to reach the same depth which was probably caused by a strong current to the north.

Tab. 1.2: MOCNESS hauls: sampled depth intervals. mab = meters above bottom.

MOC-1-01		MOC-1-02		MOC-1-03		MOC-4-01		MOC-1-05		MOC-1-06	
Net	catch depth	Net	catch depth	Net	catch depth	Net	catch depth	Net	catch depth	Net	catch depth
01	0m-30mab	01	0m-110mab	01	0m-130mab	01	0m-350m	01	0m-80mab	01	0m-160mab
02	30-80mab	02	50mab	02	800-700m	02	350m	02	90mab	02	90-160mab
03	80-20mab	03	50mab	03	700-600m	03	350-300m	03	80mab	03	70-90mab
04	1-40mab	04	70mab	04	600-500m	04	300-200m	04	800-600m	04	740m-600m
05	40-80mab	05	30-70mab	05	4500-400m	05	200-150m	05	600-500m	05	600-500m
06	40mab-0m	06	80-120mab	06	400-300m	06	150-100m	06	500-400m	06	500-300m
07	-	07	120mab	07	300-100m	07	100-75m	07	400-0m	07	300-0m
08	-	08	120-140mab	08	100-50m	08	75-50m	08	-	08	-
09	-	09	140mab-0m	09	50-5m	09	50-0m	09	-	09	-

MOC-1-07		MOC-1-08		MOC-1-09	
Net	catch depth	Net	catch depth	Net	catch depth
01	0m-740m	01	0m-30mab	01	0m-720m
02	730m	02	30-80mab	02	720-770m
03	750m	03	80-20mab	03	50mab
04	40mab	04	12-40mab	04	720-600m
05	730-600m	05	40-80mab	05	600-500m
06	600-500m	06	40mab	06	500-300m
07	500-300m	07	73mab	07	300-100
08	300-100m	08	70-10mab	08	100-50m
09	100-0m	09	10mab-0m	09	50-0m

1.4.5 Deep-Sea Observation System (DOS)

(Linke, P., Pfannkuche, O., Schönfeld, J., Bannert, B., Türk, M., Queisser, W.)

Particle flux and bottom water currents with changes in velocity and direction as well as fluctuations in hydrostatic pressure, due to tidal or meteorological influences are expected to have an impact on the exchange processes and biological interactions at the sediment/water inface in coral thickets. To monitor these oceanographic control parameters in combination with megabenthic biological activity the Deep-sea Observation system (DOS) was deployed on Galway Mound (BMP) (Figs. 1.21 and 1.22).

The long-term observatory was equipped with a wide range of sensors, sampling and experimental gear (Tab. 1.3). This included a storage CTD, three acoustic current meters, a sediment trap and a stereo camera system. SAMS/Oban deployed a number of optical sensors (transmissiometer, fluorometer, optical backscatter) in 50 cm distance from the seafloor. A 300 kHz ADCP heading upwards into the water column measured every 15 min the current regime in 3-m cells within a range of 7.6 to 110 m above bottom. Simultaneously, a downlooking 1200 kHz measured currents in 10-cm cells within the first 100 cm of the sediment-water interface. Another acoustic current meter equipped with a turbidity meter is mounted next to the sediment trap which samples in 8-day intervalls the particle deposition.

Furthermore, the foot plates of the lander were equipped with tableaus containing various substrates for larvae colonisation. These compose of: 1 round colonisation chamber filled with sand covered by a sieve (1.5mm), 2 rectangular colonisation chambers filled with sand, 2 tableaus with pebbles with various lithologies, and 2 bars with coral pieces. The rectangular chambers are closed during descend and ascend of the lander. The lids are openend by spring action triggered by burn wire and closed by the ballast release of the lander.

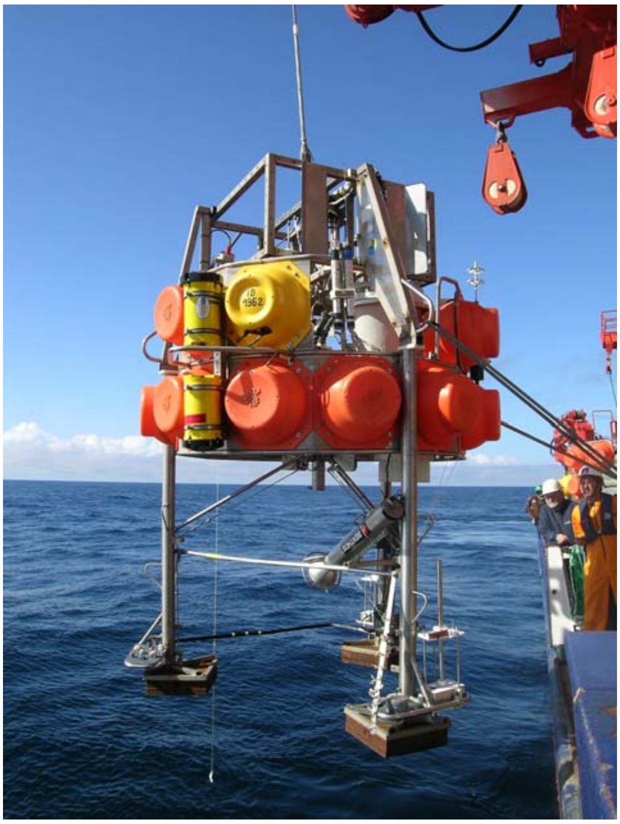


Fig 1.21: Deployment of the DOS-Lander

Fig. 1.22: The DOS Landers settled in a coral thicket on top of Galway Mound

The long-term observatory (GEOMAR modular lander, Pfannkuche and Linke 2003) was deployed video-controlled under ideal weather conditions on April 25th on top of a coral thicket of Galway Mound and will be recovered mid August with R/V POSEIDON. The time of this deployment will allow the assessment of strong seasonal fluctuations in the particle flux from the spring bloom to the summer situation. The stereo images taken in 3-hour intervals will be used for the analysis of structural changes on the reef as well as for the description of occurrence and activity of vagile megafauna. The benthic colonisation experiments will provide information about of the colonisation and modification of various substrates attached to the lander.

SAMS Optical Instruments integrated into the DOS Lander

It is thought that as suspension feeders, *Lophelia pertusa* and other cold water corals may be sensitive to increased levels of sedimentation in reef environments which may result from naturally or anthropogenic derived disturbance events. However, little is known about the natural levels of suspended particulate matter around cold water coral reefs or the upper concentrations of suspended matter in which a cold water coral can survive. Indeed visual surveys of deep-water reef environments show ripple-marked sands indicative of active near-bed sediment transport and the reef structures themselves are built upon coral frameworks infilled by mobile sediments. By deploying our optical instruments on a cold water coral reef we will obtain a baseline of natural levels and optical properties of suspended particles in such an environment. These data can be used to derive estimates of near-bed resuspension and in the future may be compared with concentrations of suspended particulate matter in disturbed cold water coral reef environments.

Tab. 1.3: Equipment and settings of the DOS Lander

Equipment	Stereo-Camera	Trap	ADCP	ADCP	MAVS-3	CTD
Model S/N	Benthos 055(B)+056(A)	KUM	RDI 0779	RDI 1015	Nobska 10107	SBE16plus 1484
Specs	30m film with 850 frames	13 sample cups	300KHz	1200 kHz	C/T/D/Turbidity	C/T/Digiquartz
Settings	200ASA / f = 11 / 0.8-1.8	8 day interval	84MB / 42V	74MB / 42V	64MB / 14.13V	8MB / 13.5V
	183min interval		15min ensemble interval		15min burst interval	10min interval
Position	downlooking	uplooking	uplooking	downlooking	uplooking	downlooking
height	164 cm	275 cm	258 cm	164 cm	286 cm	164 cm
Alignment			groove towards DOS-Lander		hole away from DOS	

Equipment	Optical package	(SAMS)		
Model S/N	UMI-datalogger 2145	C-star transmiss. 561DR	WETLABS LSS 341	Fluorometer AFLT-030
Specs		turbidity		chlorophyll
Settings	512kb / 12V			
	triggers sensors for a 60sec burst every 60min with 15sec delay			
Position	horizontal	horizontal	horizontal	horizontal
Height		50 cm	50 cm	50 cm
Alignment		parallel to crossbar	away from DOS	away from DOS

A transmissometer, light-scattering sensor and fluorometer were attached to the GEOMAR DOS Lander so as to lie 50 cm above the seabed in amongst cold water corals on the Galway Mound. The instruments were set to record readings every hour for one minute for up to four months. The results will provide estimates of particle suspension and the optical properties of the particles within this cold water coral reef environment. More specifically, data recorded from the transmissometer will provide an indication of the concentration of matter as well as the seawater clarity, whilst the light-scattering sensor and the fluorometer will monitor the turbidity and chlorophyll concentrations respectively. This work will compliment the first lander deployment on the Galway carbonate mound where the SAMS photolander provided a month-long record from these optical sensors alongside time-lapse photographs, current speed, current direction, temperature and salinity (Roberts et al. in press). This photolander was deployed at 51° 27.09N 11° 45.24W (824 m water depth). The GEOMAR DOS lander was deployed at 51° 27.28N and 11° 45.23W (806 m water depth). The lander will be recovered in August from R/V POSEIDON.

1.4.6 Benthic Bioluminescence in the Vicinity of Deep-Water Coral Habitats

(King, N., Heger, A., Jamieson, A., Wigham, B.)

In the marine environment, a large number of organisms have the capacity to emit visible light or bioluminescence. The Oceanlab ISIT (Intensified Silicon Intensifying Target/Tube) camera is designed to record deep-sea bioluminescence. Previous studies in the NE-Atlantic have successfully employed the ISIT camera to record benthic bioluminescence from a baited lander.

For this cruise, the ISIT camera was incorporated into a GEOMAR modular lander and positioned in front of a baited benthic chamber unit. In addition a Sensortek current meter was mounted on the lander frame to record current velocities, direction and also temperature, pressure and salinity. The lander was positioned on the seabed using the Oktopus video launcher system.

The main aim of this series of deployments was to study benthic bioluminescence in relation to deep-water corals and to determine whether the frequency and intensity of occurrence of spontaneous (non-stimulated) bioluminescence would change with increasing distance from the coral mounds. It was hypothesised that the frequency and intensity of bioluminescent emissions would increase in the vicinity of corals, as they are known biodiversity hotspots.

In addition, the collection of potentially bioluminescent organisms, using the adapted baited benthic chamber, allowed for the assessment of stimulated bioluminescence under lab conditions using a second SIT camera and for the identification of responsible taxa.

During the cruise, 3 deployments were attempted of which only 2 were successful in terms of collecting footage:

Deployment 1 The first ISIT-BCL deployment was undertaken on the Galway Mound (Porcupine Seabight) amongst a coral community (Stn. #221, depth ~860 m). The ISIT footage showed no consistent amount of bioluminescence. There was no evidence that bioluminescence is related to any feeding activity but emission of light was observed during the closing of the chamber, probably as a result of mechanical stimulation. As a result of the dense aggregations of corals the chamber was unable to successfully recover any sediment from the seafloor. Accompanying data from this area indicated that the dominant scavengers were lysianassid amphipods and the eel *Synaphobranchus kaupi*.

Deployment 2 The second deployment was located at the base of the Galway Mound (Stn. #235, depth ~926 m) in an area of softer sandy sediments away from any obvious coral patches. Unfortunately, this deployment was unsuccessful as the camera failed to run and the chamber was unable to collect any significant amount of sediment.

Deployment 3 The third ISIT-BCL deployment was located on an area of soft sediment at the base of Kiel Mount on the Rockall Bank (Stn. #285, depth ~950 m). During this deployment a large number of eels (*S. kaupi*) were observed and the video footage showed a significant number of large bioluminescent events.

Amphipod traps, attached to the ROBIO lander deployed in the same area, recovered lysianassid amphipods and ostracods. Lab investigations showed that the ostracods were responsible for bioluminescence. They ejected a viscous substance that emitted a pale blue light, visible to the naked eye, when mechanical (shaking) and chemical (potassium chloride solution) stimulation were applied.

In addition, amphipod and ostracod tissue samples were taken and preserved in RNA later for subsequent analysis of gene expression and eyes were frozen for visual pigment analysis.

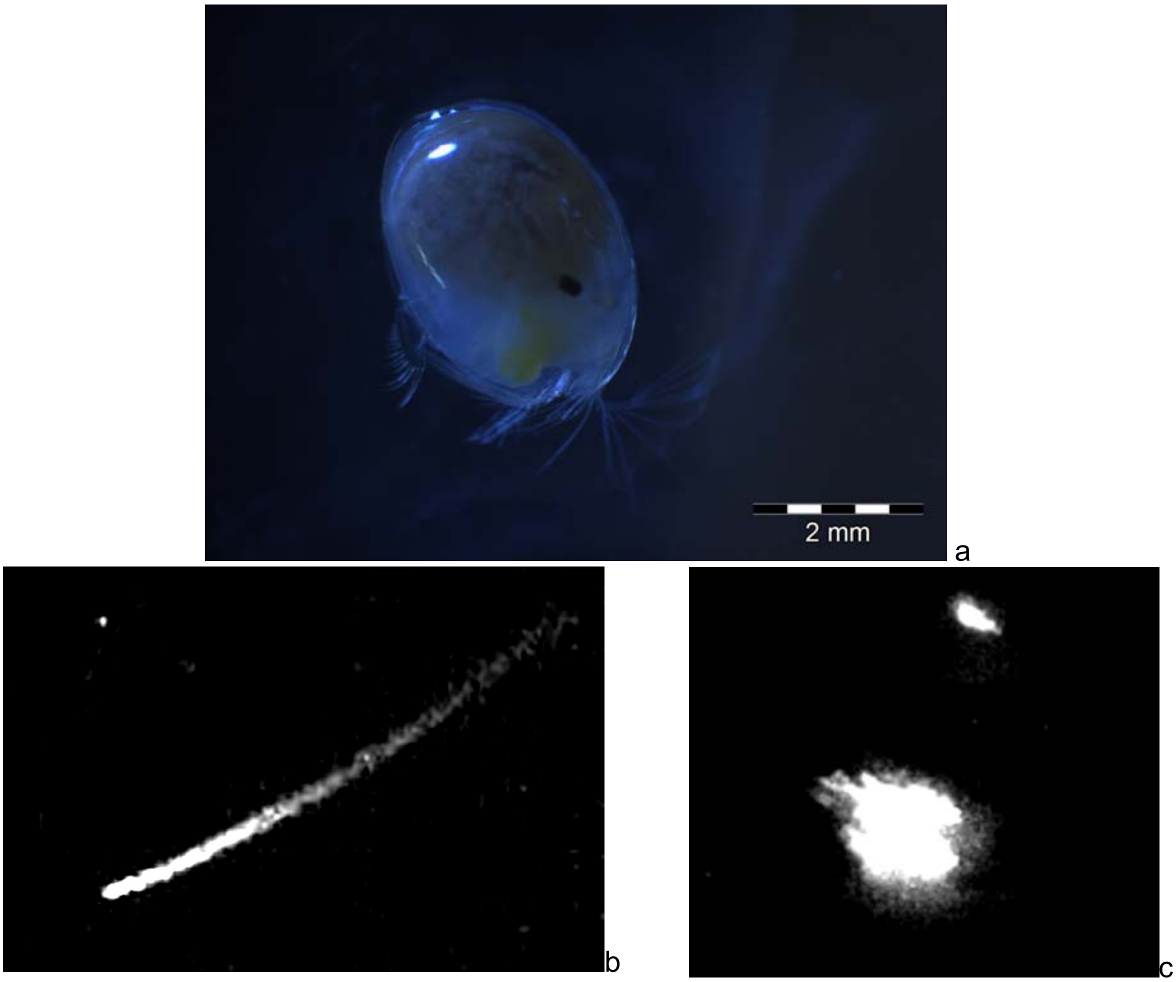


Fig. 1.23: Ostracod bioluminescence, a) Microscope image of luminescing ostracod, b) still image from ISIT video of single luminescent event on the seafloor during deployment 3, c) still image from ISIT video of large luminescent event on the seafloor during deployment 3.

1.4.7 Assessment of Scavenging Ichthyofauna Using a Baited Camera Lander

(King, N., Heger, A., Jamieson, A., Wigham, B.)

The primary aim of this experiment was to compare the distribution of scavenging ichthyofauna and invertebrates both on and off carbonate mound/coral outcropping areas in the Porcupine Seabight, and on soft sediment on the Rockall bank. The secondary aim was to obtain representative images of deep-sea fish assemblages for public outreach and education purposes.

Still photographs were captured using the baited RObust BIOdiversity lander (ROBIO) equipped with a Kongsberg digital camera and flash unit (Fig. 1.24). The lander was baited with 4 mackerel positioned 950mm in front of the camera lens on a titanium arm. The lander was deployed in "landing mode" (ROBIO may also be "tethered" above the seabed or "flown" over the seabed on a wire connected to the ship) using a 3-pointed squat clump ballast.

The baited ROBIO lander was deployed at three separate stations, 2 in the Porcupine Seabight (PSB) and 1 on the Rockall Bank.

Deployment 1 The ROBIO was first deployed south of the Belgica Mound Province (Stn. # 202, depth 931m) at a location previously identified as a bioluminescent hotspot (E. Battle pers comm.). This location was in an area of soft sediment close to buried carbonate mounds (De Mol et al., 2002). Digital still images were captured every minute for a total of 6 hrs 24 min post-touchdown. The images revealed the dominant scavengers to be the eel *Synaphobranchus kaupi* and lysianassid amphipods. Other fishes attracted to the bait were several species of elasmobranch (Fig. 1.23a.) and the teleost fishes, *Mora moro* and *Phycis blennoides*. Baited traps attached on the underside of the lander recovered a number of lysianassid amphipods and potentially other small invertebrates. Bioluminescence was observed within the traps using a Silicon Intensifying Target (SIT) low-light camera. However, the organisms responsible were not identified.

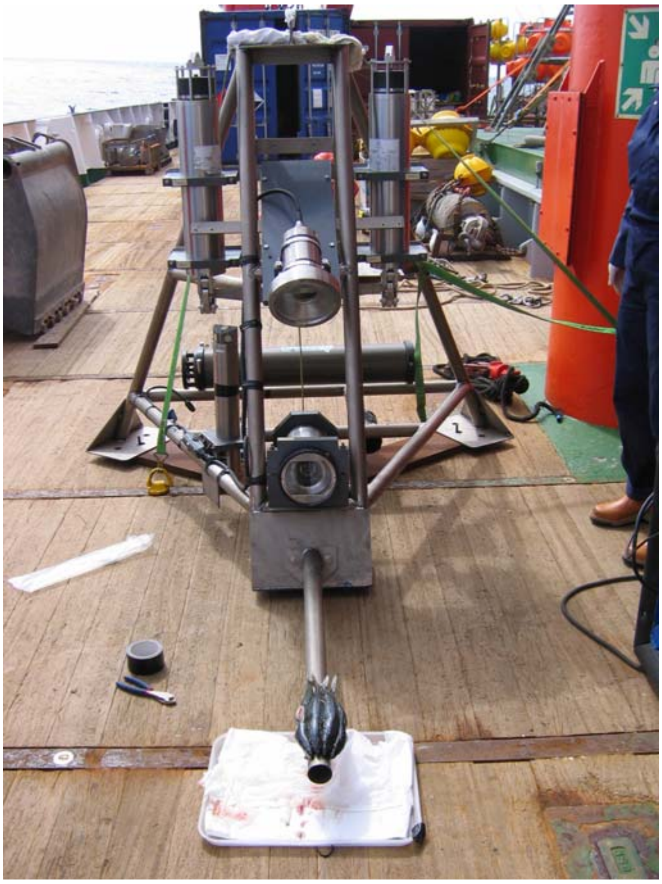


Fig. 1.24: The RObust BIOdiversity lander (ROBIO) showing baited arm, camera, flash and twin acoustic releases.

<u>Deployment 2</u> The second ROBIO deployment was located on the periphery of the Pollux Mound (Stn. # 246, depth 981m). Digital still images were captured every minute for a period of 5 hours 56 minutes. during the night and early morning of the 25th-26th April. The lander settled at a 10° tilt, possibly a result of resting on a raised area of coral outcropping. *Madrepora* sp., *Acapnella* sp. and unidentified sponge species are clearly visible on the benthos (Lydia Beuck, personal comm.). The dominant scavengers were the teleost fishes, *Mora moro* (Fig. 1.25a.) and lysianassid amphipods. There was a clear reduction in the number of *Synaphobranchus kaupi* attracted to the bait compared to deployments 1 and 3. Elasmobranch species attracted to the bait included *Galeus* sp. and an unidentified Scyliorhinid. Benthic invertebrate fauna observed were the crustaceans *Bathynectes* sp. and *Munida tenuimana*. Bioluminescence was not recorded from the amphipods recovered in the traps.

Deployment 3 The third ROBIO deployment was on the Rockall Bank in an area of soft sediment at the base of the Kiel Mount (Stn. #286, depth 934 m). The amount of bait placed on the titanium arm was increased to 8 mackerel and one additional bait fish was secured inside the pole to prevent early removal of the bait by large scavengers. The dominant scavengers attracted to the bait were the eel *Synaphobranchus kaupi,* lysianassid amphipods and several species of elasmobranch, including *Centrophorus* sp. (Fig. 1.25b) and *Deania calceus* (Fig. 1.25c.). Teleost fishes *Mora moro* and *Phycis blennoides* were also present at the bait. Invertebrate fauna observed in the area surrounding the bait were a gastropod mollusc, *Colus* sp., pagurid crabs, a spider crab and numerous ophiuroids. Numerous ostracods appeared to swarm around the bait and be consumed by *Synaphobranchus kaupi*. Both amphipods and ostracods were recovered in baited traps positioned on the underside of the lander.

a

b

c

Fig. 1.25: a) *Mora moro.* b) *Galeus* sp. c) *Synaphobranchus kaupi* and *Deania calceus*. For scale see the full lander in Fig. 1.24.

1.4.8 Sediment Sampling and Foraminiferal Studies

(Schönfeld, J.)

Among small benthic organisms, foraminifera are found in all marine environments, depict high species richness, and their tests are well preserved in the fossil record. It is commonly recognized that deep-sea benthic foraminiferal faunas are strongly structured and reflect changing environmental conditions. Over the last three decades, a basic concept has been developed how environmental factors, in particular food and oxygen, influence benthic foraminiferal assemblages (Altenbach and Sarnthein, 1989; Jorissen et al., 1995; Fariduddin and Loubere, 1997; Van der Zwaan et al., 1999; Fontanier et al., 2002). A suite of key species was assessed that serve as reliable indicators for the origin, amount, and quality of particulate organic matter reaching the sea floor (Gooday, 1988; Gooday and Lambshead, 1989; Caralp, 1989; Altenbach et al., 1999) and a serious drawdown in bottom-near water oxygenation (Kaiho, 1994; Baas et al., 1998; Cannariatto and Kennett, 1999; Bernhard and Sen Gupta, 1999; Schönfeld, 2001). These valuable taxa for palaeoceanographic and palaeoecological interpretations represent, however, only a few percent of all species present. From concomitant variations in species-independent assemblage parameters as abundance, diversity, and dominance it is evident, that the entire fauna responds to changing environmental conditions (Murray, 2001; Gooday, 2003). Biotic processes such as competition, predation, facilitation, disturbance, recruitment, and interaction with large metazoans and bacteria leave also an impact in the structure of foraminiferal communities (Haward and Haynes, 1967; Dobson and Haynes, 1973; Alexander and DeLaca, 1987; Freiwald und Schönfeld, 1996; Beaulieu, 2001; Ernst et al., 2002; Langezaal, 2003). This web of direct and indirect effects and its expression in assemblage parameters and foraminiferal distribution patterns is yet partly known and poorly understood.

The distribution pattern of benthic foraminifera from the Porcupine and Rockall areas to the south and west off Ireland is only partly known, and it has not been systematically compiled to date. Near-shore studies concentrated on western Irish bays, Bristol and St. Georges Channel and provided only regionally confined information (Heron-Allen and Earland, 1913; Murray, 1970; Dobson and Haynes, 1973; Lees et al., 1969). A definition of benthic foraminiferal associations, survey of their distribution, and assessment of primary controlling environmental factors was presented by Weston (1985) for the Porcupine Seabight and Western Approaches continental slope. The carbonate mound province on the eastern slope of the Porcupine Seabight was left out, probably because the grab samples contained a high amount of sand-sized detrital material (Weston, 1982). A first description of benthic foraminiferal faunas from carbonate mounds is based only on four gravity cores from the Porcupine Seabight (Coles et al., 1996). The foraminiferal abundance was lower but the diversity was higher on the mounds as compared to the ambient sediments suggesting that the hard substrates provide more niches for a wider variety of foraminiferal taxa.

The foraminiferal studies intend to improve the sample coverage on the western Irish margin in order to facilitate a systematic survey of benthic foraminiferal species distribution and assemblage parameters. The regional scope is combined with detailed investigations of micro and meso-scale patchyness for a determination of microhabitat structures and biofacies patterns. Together with a joint biodiversity assessment including macrofaunal groups, the data will reveal biotic interactions and limiting environmental factors. This will help to localise key areas of high environmental sensitivity for foraminiferal assemblages and to describe the interaction with ambient biocoenoses. Emphasis is likewise given to abiotic factors. We will assess the influence of different trophic regimes, near-bottom currents and substrate properties on sensitive key areas.

Sedimentary archives are studied in order to constrain periods of elevated environmental stress during the Holocene and last Glacial and to describe the response of foraminiferal diversity and assemblage structure. These studies are accompanied by colonisation experiments. They may help to develop an understanding how fast a living assemblage will react to profound environmental changes in a way that the signal is transferred to the fossil record.

Paleoceanographic objectives for sediment coring were to obtain records of carbonate mound development, intermediate water circulation, sediment accumulation during of Late Pleistocene climatic fluctuations. Especially we intend to trace the Glacial North Atlantic Intermediate Water formation that has been suggested to have taken place in this region (Saidov and Haupt, 1997).

Surface sediment sampling

A box corer was deployed at 15 stations in the Belgica Mound province and at Kiel Mount, Rockall Plateau without technical problems (Fig. 1.26 and 1.27). The box corer used permits the recovery of 50 x 50 x 50 cm of surface sediments. When on board, the overlying water was sucked off and passed through a 0.3 mm mesh to collect small, vagile benthic organisms. The surface sediment or coral rubble was then sampled as described below.

A Van Veen Grab sampler was used at 29 stations in the Belgica Mound province, at Kiel and Franken Mound, Rockall Plateau. Even though the device was deployed regularily with a pinger in order to recognize bottom contact, it often failed and brought no substantial recovery. Representative samples were only retrieved from dense coral thickets or homogenous sands. The sediment surfaces from sandy bottom were occasionally well preserved. When on board, the lids were opened for a first assesment of sample quality and decision for subsequent procedures. Once the surface sediment was well preserved, sampling was performed through the lids. In case the grab contained coral rubble, a few dropstones or shell debris, it was opened over a plywood tray, documented and sampled for macrofauna. The inventory of living makroinvertebrates is given in the chapter on macrofaunal analyses.

Sampling procedure for foraminiferal studies

The foraminiferal studies require largely undisturbed sediment surfaces and a representative coverage of different microhabitats and small-scale variations in sediment composition. Thus we mainly focused on box core samples. Van Veen and TV grab samples were also considered in case a first visual inspection suggests that material from the immediate surface was recovered (Fig. 1.26 and 1.27).

The uppermost centimetre was sampled on box core surfaces. We used a frame of 87,6 cm^2 that was pushed in the sediment at two different places. A representative coverage of different microenvironments on the sediment surface was attempted. The sediment was carefully removed with a spoon. A 1 cm - gauge on the inner side of the frame helped to keep the required depth level. The final sample volume was marked on the vial, and the surface sample was immediately conserved and stained with a solution of 2 grams Rose Bengal in 1 litre Ethanol (technical quality, 98%) (Lutze and Altenbach, 1991; Murray and Bowser, 2000). This sample will be used to study the living, shallow epi- and endobenthic foraminifers, and the dead assemblage in the surface sediment.

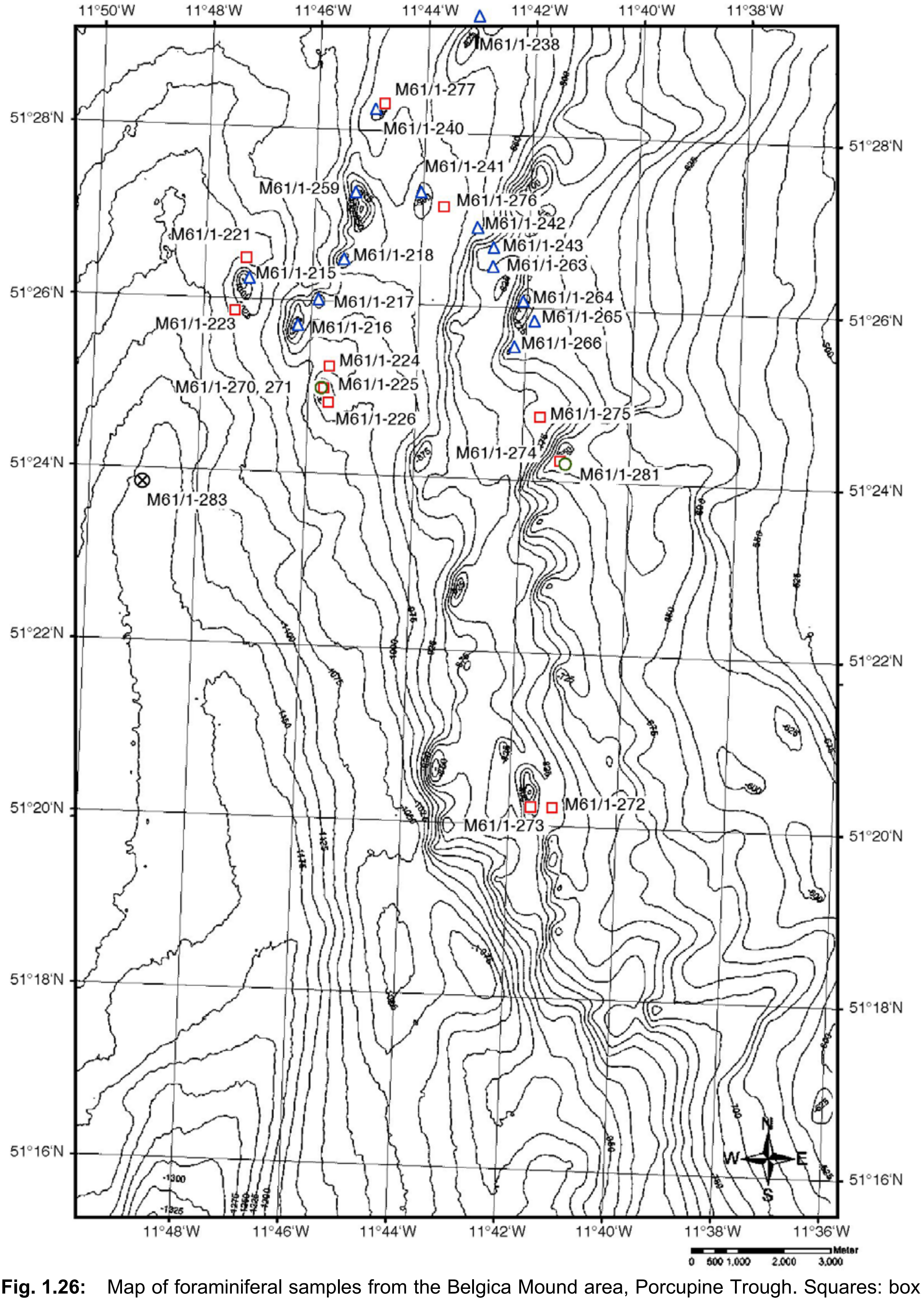


Fig. 1.26: Map of foraminiferal samples from the Belgica Mound area, Porcupine Trough. Squares: box cores, triangles: grab samples, circles: sediment cores, crossed circle: multicorer. Note that the colonization experiment is deployed at the location of sample M61-1-259 on top Galway Mound.

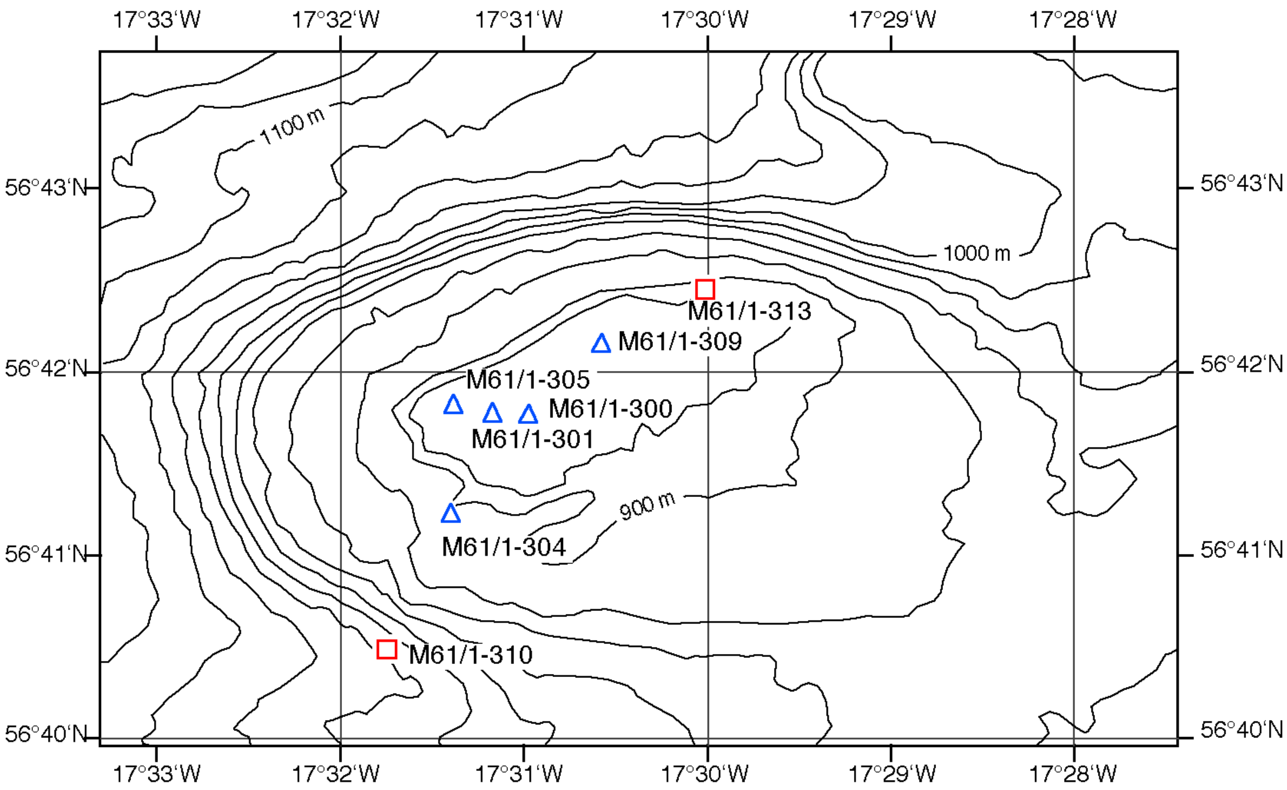


Fig. 1.27: Map of foraminiferal samples from Kiel Mount area, Rockall Bank. Squares: box cores, triangles: grab samples.

A representative suite of elevated hard-substrates like dropstones, coral debris or mollusc shells were carefully removed from the sediment surface of box cores and conserved in Rose Bengal - Ethanol too. These objects will be examined for attached epibenthic foraminifers (Oschmann, 1990; Schönfeld, 1997; 2002). Staining facilitates the recognition of living specimens, as it has been proven that empty tests of *Placopsilina confusa* and *Cibicides refulgens* still stick to the host after reproduction. Particular attention was paid for a careful handling of these objects to not destroy the "mudline" of fine, adherent sediment that serves as zero level for the attachment height of epizoans.

After surface sampling and removal of elevated objects, a 10 cm^3 syringe sample was taken from the surface close to the frame. This sample will be used to analyse the organic carbon and chlorine content of the surface sediment. The lid of the box corer was opened and an archive box covering the near-surface strata was taken as reference. Furthermore, a 2 cm - spaced series of 10 cm^3 syringe samples was taken for studies of Holocene foraminiferal and palaeoceanographic records.

A different sampling scheme was followed once the box corer or grab recovered coral rubble. As the original texture or framework was mostly disarranged due to sampling, a zero level could not be defined. Therefore, a representative variety of hard-substrates were removed from different places of the sample and conserved in Rose Bengal - Ethanol. Preference was given to pieces that show overgrowth by foraminifera (mostly large specimens of *Cibicides lobatulus* or *C. refulgens* visible by eye), hydroids, crinoids or sponges. Interstitial sediment was sometimes present around coral fragments in the lower part of the box core or grab samples. The soft, upper levels of this sediment were scraped off with a spoon as separate sample that was conserved in Rose Bengal - Ethanol too.

Sediment coring

We used a conventional gravity corer with tube lengths of 3 and 6 m and a weight of 1.5 tons. Three gravity cores with a total length of 1194 cm were recovered from five stations. A 277 cm and a 405 cm and long core of hemipelagic foraminiferal mud with abundant coral fragments were retrieved from the top of Pollux Mound (Stat. 271). Another core from the vicinity of a buried mound retrieved 512 cm of dark grey hemipelagic mud (Stat. 281) (Fig. 1.26). Gravity coring was not successful in lag deposits near mounds Galway, Therese and Pollux (Stat. 282), and in foraminiferal sands overlying brown muds to the south of Kiel Mount (Stat. 312).

The cores were cut into one-metre sections and stored under cool conditions. Opening, description and sampling on board was dismissed, as logging and X-Ray tomography will be done before opening. The computer tomography images will provide further insight into the abundance and orientation of coral fragments in the sediment succession.

Colonisation experiments

Benthic colonisation experiments were deployed with the DOS lander.The colonisation experiment comprised a variety of natural hard and soft substrates mounted to the footplates of the lander. We chose dropstone-alike beach pebbles of limestones, basalts, and granite as hard substrates and exposed them horizontally close to the seabed. Living and dead coral fragments and limestone pebbles were mounted on vertical poles from 5 to 60 cm above the base of the footplates. Coral fragments were sterilised, and all hard substrates were stripped for epizoans before deployment. Soft substrates include carbonate sand, silty terrigenous sand, and mud. The sediments were also sterilised before deployment, and they were exposed in chambers mounted to the lander footplates.

The substrates simulate various niches of the coral mound environment. Benthic foraminiferal reproduction is considered to take place shortly after spring bloom (Bertram and Cowan, 1999; Gooday and Lambshead, 1989; Gooday and Huges, 2002). The recruitment of elevated substrates is most likely effected by propagules displaced by bottom-near currents (Mullineaux and Butman, 1990; Beaulieu, 2001; Schönfeld, 2002). The temporal and environmental setting thus provides favourable conditions for a recruitment of the exposed substrates.

1.4.9 Macrofauna Documentation: The Hidden Biodiversity of Cold-Water Coral Ecosystems

(Beck, T., Freiwald, A., Taviani, M., Vertino, A., Schiemer, I.)

The species diversity of the cold-water coral ecosystem is still poorly explored. This is especially true for the macrofauna that is generally not visible on underwater photographs or video documentation taken from ROVs, OFOS or manned submersibles. During M61-1 great effort was invested to document the fauna alive collected the various sampling gears immediately after sampling. Many species presented here, are illustrated alive for the first time.

Directly after the photographic documentation of the freshly taken seabed samples, all apparent living animals were removed and were placed into seawater-filled basins that were stored in the cold room. After the geological/sedimentological sub-sampling the remaining surface sediment was sieved carefully using mesh sizes from 0.2 to 4 mm. Of main importance was the good preservation of fragile animals. Next step in processing was detailed sorting of living animals under the microscope.

A photographic documentation system was then used to take digital images of the living animals. This time consuming work, however is of utmost importance as many taxa loose important diagnostic features once they are dead and fixed. The IPAL doc umentation system consists of a computer-guided digital camera system mounted on a binocular. The ANALYSIS software package provided a multitude of different photographic features.

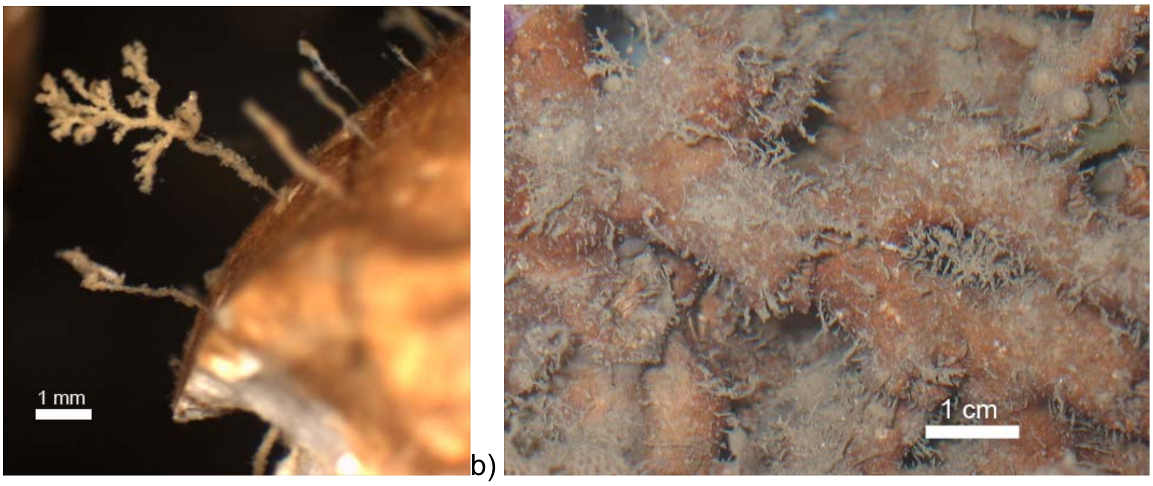
Specimens larger than 3 cm were documented using an ordinary digital camera. As a last step the remaining sieve fraction was either fixed with 70% Ethanol or simply air-dried. Taxonomic groups not covered by the expertise on board were documented, using the photographic documentation system provided by the IPAL group. The documented specimens were kept separately and will be sent to specialists for further reliable identification.

In situ documentation is of major interest concerning all kind of epifauna. In the present context especially the in situ documentation of epifauna on coral framework allows to get more information about the species associations of that specific substrate. Due to the fact that the studied coral habitats are not easily accessible, the knowledge about the habitat and the animals living there is still very limited. Even more limited is the knowledge about species ecology and behaviour. Many of the species sampled on M61-1 have been documented alive for the first time.

In the following, some first results, focusing on faunal highlights are presented:

Foraminifera

Komokiacea Relatively large sized unicellular benthic organisms build up of cytoplasm surrounded by agglutinated material (Fig. 1.28a). Mostly reported from deep-sea habitats. This group is classified within the foraminifera. Members of this group have been found to be the main builders of the characteristic fluffy coverage of exposed dead coral framework (Fig. 1.28b). Komokiacea have also been found on other hard substrate during M61-1.

a) 

b)

Fig. 1.28: a) Komokiacea, very frequent hair-like epifauna on dead coral, large specimen 4mm. b) Branch of dead *Lophelia pertusa* densely covered by unidentified komokiaceans.

Porifera

Several large and well-preserved specimen of the hexactinellid sponge *Aphrocallistes bocagei* (Fig. 1.29a) have been sampled (see benthic sample protocol for stations 215, 216, M61-1-217, 218, 221, 222, 223, 224, 225, 226, 240, 241, 259, 272, 317, 318). This species turned out to be one of the most common sponges in deep-water coral habitats of both the Porcupine-Seabight and the Western Rockall Bank. Dead sponges were often used as substratum mainly by a typical yellow-coloured species expanding into the skeleton of *Aphrocallistes*). A bright yellow non-agglutinating zoantharian species appeared to grow exclusively on *Aphrocallistes*. Another hexactinellid sponge, *Mellonympha velata*, was found in the sample M61-1-215 (Fig. 2b). This species is relatively rare compared to *Aphrocallistes*. A large number of small-sized sponge species is present and awaits further investigations by sponge taxonomists.

a) b)

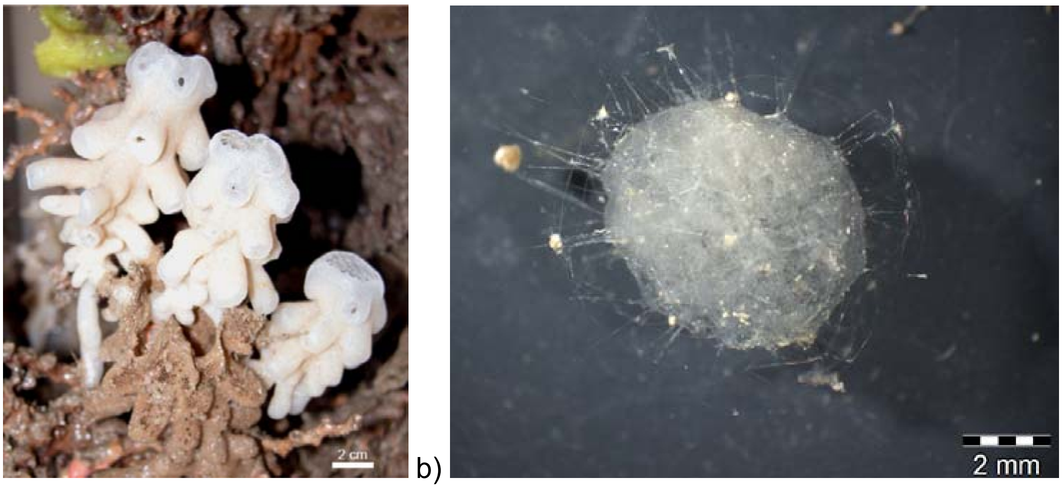


Fig. 1.29: a) Three juvenile *Aphrocallistes bocagei* settling on a subfossil *Aphrocallistes*, height about 10 cm. b) Hexactinellid sponge ?*Mellonympha velata,* often growing in clusters of several species, may reach 12 cm in height.

Cnidarians

Hydroids A large number of densely branched non-calcified hydroids are found as epifauna on *Lophelia* and *Madrepora* frameworks as well as on dropstones (Fig. 1.30a). In samples from the dropstone habitats also stylasterids (calcified hydroids) were present (Fig. 1.30b). The colonies of *Pliobothrus symmetricus* were big enough to be also identified from OFOS imagery. In sample M61-1-223, one specimen showed typical feeding traces of the parasitic gastropod *Pedicularia sicula* (see benthic sample protocol for stations 215, 223, 225, 226, 238, 241, 242, 276). In some coral samples other stylasterids (*Stylaster* sp.) were growing on dead coral skeleton (see benthic sample protocol for stations 300, 309, 311).

Zoantharians A brownish stolonial species that normally agglutinated a lot of particles commonly occurs on each kind of hard substrate. *A. bocagei* skeletons were sometimes settled by a yellow-coloured species, which seem to be restricted to that special substrate (Fig. 1.31a).

Actinians Several coral samples contained actinians. Most frequent was a small species (<3cm) of soft consistence and pale reddish/pink colour. Another species formed dense clusters growing on coral fragments. This small actinian (<3cm) is recognizable by its orange to red mouth plate and the compact growth form. It is related to the genus *Nemanthus* (Fig. 1.31b).

Scleractinians *Lophelia pertusa* and *Madrepora oculata* were the most frequently encountered species in all benthic samples (Stat.-No: 215, 216217, 218, 221, 222, 223, 224, 225, 226, 238, 239, 240, 241, 242, 243, 259, 260, 264, 266, 273, 275, 276, 277, 300, 301, 305, 306, 309, 313, 317, 319). The solitary corals *Desmophyllum cristagalli*, *Caryophyllia sarsiae* und the worm-like *Stenocyathus vermiformis* were frequently present in the sediment samples (for solitary corals see benthic sample protocol for stations: 215, 216, 221, 223, 224, 225, 226, 241, 242, 259, 260, 264, 273, 274, 277,300, 301, 305, 309, 313). Living specimens were very rare.

Only once (Stat. 274) few *Fungiacyathus fragilis* and *Flabellum macandrewi* (Fig. 1.32a) have been found.

Antipatharians A very fragile branched species probably of the genus *Parantipathes* (Fig. 1.32b) was sampled on station 264.

Alcyonarians Some specimens of the stolonial species *Anthothela grandiflora* were sampled (Fig. 1.32c) (Stat. 225, 259). This species is very spectacular because of its intense purple colour and also has been documented with the OFOS system.

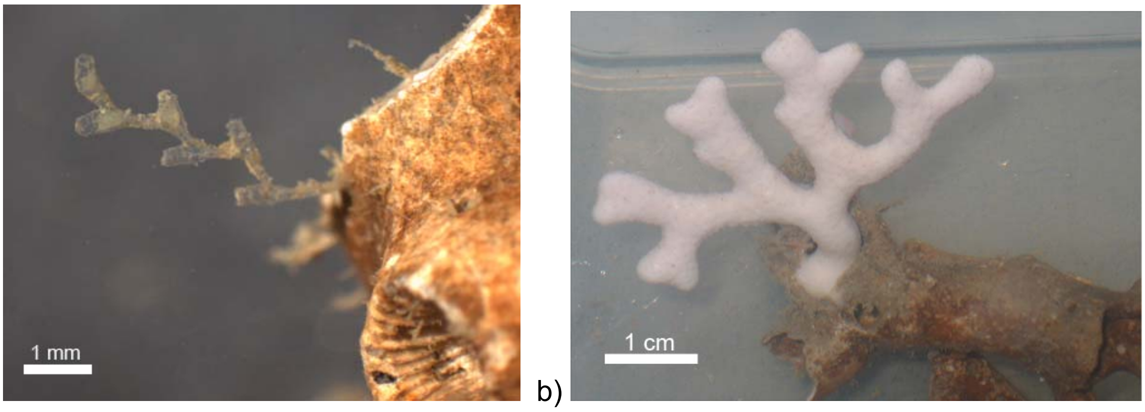
a)


Fig. 1.30: a) Unidentified hydroid colony, epifaunal on dead coral, 4 mm in length, M61-1-223. b) *Pliobothrus symmetricus*, most characteristic feature of the dropstone habitat, colony 4 cm high.

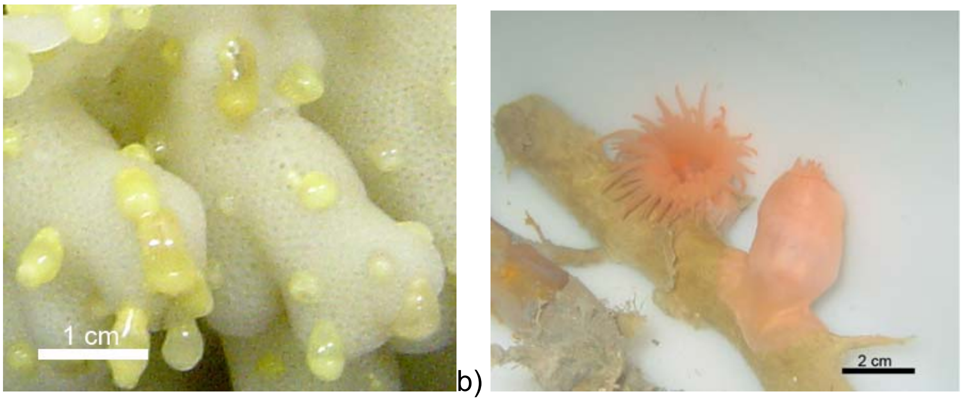
a)


Fig. 1.31: a) *Aphrocallistes bocagei* settled by yellow zoantharians only found on *Aphrocallistes* (M61-1-225). b) Unidentified actinian (?*Nemantus* sp., with typical orange-red mouth plate, often forms dense clusters on dead coral, 2-3 cm in diameter.

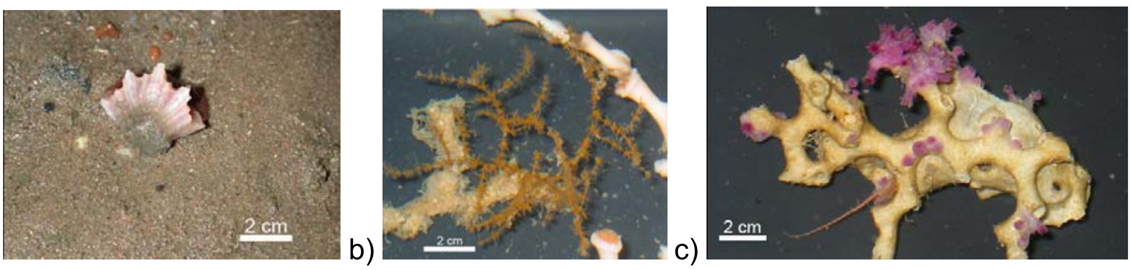
a)


Fig. 1.32: a) *Flabellum macandrewi*, this solitary coral is living on soft sediment. M61-1-274. b) fragile antipatharian, probably *Parantipathes* sp., Belgica Mound station M61-1-264. c) *Anthothela grandiflora*, “stolonial” alcyonarian growing on dead coral framework. M61-1-225.

Gorgonians Several specimens of the species of *Acanthogorgia armata* and *Paramuricea* sp. have been sampled (Stat. 216, 217, 225, 259, 264). Different amphipods and Solenogastres are associated with these species indicating a mutual relationship between the hosting gorgonian and the associa-ted species (Fig. 1.33). There has been no indication for the presence of parasitic amphipods. One unidentified gorgonian was sampled. Subfossil fragments only represented the group of the Isidiids. However, living isidiid corals were frequently documented on Kiel Mount with OFOS.

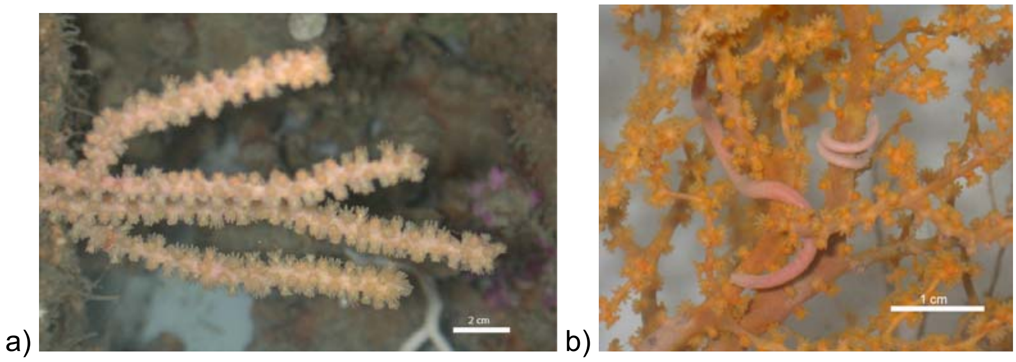


Fig. 1.33: a) *Acanthogorgia armata*, frequently occurring in coral habitats, specimen 15 cm high, M61-1-225. b) *Acanthogorgia armata* (gorgonian) with associated Solenogastres. Caught in MOCNESS station M61-1-234.

Molluscs

The following species were found in almost every sample from coral habitats: *Addisonia excentrica, Alvania cimicoides* (Fig. 1.34a)*, Alvania jeffreysi* (Fig. 1.34b)*, Alvania zetlandica, Amphissa acutecostata* (Fig. 1.34c)*, Anatoma crispata, Asperarca nodulosa* (Fig. 1.34d)*, Astarte sulcata, Boreotrophon clathratus* (Fig. 1.34e)*, Calliostoma* cf. *leptophyma , Chlamys sulcata, Delectopecten vitreus* (Fig. 1.34f)*, Emarginula* cf. *christiaensi, Heteranomia squamula, Hiatella arctica, Iphitus tuberatus* (Fig. 1.35a)*, Propilidium exiguum, Pseudosetia turgida, Puncturella noachina, Pyrunculus ovatus, Strobiligera* sp. and *Talassia dagueneti.* Also living specimen of all these species were found and documented! We regard these 22 species as characteristic for the coral habitat in all the different study sites. For some of the cited species also their specific faecal pellets were documented (Fig. 1.35b-d). The majority of the "coral species" are gastropods. There are many particularly small species that seems to be specially adapted to this habitat. Most of the small species are detritivorous or feeding on foraminifera. The larger species either feed on Porifera or other sessile animals. Only few species are carnivorous like *Boreotrophon clavatus.* Several eulimids were found. Preliminary identification was only possible for some specimen belonging the genus *Fuscapex.*(Fig. 1.35e). Only one gastropod species was found which probably feeds on scleractinians. *Iphitus tuberatus* is not yet known by direct observation to feed on scleractinians. Other species of the genus *Iphitus* are known to be parasites.

Several authors suggest a relationship between *I. tuberatus* and scleractinian corals (Taviani & Sabelli, 1982; Bouchet & Warén, 1986). Bouchet & Warén (1986) namely mentioned *Lophelia*. Onboard, a small experiment has been carried out. Several of the living *Iphitus tuberatus* specimens were kept in small containers together with pieces of living *Lophelia* and *Madrepora*. During one week of observation, no obvious interest of *Iphitus* to approach the living parts of the corals has been documented.

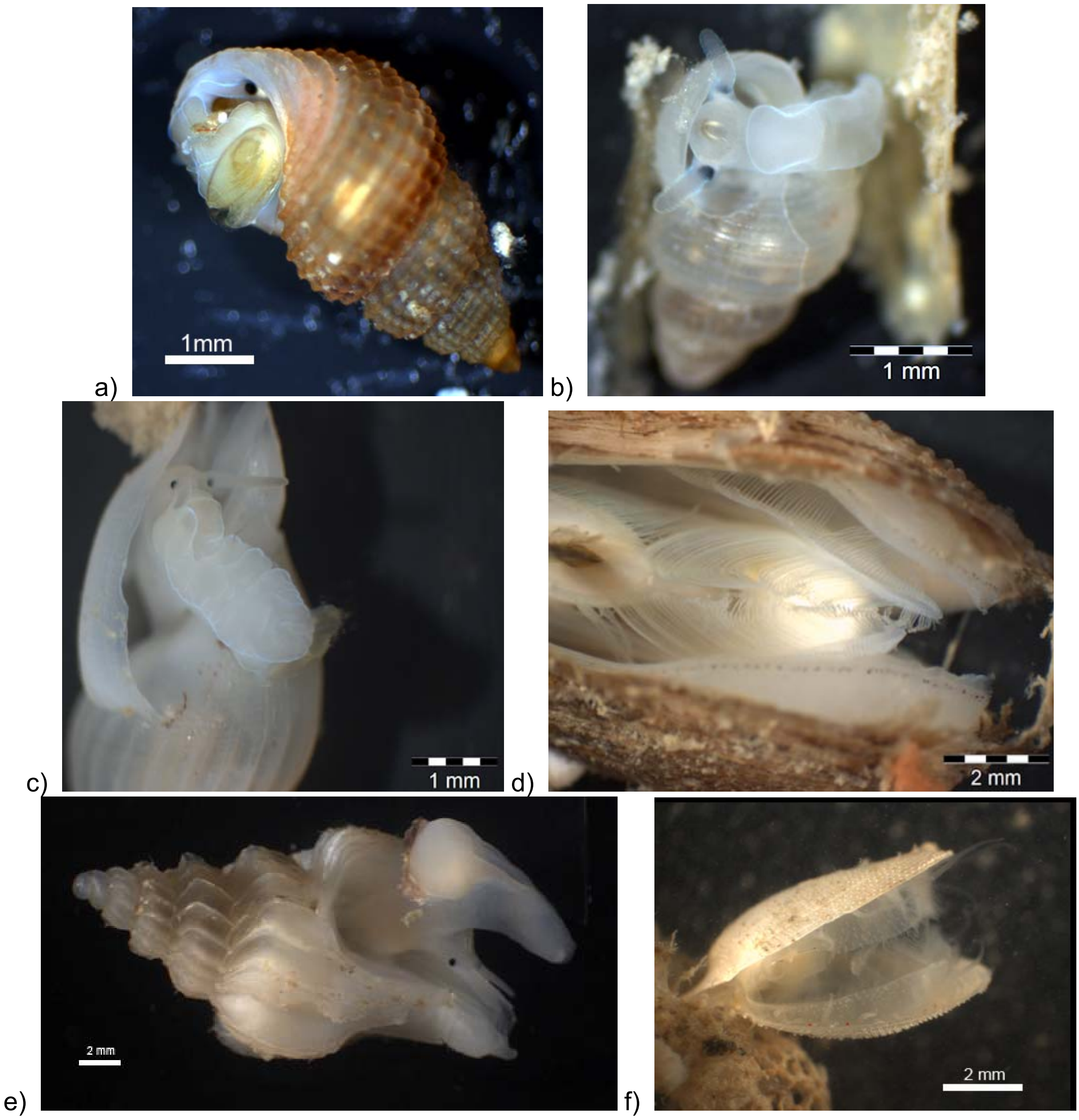


Fig. 1.34: a) *Alvania cimicoides*, 3.5 mm. This is the commonest rissoid gastropod in coral habitats, M61-1-234. b) *Alvania jeffreysi* one of the most frequent gastropod species in the coral habitat, 2 mm, M61-1-234. c) *Amphissa acutecostata* the most frequent gastropod in all samples, up to 7 mm. M61-1-272. d) *Asperarca nodulosa* (bivalve). Detail of soft parts, note the branchiae and the eyes, body size 1.4 cm. Present in all coral samples. e) *Boreotrophon clathratus*, 1.3 cm, carnivorous species, only found alive in M61-1-234. f) *Delectopecten vitreus* (Pectinidae), very common in coral habitats, 1.4 cm, M61-1-225.

The sampling on Kiel Mount brought up some spectacular findings. Marco Taviani identified several mollusc species alive that were described only from the early Pleistocene bathyal coral deposits at Messina, Sicily, some 2 Million years ago. The most spectacular findings were several specimens of a very characteristic cone-shaped limpet caught on station M61-1-300, attributed to genus of *Fissurisepta*. This species seems to be *F. rostrata* Seguenza, 1862, which has been described from Pleistocene bathyal coral deposits from Sicily (Fig. 1.36a). Since the description in 1862, this species has been reported only once by Jeffreys (1882).

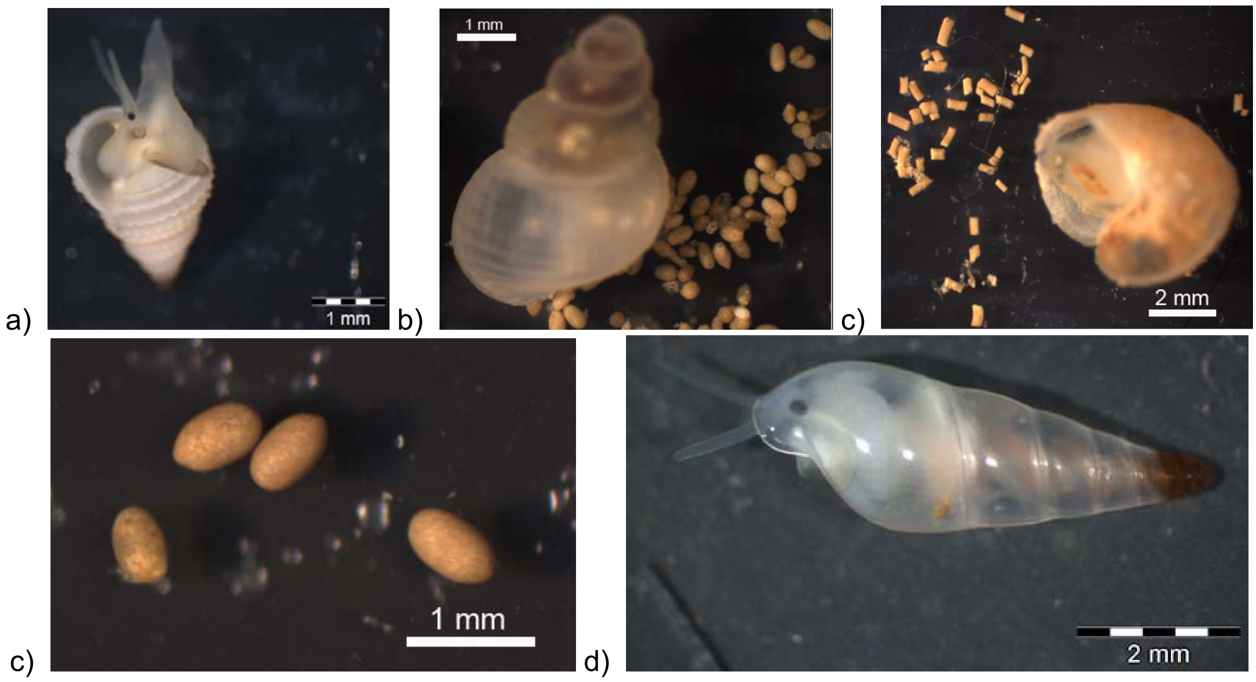


Fig. 1.35: a) *Iphitus tuberatus*, 2 mm, possibly parasitic on corals, M61-1-234. b) *Alvania jeffreysi* with faecal pellets, shell 2,3 mm, M61-1-234. c) *Anatoma umbilicata* with fecal pellets, M61-1-234 d) Faecal pellets of *Alvania cimicoides*. e) *Fusceulima* sp., eulimid gastropod parasitic on echinoderms, characterised by its brownish protoconch, M61-1-234.

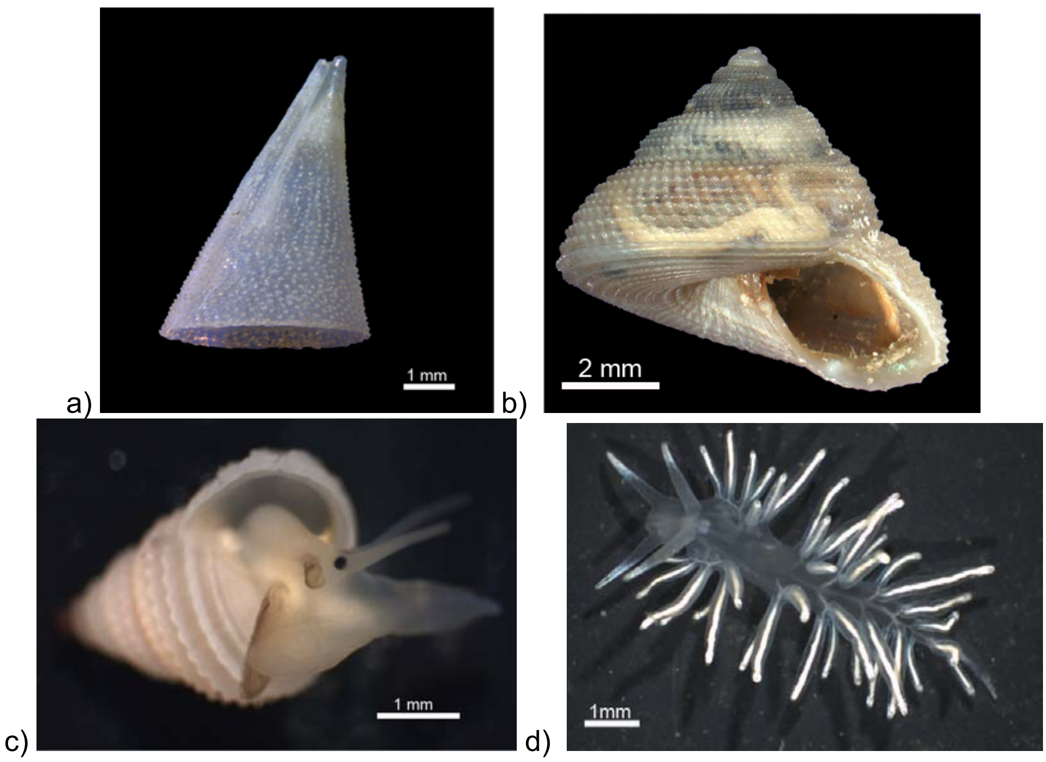


Fig. 1.36: a) *Fissurisepta rostrata*, large specimen 4 mm high. Since it's description by Seguenza this species only has been reported once in European waters. Found in sample M61-1-300 on Kiel Mount. b) *Ancistrobasis reticulata*, a very rare species, several findings have proven the presence of healthy populations at least on Rockall Bank. M61-1-234. c) *Iphitus tuberatus*, 2 mm, possibly parasitic on corals. M61-1-234. d) Unidentified Nudibranch (Gastropoda), 5 mm, only this specimen found. Little Galway (Belgica) Station M61-1-218, 871 m.

From a bio-geographical point of view the repeated finding of living *Ancistrobasis reticulata* is noteworthy (Fig. 1.36b). This species seems to be present in well-installed populations on Western Rockall Bank as well as in the Porcupine Seabight. The occurrence in the study areas is an important extension of its previously known range. *Ancistrobasis reticulata* is usually living in the western parts of the Atlantic and elsewhere was reported only with a single specimen from Iceland (Warén, 1991) .

Another uncommon gastropod, the caenogastropod *Talassia dagueneti* was also found alive (Fig. 1.36c). This species has not yet been found so far north (pers. comm. A. Warén). Several findings of living specimens are supporting the presence of a healthy population in the Porcupine Seabight. At station 218 from Little Galway Mound the only nudibranch was found (Fig. 1.36d).

Polychaetes

Polychaetes were represented in almost all the benthic samples. In coral samples many different species were present. The most striking species is the large *Eunice norvegica* that reaches up 20 cm in length (Fig. 1.37a-c). This species lives closely associated to the colonial scleractinians *Lophelia* and *Madrepora*.

Almost no coral colony has been found without *Eunice* being present. A very characteristic reddish Polychaete of the family Hecionidae was also present in nearly all samples containing dead or living coral (Fig. 1.37d). In some boxcore samples from the Belgica area, another large species was found. This species resembles *Eunice norvegica* but is bigger (up to 25 cm) and of brownish colour. It always was found burrowed in the sediment. On dropstones and coral framework, a large number of serpulids were found. Attached to larger pieces of dead coral framework u-shaped tubes of a chaetopterid worm was found, some of them were still containing the animal. This species has only been found in samples from the western Rockall Bank.

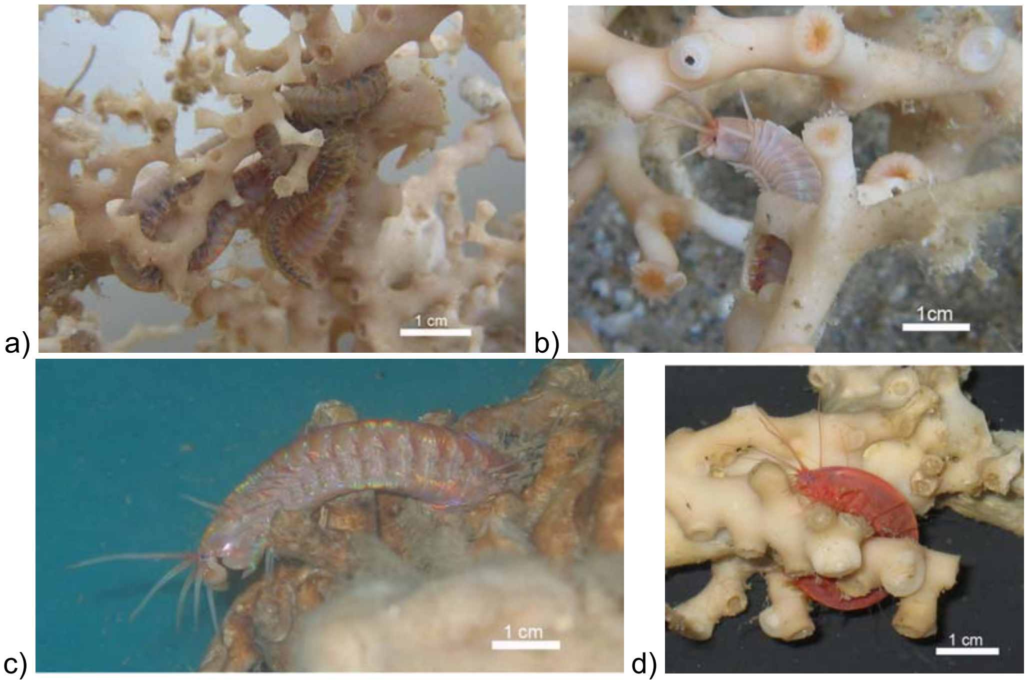


Fig. 1.37: a-c) *Eunice norvegica*, large polychaete that may reach 20 cm (a), co-occurring in close association with with *Lophelia* (d) and *Madrepora* (a). d) Not closer identified hecionid polychaete, beside *Eunice* the by far most frequent large polychaete in coral habitats, 4 cm.

Crustacea

A large number of different, not further identified cumaceans (Fig. 1.38a), amphipods (Fig.1.38b and c), isopods and caprellids (Fig. 1.38d) were found in various samples. The distinctive amphipod species *Epimeria tuberculata* was a rather common one in the Belgica Mound Province. The species of Epimeria are very opportunistic and feeding on each kind of prey. A frequent brachyuran species in coral samples was *Bathynectes maravigna* (Fig. 1.38e), a portunid crab. Squatlobsters (*Munida* sp.) (Fig. 1.38f) were also caught in various samples. Two different balanids (cirripeds) has been encountered. *Verruca stroemia* is frequently growing on all kind of hard substrate. Another species, presumably *Bathylasma* sp. is a most characteristic feature of the dropstone habitats.

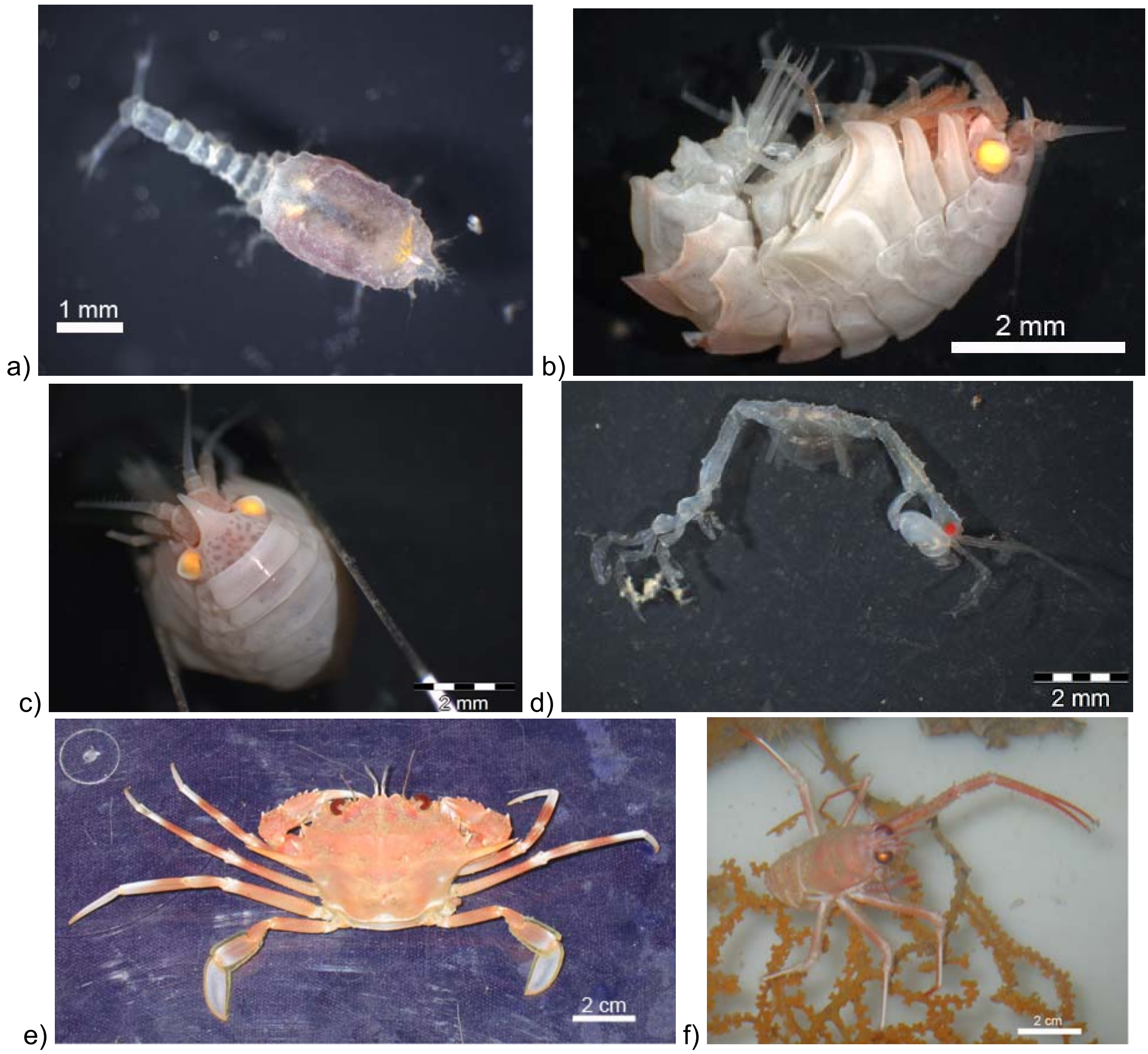


Fig. 1.38: a) Unidentified cumacean frequently found in sieved fractions >0.5 mm, 3 mm in length. M61-1-273. b+c) *Epimeria tuberculata*, 4 mm, rather common in samples from the Belgica province, M61-1-224. c) Detail: Head and eyes. d) *Bathynectes maravigna*, portunid crab, common in coral habitats, carapax 3 cm in diameter. M61-1-225. f) Squatlobster (*Munida* sp.), 5 cm in length, often hiding under coral framework. M61-1-234.

Echinoderms

Echinoderms were found frequently. The echinoid *Cidaris cidaris* was a common species in many samples. Very often its large spines reported its former presence. One specimen of the genus *Echinus* was sampled (Fig. 1.39a) on station M61-1-225. Unstalked crinoids of a not closer identified species were found sitting on top of dead coral framework or *Aphrocallistes* (Fig. 1.39b) (M61-1-305, M61-1-306). Few starfish were caught in the sediment samples. *Ceramaster* sp. (Fig. 1.39c) and *Porania pulvillus* (Fig. 1.39d) were the only species sampled.

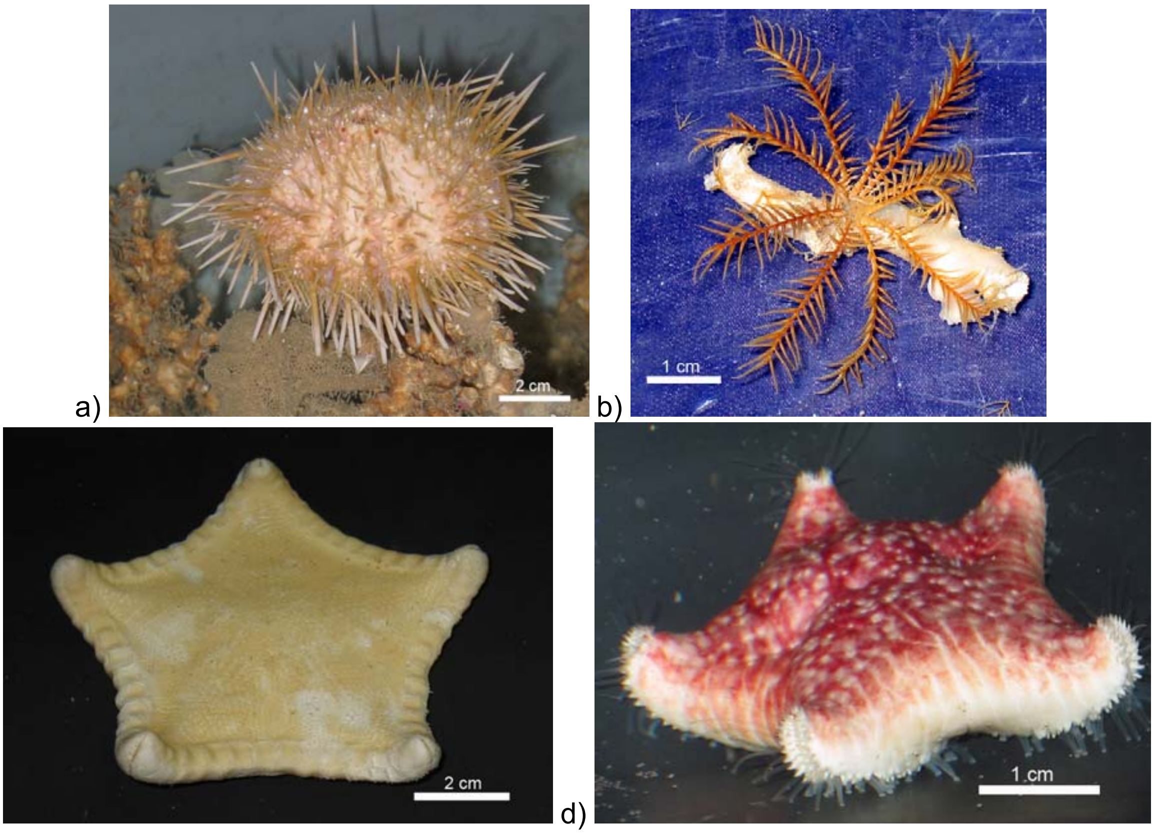


Fig. 1.39: a) *Echinus* sp. One of the largest sea urchin in coral habitats, 7 cm, M61-1-225. b) Unstalked crinoid unidentified, diameter 6 cm. M61-1-305. c) *Ceramaster* sp. common starfish in coral habitats in the Porcupine Seabight, 7 cm, M61-1-234. d) *Porania pulvillus*, cushion starfish, feeding on dead coral epifauna, 4 cm, M61-1-234.

Brachiopods

Small brachiopods living attached to coral framework were common throughout the study area (mainly *Neocrania anomala* and juvenile *Terebratulina* sp. (Fig. 140a).

Bryozoans

Bryozoans were in all samples one of the most important groups growing on various hard substrates. Cyclostome bryozoans showed to be the dominant group on dead coral framework (Fig. 1.40b).

Pterobranchia

The very characteristic dark coloured stolonial network of *Rhabdopleura normani* was regularly found on dead coral pieces.

a) 

b) 

Fig. 1.40: a) juvenile brachiopod of the genus *Terebratulina*, note the faecal pellets. This species is a frequent feature in dead coral epifauna, M61-1-221. b) Very fragile specimen of a cyclostome bryozaoan. Height of the colony is 2.5 mm. M61-1-221.

1.4.10 Megafauna Documented with the OFOS System: First Trends

(Freiwald, A., Beck, T., Vertino, A.)

The megafauna data obtained from the OFOS system provide a first impression of the presence and abundance of organisms larger than 10 cm body size in the cold-water coral ecosystem. It is a valuable tool to document the megafauna of cold-water coral ecosystems. The knowledge of the scale and the always downward-looking cameras will facilitate the statistical analysis of the megafauna in relation to benthic habitats and the sedimentary environment.

Based upon the onboard analysis of the megafauna from the OFOS video-tapes and the processed slides, five major groups are discernible: Porifera, Cnidaria, Arthropoda, Echinodermata and fish. A detailed taxonomic assessment will follow in the home laboratory.

Porifera

Sponges with a large body size originated from two major groups, the Hexactinellida (glass sponges) and the Demospongia (Fig. 1.41). The hexactinellid *Aphrocallistes bocagei* occurs very abundant in the deep coral-covered carbonate mounds of the BMP (Castor Mound and Pollux Mound) (Fig. 1.41a). Few *A. bocagei* were noted on the Erik Mound. In the WRB, this species was observed rarely on Franken Mound. In all cases documented, *A. bocagei* uses dead coral colonies as a hardsubstrate. The silicate skeleton is pale white or greenish-brown when the sponge is dead. Large specimens measure 25 cm in height. In a number of slides, small yellow spots are visible on the tubular-branching skeleton of *A. bocagei*. These objects turned out to be actinians that settle upon the sponge skeleton (see section of macrofauna).

Demospongia are more diverse, but large specimens are quite rare in the BMP. On Castor Mound, some 10 cm-high white sponges with an external meshwork of megascleres colonise life and dead corals (Fig. 1.41b). A yellow encrusting sponge was often documented settling on dead coral colonies on Castor Mound (Fig. 1.41c). The highest diversity of sponges, however, was recorded on Kiel Mount. The basalt outcrops are densely covered by *Phakellia*- or *Axinella*-type sponges (Fig. 1.41e) and are locally associated with branched sponges, which may represent *Antho* sp. (Fig. 1.41f). On shelly substrates, an up to 20 cm high cup sponge with a wide osculum was commonly found (Fig. 1.41d). The sponge community on Kiel Mount strongly resembles those from the Logachev Mound Province, on the other side of Rockall Bank (Freiwald, 2002).

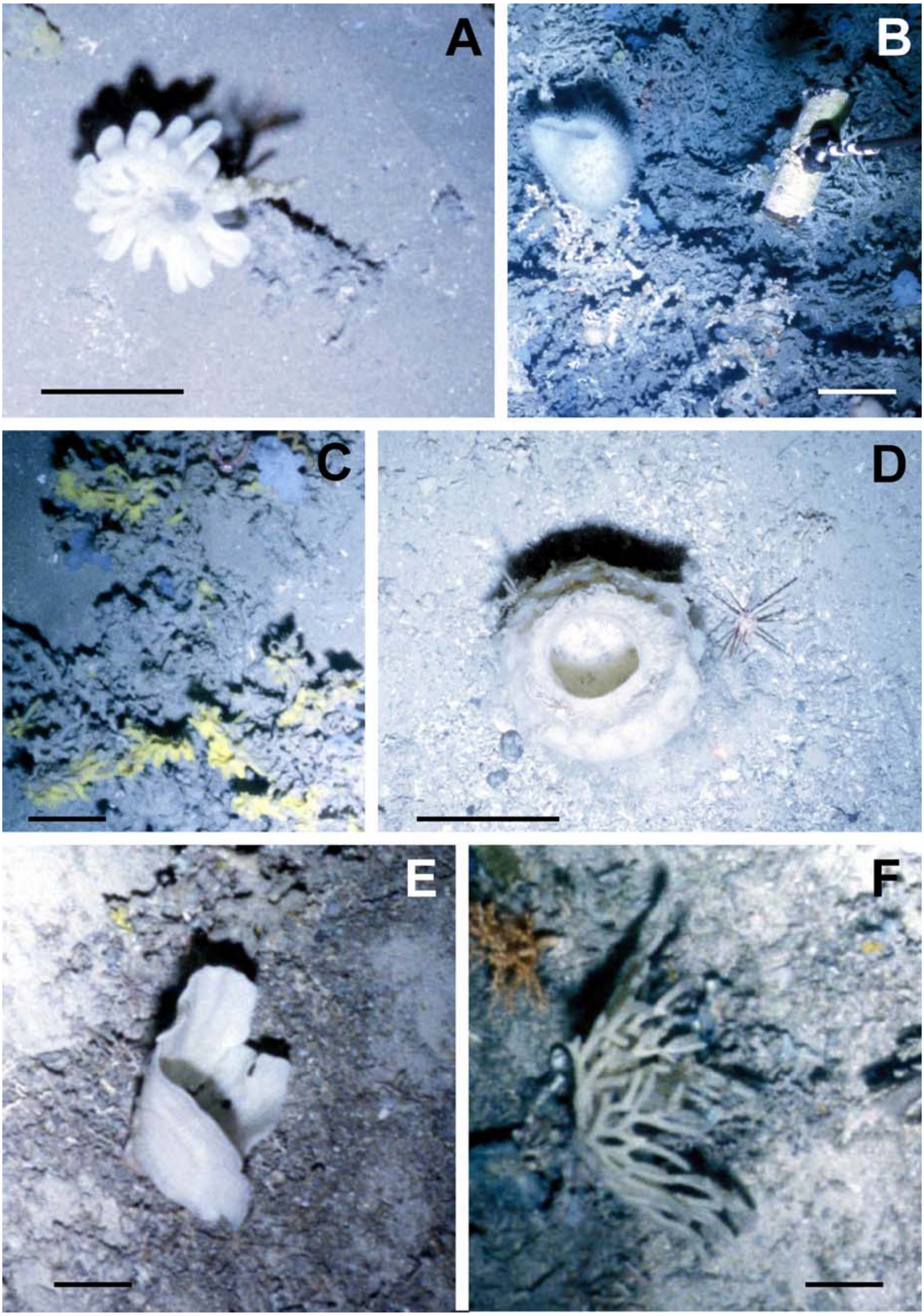


Fig. 1.41: Megafauna Porifera.: a) *Aphrocallistes bocagei* (Castor Mound), b). Sponge with a meshwork of external megascleres (Castor Mound), c). Yellow dead coral-encrusting sponge (Castor Mound, d). Large cup-shape sponge (Kiel Mount), e) Fan-shaped sponge (Kiel Mount), f) Branched sponge *(Antho?* sp., Kiel Mount. All scale bars represent 10 cm length.

Cnidaria

The most diverse megafauna group are the cnidarians which are represented by hydroids, actinians, scleractinia, octocorals and antipatharians (Figs. 1.42-1.45).

Hydroids Thecate hydroids were only observed on Franken Mound. The small tree-like colonies grow directly upon a limestone crust and may represent *Nemertesia* sp. (Fig. 1.42b). More common are stylasterids. The calcified hydrocoral *Pliobothrus symmetricus* is confined to dropstone pavements in the gulleys adjacent to the carbonate mounds, were strong currents have prevented sedimentation since the time of IRD release to the seabed (Fig. 1.42a and e). The colonies rarely exceed 6 cm in height and are dichotomously branched. *P. symmetricus* was seen on OFOS images in the BMP area (Castor Mound, Erik Mound) and at the deep slope of Kiel Mount, WRB. The larger genus *Stylaster* sp. was found alive only in the coral thickets of Franken Mound (WRB). Huge (>30 cm) fossil colonies of *Stylaster* sp. were photographed on large boulders at the foot of Kiel Mount.

Scleractinians The prime target of M61-1 was the documentation of environmental conditions of the framework-constructing corals *Lophelia pertusa* and *Madrepora oculata* (Fig. 1.42c and d). These two species were found on any location surveyed with the OFOS system. Most active growth in the BMP of these azooxanthellate corals takes place on Castor Mound, preferably around the upper slopes and the summit. Further upslope life coral coverage decreases continuously when comparing the results of Castor Mound, Pollux Mound and Erik Mound. The developmental stage of the coral framework rarely exceeds that of a thicket stage. A thicket is characterised by less than 1 m-thick coral framework growth and debris accumulation during the entire Holocene. Reef framework (> 1 m thickness) was not observed on M61-1. Interestingly, even in actively growing coral thickets, the percentage coverage is relatively low (quantified data will be statistically analysed at a later stage). This also fits with OFOS documentations of the large coral thickets on Franken Mound (WRB). There is strong evidence, that ongoing larval settlement of both the framework-constructing corals is ongoing (Fig. 1.42d). Solitary scleractinians have been recorded on Joe's Nose *(Flabellum macandrewi)* and Kiel Mount *(Caryophyllia* cf *sarsiae, Desmophyllum cristacalli, Flabellum macandrewi).*

Actinians Actinains are quite diverse but are generally difficult to identify on OFOS images. Common soft bottom dwellers on muddy to coarse sands are the so-called cylinder roses, or, cerianthiids, with their long and thin tentacles (Fig. 1.43a). This group primarily is found in any off mound environment. The large actinian *Bolococera tuediae* was only found muddy and unrippled off mound sediments (Fig. 1.43f). On Franken Mound, a reddish-brown not yet identified actinian colonises dropstone boulders at a very localised spot (Fig. 1.43b). A notable finding was the very abundant occurrence of *Actinauge* sp. on the entire southern slope of Castor Mound (Fig. 1.43d). This actinian has a sac-like body of white colour measuring 5 – 6 cm when erected. The upper external wall of this species is structured by large knobs. Both the oral disc and the tentacle crown are intensely red-coloured. If present, it occurs in large aggregations on dead coral colonies. This actinian has only been found on coral limestones in the Pelagia Mound Province, southeastern Rockall Trough. A more widespread and common actinian in all areas surveyed is a large (>15 cm) species with an umbrella-like oral disc surrounded by relatively short tentacles. Both the oral disc and the tentacles are orange coloured. Although, we have to confirm the taxonomic status of this species, it may well be *Phelliactis hertwegii* (Fig. 1.43e). This species is attached to dead corals and, rarely, to boulders.

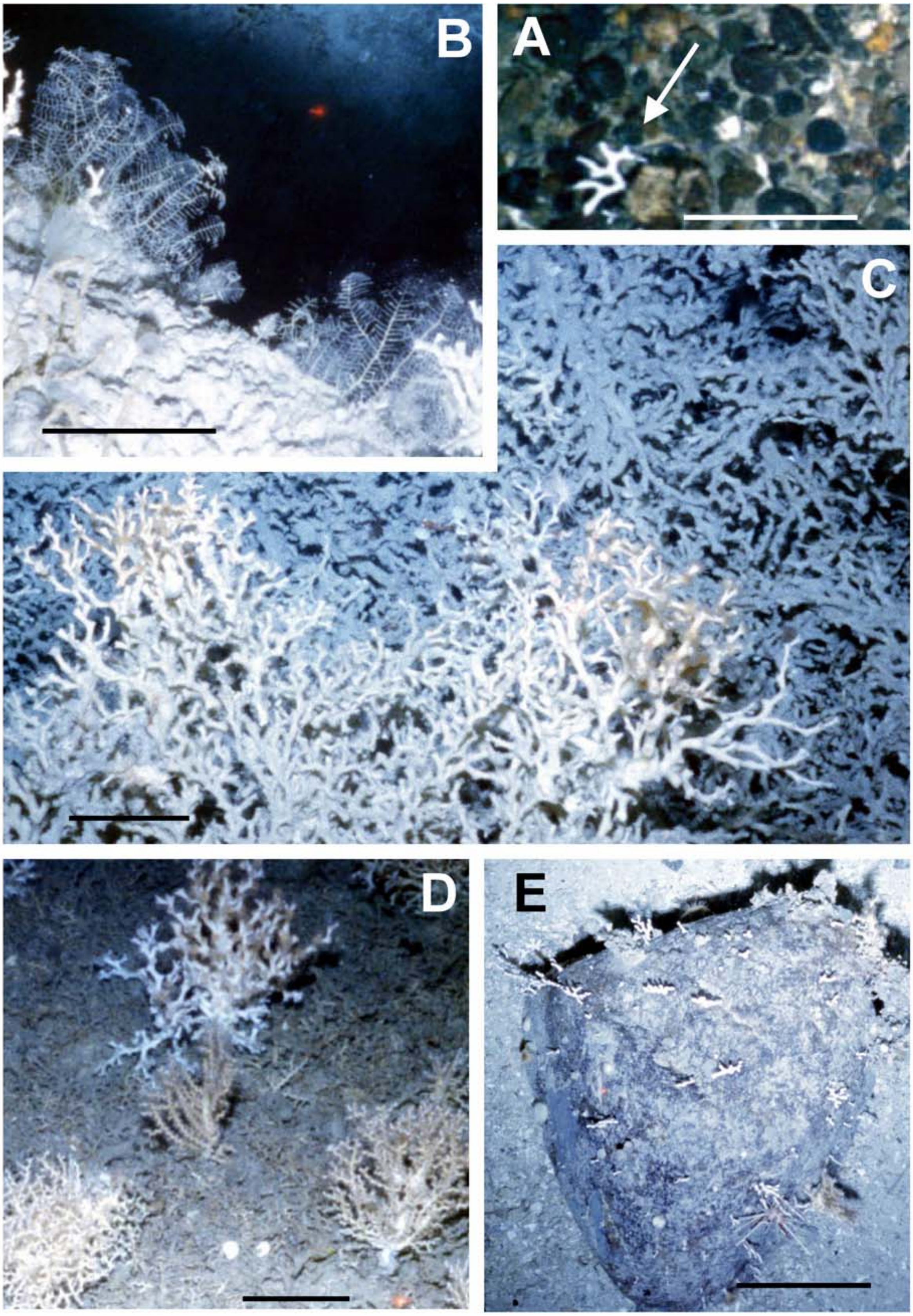


Fig. 1.42: Megafauna Cnidaria I: a) *Pliobothrus symmetricus* (arrow) growing on a dropstone pebble (Erik Mound), b) Thecate hydroid colonies, probably *Nemertesia* sp. (Franken Mound), c) Coral thicket consisting of *Lophelia pertusa* (Franken Mound), d) Recently settled *L. pertusa* (central) and *M. oculata* (right) colonies (Franken Mound). e) Several *P. symmetricus* on a boulder (Kiel Mount). Scale bars represent 10 cm.

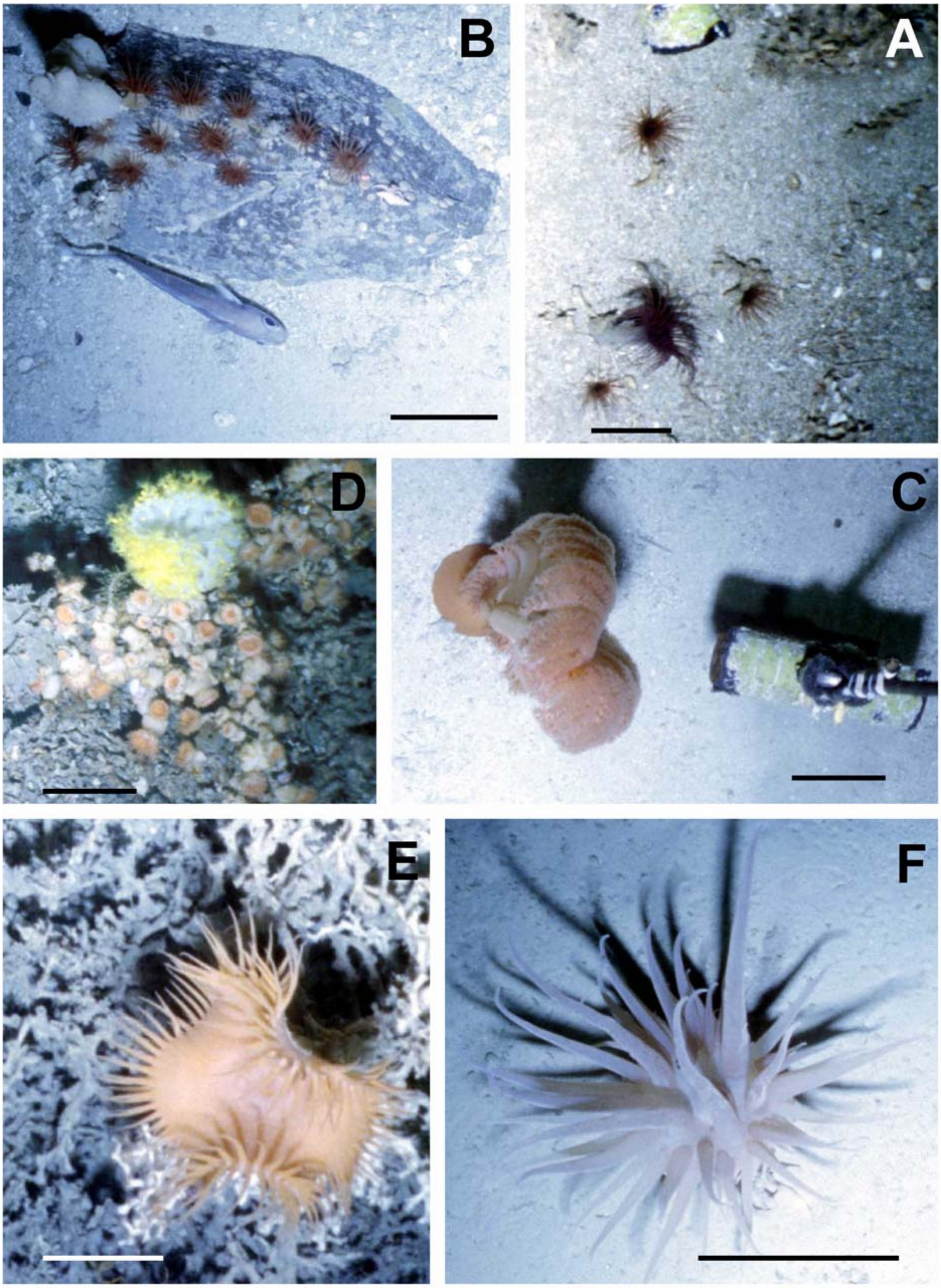


Fig. 1.43: Megafauna Cnidaria II: a) Ceriantiid actinians (Joe's Nose). b) A group of unidentified actinians living on a dropstone (Franken Mound), c) The sea pen *Pennatula* sp. (Kiel Mount), d) A cluster of *Actinauge* sp. (Castor Mound), e) Probably *Phelliactis hertwegii* with a folded oral disc (Franken Mound), F. *Bolocera tuediae,* a soft bottom dweller (Franken Mound). Scale bars refer to 10 cm length.

Octocorals Octocorals represent a diverse group amongst the megafauna. On soft bottoms, sea pens represented by a red *Pennatula* sp. are commonly distributed. Rich sea pen grounds were recorded from the upper slope and summit region of Kiel Mount (Fig. 1.43c). Another soft bottom dweller is a *Drifa*- or *Capnella*-like octocoral that was found in locally large numbers in the WRB only (Fig. 1.44e). One of the most common octocorals is the gorgonian *Acanthogorgia* cf. *armata* (Fig. 1.44b). On the summit of Castor Mound, this species forms extended meadows growing on dead coral framework. The purple octocoral *Anthothela grandiflora* was only documented from Pollux Mound (Fig. 1.44a). *Paragorgia arborea* was found in great numbers growing on boulders on Kiel Mount (Fig. 1.44c and d). Both, the red and white colourmorphs are present. This species was not recorded during earlier ROV-surveys in the region. Kiel Mount was also the only site were some isidiid bamboo corals were frequently observed (Fig. 1.44f and g).

A *Plumarella*-like gorgonian with a characteristic pinnate branching pattern was photographed several times on Kiel Mount (Fig. 1.45c). On Franken Mound, several yet not closer identified gorgonian or antipatharian colonies were documented (Fig. 1.45d and g). The strongly coiled species, however, was documented on any OFOS survey (Fig. 1.45e). The red brown antipaharian *(Parantipathes* sp., Fig. 1.45b) is widely distributed in the coral habitat and on boulders. This species is inhabited with decapod crabs *(Chirostylus* sp., Fig. 1.45b). A dark red antipatharian species with a dense polyp package was only observed on Kiel Mount (Fig. 1.45a). Almost all of the briefly introduced cnidarians have been sampled with grabs or box corers on M61-1 or on previous cruises to the carbonate mounds- and very often with their associated fauna. A network of taxonomic experts for bathyal cnidarians has been established and will add to the poor taxonomic and ecological knowledge of these groups in the NE Atlantic.

Arthropods

Amongst the arthropods, mostly decapod crabs are identifiable (Fig. 1.46). One of the largest species is *Paromola cuvieri* (Fig. 1.46a and b). This crab occurs in the coral thicket, on off mound muddy sand areas and on boulders. It carries sessile organisms such as sponges and gorgonians with its abdominal legs around. Another large crab is *Chaecon affinis* that was often documented scavenging food (Fig. 1.46c and d). Further examination of the video-tapes and still photographs will show us the kind of food. A somewhat smaller decapod is *Bathynectes maravignae* that shows an affinity to coral thickets (Fig. 1.46f). Barely visible on OFOS images, but the most abundant decapod is the squatlobster *Munida* sp. (Fig. 1.46e). *Munida* lives in burrows in the soft sedimentary facies in close proximity to the coral habitat.

Chirostylus sp. has been mentioned in the previous section. This species was documented only on antipatharian colonies, thus indicating a mutual relationship. Smaller arthropods generally are not identifiable from the OFOS images, except for barnacles that commonly occur together with the stylasterid *Pliobothrus symmetricus* in the dropstone-rich gulleys.

Echinoderms

Echinoderms are represented with the following classes amongst the OFOS megafauna assessment: Crinoidea, Asteroidea, Ophiuroidea, Echinoidea and Holothuridea. Crinoids, although not illustrated here, were noticed rarely in the BMP but are common on Kiel Mount. In most cases, the unstalked crinoids use elevated positions as resting places such as scleractinian, or gorgonian colonies. The comatulid crinoids belong to *Koehlermetra porrecta* and *Antedon* sp.

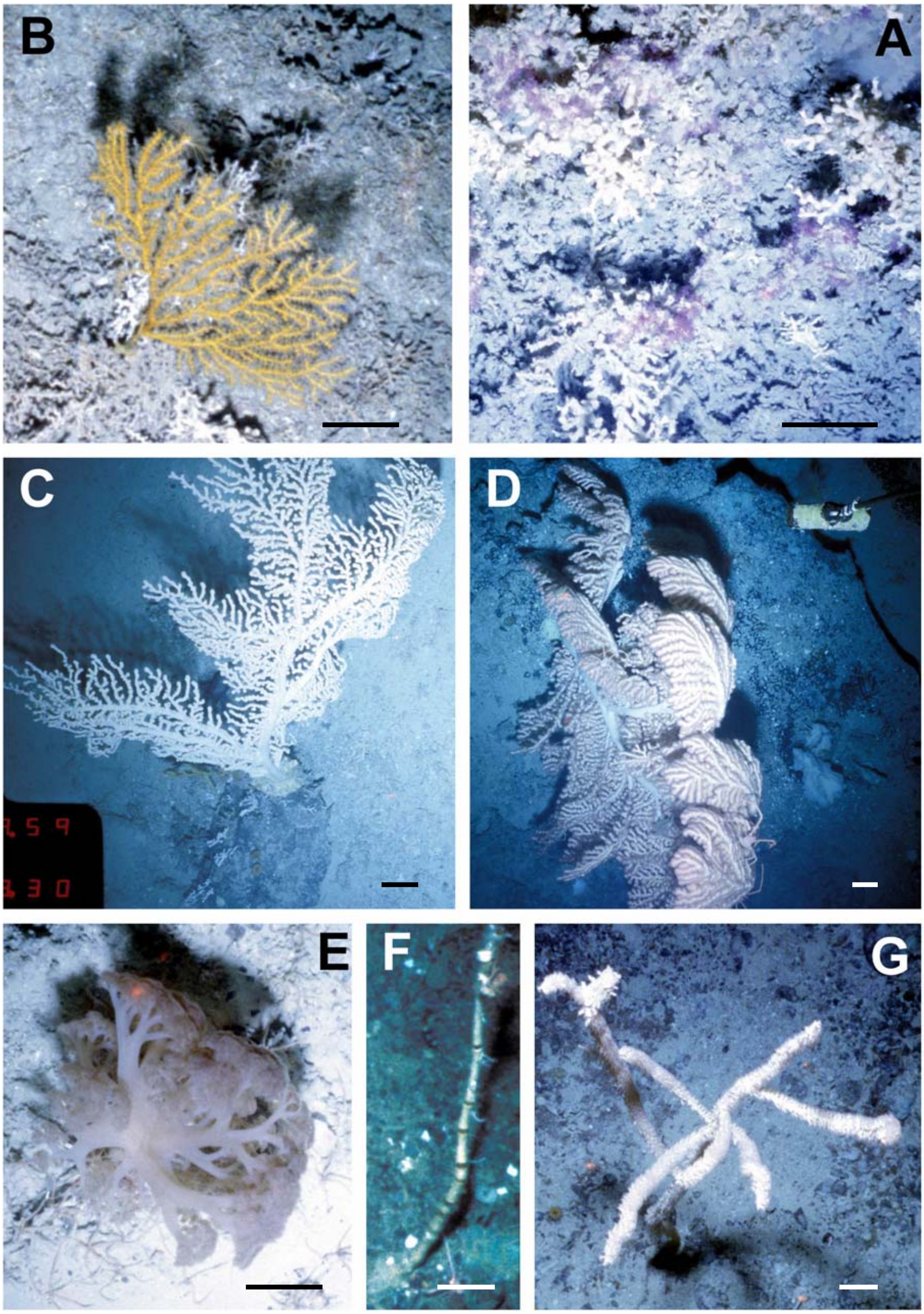


Fig. 1.44: Megafauna Cnidaria III: a) *Anthothelia grandiflora* (Pollux Mound), b) *Acanthogorgia* cf. *armata* (Erik Mound), c) White colourmorph of *Paragorgia arborea* (Kiel Mount), d) Red colourmorph of *P. arborea* (Kiel Mount), e) *Drifa* sp. or *Capnella* sp. (Franken Mound), f) Stem of a bamboo coral (Isidiidae, Kiel Mount), G. Live isidiid coral (Kiel Mount). All scale bars refer to 10 cm length.

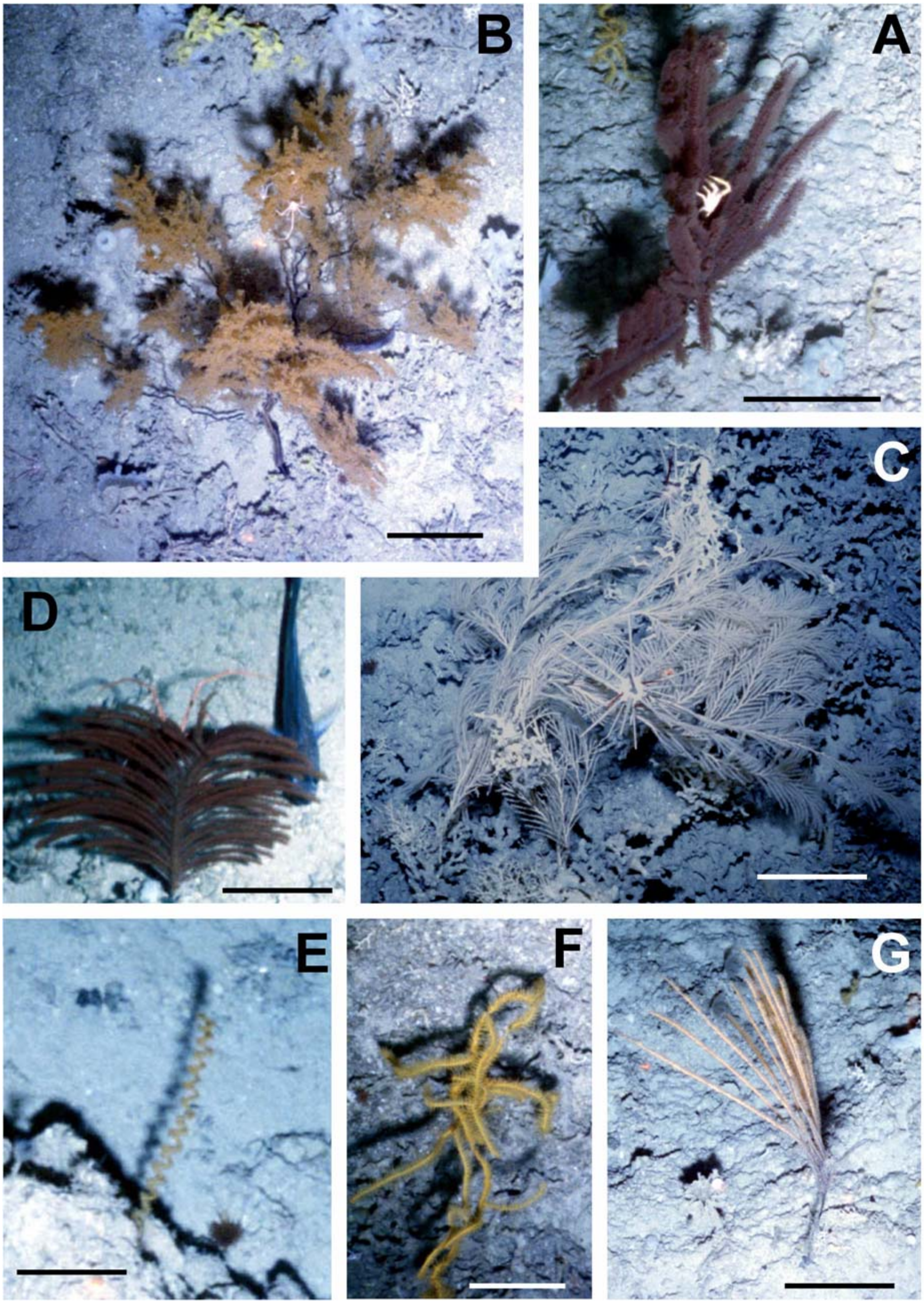


Fig. 1.45: Megafauna Cnidaria IV: a) *Parantipathes* sp. with the decapod *Chirostylus* sp. clinging between the branches of the antipatharian (Kiel Mount), b) unidentified antipatharian colony (Kiel Mount), c) *Plumarella* sp. was only found on Franken Mound, d) to g) unidentified gorgonian and antipatharian colonies from Kiel Mount. All scale bars refer to 10 cm length.

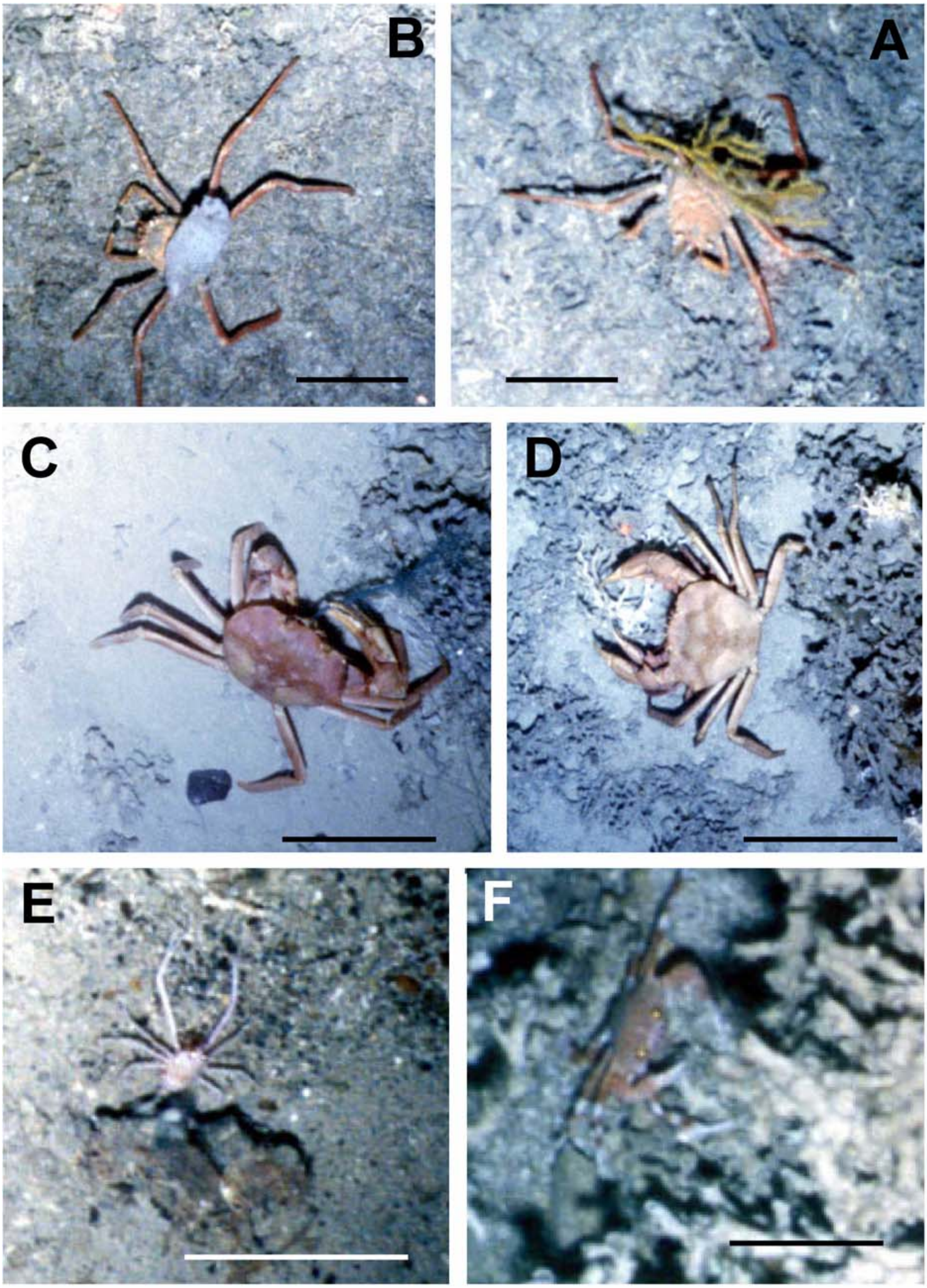


Fig. 1.46: Megafauna Arthropoda. a) and b) *Paromola cuvieri* carrying *Aphrocallistes bocagei* (b) and *Acanthogorgia* cf. *armata* with ist abdominal legs around (Erik Mound), c) and d) *Chaecon affinis* consuming food (Kiel Mount), e) The squatlobster *Munida* sp. (Kiel Mount), f) *Bathynectes maravignae* (Joe's Nose). All scale bars refer to 10 cm length.

Asteroids are most abundant in the coral thickets and to a lesser degree in the off mound sandy environments. Most star fish species found in the coral habitat have a cushion-shape growth habit (Fig. 1.47a to d) and strongly resembles *Ceramaster* sp. (Fig. 1.47a and c) *Porania* sp. (Fig. 1.47b) and *Poraniomorpha* sp. (Fig. 1.47e). The latter species is mostly found crawling on living *Lophelia* and *Madrepora*. Pale red asteroids with 5 long arms and a small oral disk (Fig. 1.47f) seem to prefer the corals proximal off mound muddy sand areas.

Holothurians were abundant on muddy sand areas on and around Kiel Mount with *Benthogyne* as the major genus (Fig. 1.47h). Under contrast-rich illumination and shadowing effects, the small encrusting holothurians, *Psolus* sp., become detectable on OFOS images (Fig. 1.47g). The latter genus is confined to hardsubtrates such as boulders or coral colonies.

Epibenthic sea urchins show highest densities within the coral rubble and coral thicket facies. *Cidaris* cf. *cidaris*, however, was documented in any facies, regardless of off mound or on mound environments (Fig. 1.48a). More restricted to living corals is Echinus cf. acutus, a whitish urchin that occurs both in the BMP and WRB area (Fig. 1.48b). Some brownish to violet colourd echinothurids, probably represented by *Araeosoma* sp. (Fig. 1.48d), and *Hygrosoma/Sperosoma* sp. (Fig. 1.48c) were frequently encountered on Franken Mound.

Despite the almost ubiquitous occurrence of brittle stars, they are hardly visible on OFOS images, except for areas, were a strong colour contrast provided a clear view on a plain seabed. On the western upper slope of Kiel Mount, certain muddy sand sheets were densely populated by ophiuroids of a yet not identified species (Fig. 1.48e).

An orange-coloured sea urchin-shaped organism of yet not known origin was documented on Kiel Mount (Fig. 1.48f). It may well be a cnidarian but any hints are welcomed.

Fishes

The topographically complex carbonate mound and seamount habitats attract many bathydemersal fish species. Some of them were photographed with the OFOS system and are described and illustrated (Fig. 1.49). A rarely documented shark is *Oxynotus paradoxus,* the sailfin-roughshark (Fig. 1.49a). The biology of this species is poorly known. *O. paradoxus* is oviparous and preys upon benthic invertebrates in the bathyal zone. A more common shark found in the BMP and WRB is *Galeus melastomus,* the blackmouth catshark (Fig. 1.49b). This oviparous species feeds on benthic and midwater invertebrates. Skates are represented by *Bathyraja* sp. that we only could document on Kiel Mount (Fig. 1.49c). A very abundant fish is *Lepidion eques,* the North Atlantic codling (Fig. 1.49d). This bathydemersal fish feeds on crustaceans and polychaetes. The monkfish, *Lophius piscatorius,* was found laying in the coral rubble facies and on plain sandy substrates and is of highly commercial interest (Fig. 1.49e). *L. piscatorius* lies half-buried in the sediment waiting for its prey. It attracts mainly fishes by means of its fishing filament on the dorsal part of the head. Adult specimens can attain up to 2 m size. The blue ling, *Molva dypterygia,* was only found in the WRB in some quantities (Fig. 1.49f). This non-migratory, demersal fish feeds on crustaceans and small fish and is commercially fished. Fully grown specimens measure up to 1.55 m in length. The scorpenid fishes are represented by two species. *Trachyscorpia cristulata,* spiny scorpionfish, is commonly found on muddy or sandy habitats (Fig. 1.49g). The size varies from 15 – 55 cm. *T. cristulata* feeds on benthic crustaceans and cephalopods. The scorpenid blackbelly rosefish, *Helicolenus dactylopterus,* is a common species in both survey areas (Fig. 1.49h). It is found in soft bottom areas and in the coral habitat and feeds on both benthic and pelagic organisms (crustaceans, fishes, cephalopods and echinoderms). This species is of commercial interest.

The bathypelagic false boarfish, *Neocyttus helgae*, was found commonly on those mounds that are characterised by active coral growth and strong current velocities (Fig. 1.49i). *N. helgae* is frequent on Castor Mound and was much rarer on the shallower mounds. In the WRB, *N. helgae* is common on Franken Mound. The biology of this species is poorly known.

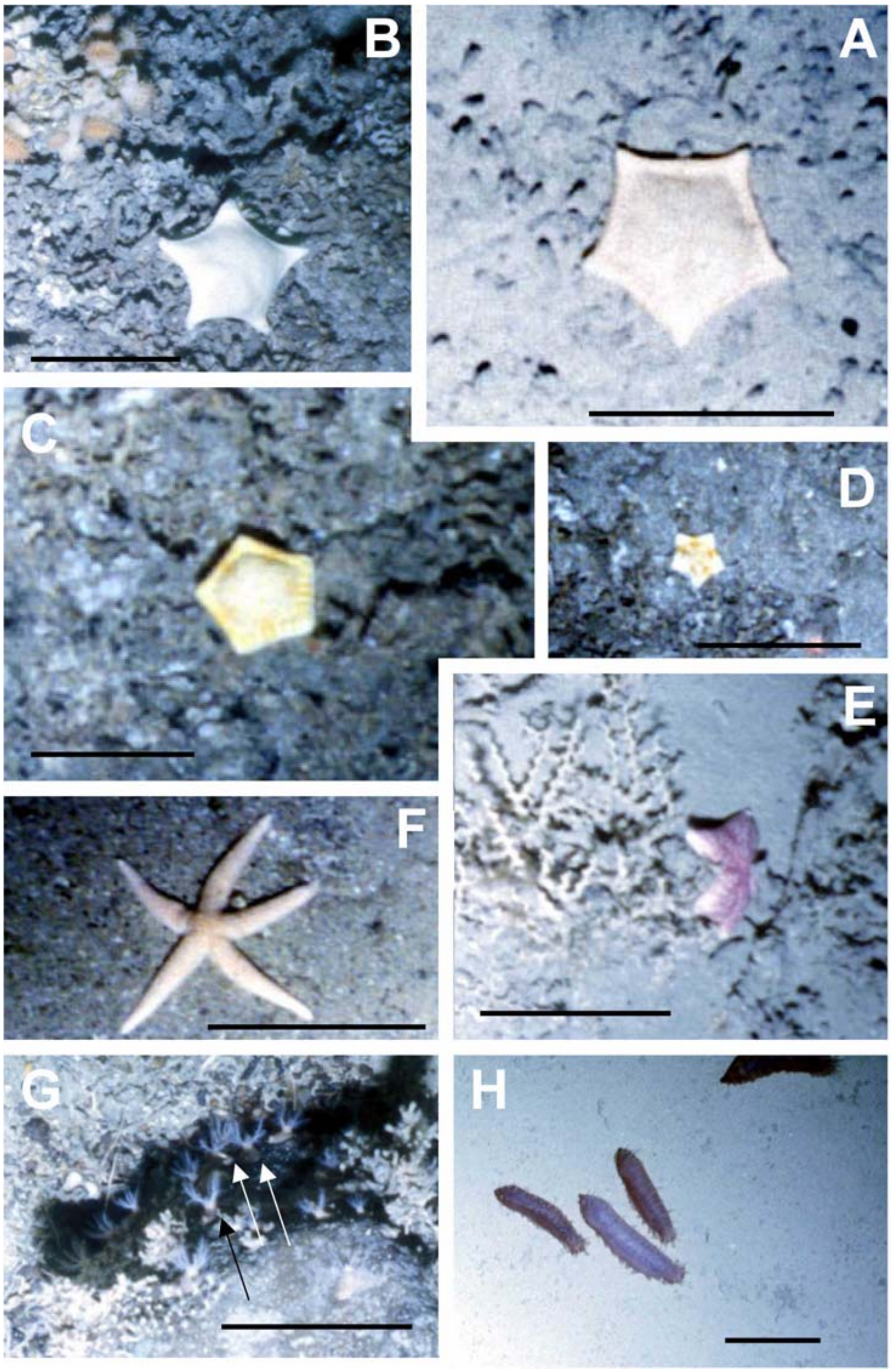


Fig. 1.47: Megafauna Echinodermata I: a) *Ceramaster* sp. (Kiel Mount), b) *Porania* (?) sp. (Castor Mound), c) Coloured *Ceramaster* (?) sp. (Joe's Nose), d) unidentified asteroid (Joe's Nose), e) *Poraniomorpha* sp. (Franken Mound), f) unidentified asteroid (Franken Mound), g) *Psolus* sp. (Kiel Mount), h) *Benthogyne* sp. (Kiel Mount). All scale bars refer to 10 cm length.

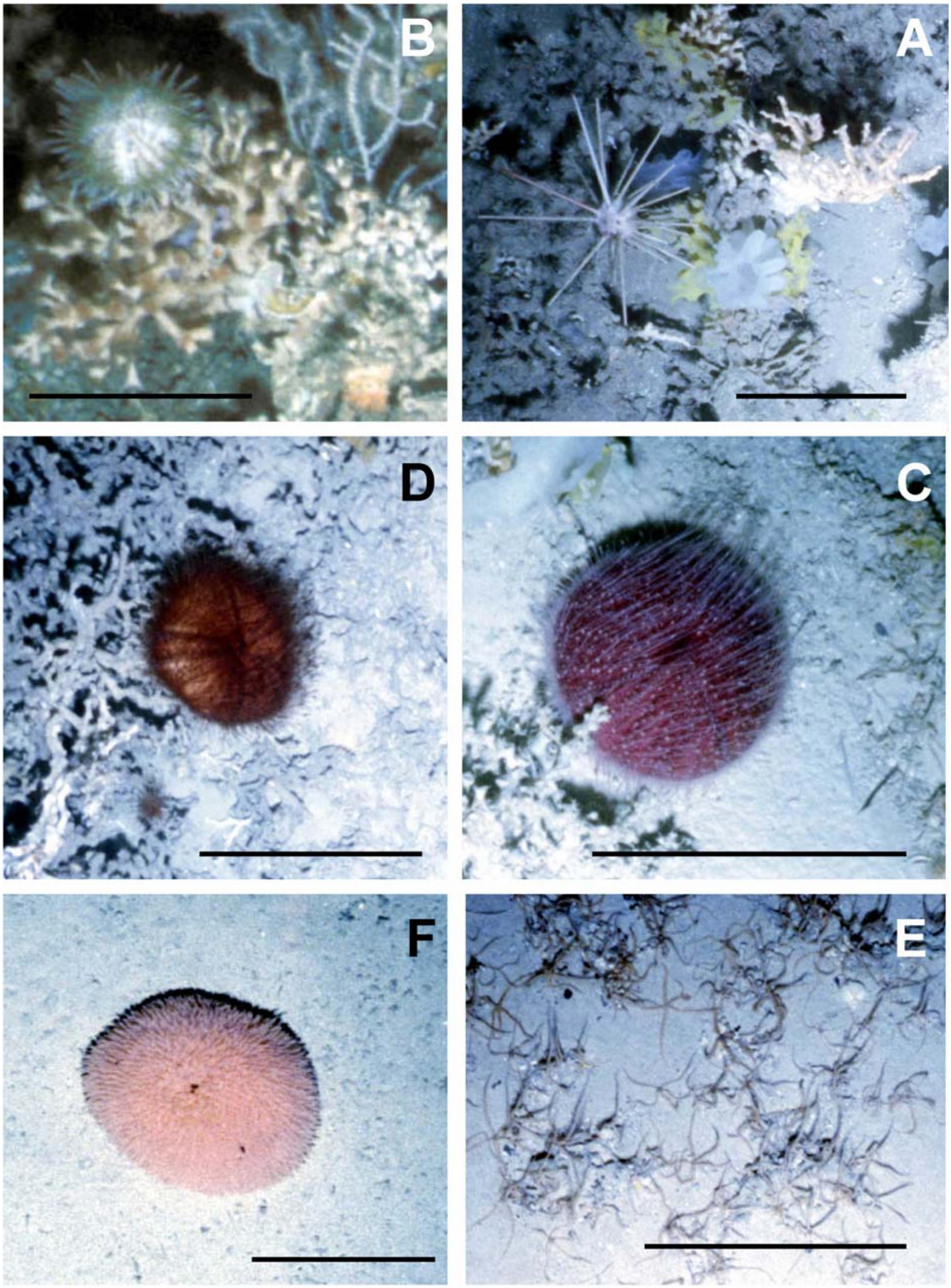


Fig. 1.48: Megafauna Echinodermata II: a) *Cidaris* cf. *cidaris* (Castor Mound), b) *Echinus* cf. *acutus* (Castor Mound), c) Echinothurid, probably *Hygrosoma* sp. or *Sperosoma* sp. (Kiel Mount), d) Echinothurid, probably *Araeosoma* sp. (Franken Mound), e) Aggregation of ophiuroids (Kiel Mount), f) Conundrum, probably not an echinoid but what (Kiel Mount)? All scale bars refer to 10 cm length.

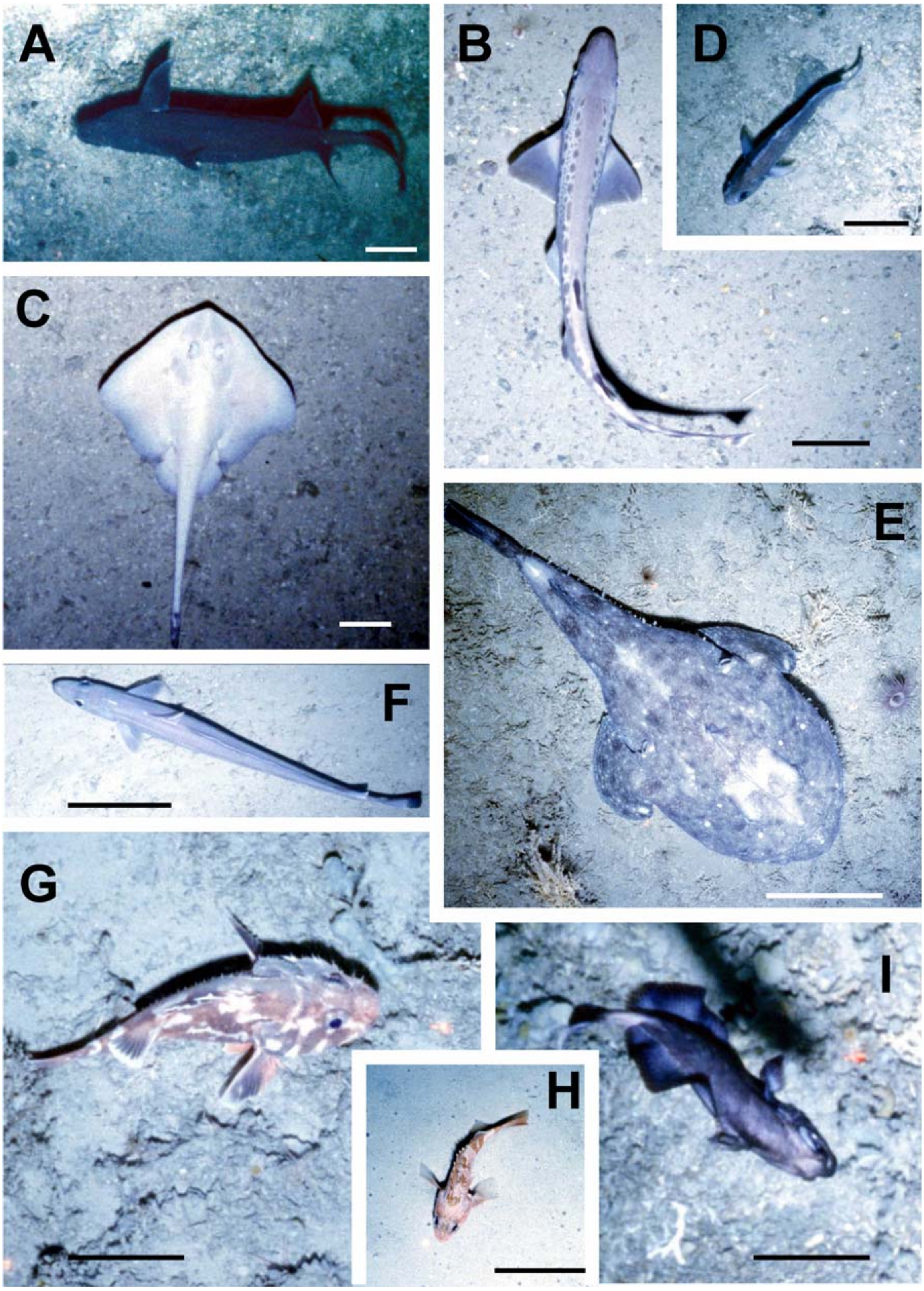


Fig. 1.49: Megafauna fishes: a) Sailfin-roughshark *Oxynotus paradoxus* (Kiel Mount), b) Blackmouth catshark *Galeus melastomus* (Joe's Nose), c) *Bathyraja* sp. (Kiel Mount), d) Atlantic codling *Lepidion eques* (Kiel Mount), e) Monkfish *Lophius piscatorius* (Erik Mound), f) Blue ling *Molva dypterygia* (Kiel Mount), g) Spiny scorpionfish *Trachyscorpia cristulata* (Kiel Mount), h) Blackbelly rosefish *Helicolenus dactylopterus* (Franken Mound), i) False boarsfish *Neocyttus helgae* (Kiel Mount). All scale bars refer to 10 cm length.

1.5 The Weather during R/V METEOR Voyage M61-1

When R/V METEOR left Lisbon on April 19th, 2004, a gale center 970 hPa over the Hebrides and a secondary low southwest of Ireland governed the Northeastern Atlantic. So the ship met with southwesterly winds 5 Bft when she put out to sea.

However there was another gale center 983 at 53 North 38 West. It intensified to 975 hPa by the next day, moving east quickly. On April 21st, the gale center of 972 hPa was in the vicinity of the Irish west coast before it turned north and began filling. Heading north to the Porcupine Sea Bight R/V METEOR experienced southwesterly gales of 7 to 8 Bft when the cold front extending from the gale center was near, abating to 5 Bft when it had passed.

The next gale center had already deepened to 980 hPa east of Newfoundland, but when nature repeats itself it does not do so exactly. Hence, this gale center turned north at longitude 30 West, reaching the southern rim of the Irminger Sea by April 23rd. R/V METEOR reached her first working area reporting southwesterly winds of 5 Bft sometimes up to 6 Bft.

The Atlantic Subtropical High, by the way, had been centered southwest of the Acores when the ship left port but had retreated to its winterly position near Bermuda and so had not been a prominent feature of the synoptic chart as yet. However, a wedge of 1026 hPa had hovered south of the Acores, and now that the gale centers were roaming waters more westerly than the days before this wedge had migrated northeast, being a high of 1028 over England on April 24th. The high then moved on to Scandinavia.

As the gale center moved further north slowly, moderate southwesterly winds were felt while coral samples were taken from the carbonate mounds.

The next gale center to pass the vicinity of Cape Race, Newfoundland, did so on April 25th when already at the peak of its development, 975 hPa. The strong advection of warm air to the east of it reintroduced the Acores High of 1030 hPa on April 26th at 50 North 20 West. At R/V METEOR´s position winds veered north 6 Bft.

Though sea level pressure in the gale center rose warm air advection continued so that the high was strengthened further. Meanwhile, lows began forming over northern France and the Bay of Biscay. On April 28th, the high was situated at 55 North 25 West, sea level pressure having risen to 1035 hPa. On the other hand, the lows had deepened to 1003 hPa. In consequence, strong north-easterly winds of 7 Bft inhibited the ship when she was heading for her second area of investigation, the Rockall Bank. Once having arrived there the winds abated to 5 Bft, and there were even light westerlies on April 30th. These were due to the fact that the lows moving north from Newfoundland had reached south-western Greenland, thereby inducing lows on the southeast coast of that island. Conditions for the development of gale centers being favourable there, the first one moved through Denmark Strait, its fronts reaching south from the center and thus weakening the northern rim of the dominant high.

That high moved west slowly, its strength being 1032 hPa.

The Rockall Bank was influenced little, and so the ship enjoyed moderate north-westerly winds on May 1st. However, the high strengthened again to 1035 hPa, and on the other hand, winds in the upper air changed towards the end of the voyage. These resulted in secondary lows forming on the Southeast Greenland coast moving in a more southerly direction, thereby shifting the main gale center south to Scotland when the ship called at Cork on May 5th. Strong north-westerly winds to gales had accompanied her there from the Rockall Bank on.

1.6 Station List M61-1

Stat. No.	Gear	No.	Area	Date	Start	Coordinates			at depth	Coordinates			off bottom	Coordinates		end stat.	Coordinates		Observations and subsam-ples
					Time (UTC)	Lat. °N	Long. °W	depth (m)	Time (UTC)	Lat. °N	Long. °W	sampling depth (m)	Time (UTC)	Lat. °N	Long. °W	Time (UTC)	Lat. °N	Long. °W	
202	ROBIO	1		22.04.04	12:42			919				**919**		51°09,90	11°39,73	13:00			flag down
203	OFOS	1	BMP: Castor	22.04.04	17:25	51°26,56	11°47,07	1067	17:59	51°26,50	11°47,22	**1063**	19:05	51°25,83	11°47,25	19:31	51°25,65	11°47,20	
204	OFOS	2	BMP: Pollux	22.04.04	19.52	51°25,44	11°45,34	989-999	20:18	51°25,34	11°45,45	**984**	21:32	51°24,64	11°45,86	21:57	51°24,36	11°45,74	
205	CTD/Ro	1	BMP: Galway	22.04.04	22:46	51°27,87	11°45,05	923-925	23:10	51°27,85	11°45,07	**924**	23:11	51°27,85	11°45,07	23:29	51°27,86	11°45,08	BWS 1;2
206	CTD/Ro	2	BMP: Galway	22.04.04	23:45	51°27,63	11°45,27	916-920	00:07	51°27,64	11°45,25	**907**	00:09	51°27,64	11°45,25	00:28	51°27,64	11°45,26	BWS 3;4
207	CTD/Ro	3	BMP: Galway	23.04.04	00:41	51°27,45	11°45,28	864-871	01:02	51°27,44	11°45,30	**859**	01:03	51°27,44	11°45,30	01:20	51°27,43	11°45,31	BWS 5;6. no bottom contact
208	CTD/Ro	4	BMP: Galway	23.04.04	01:36	51°27,28	11°45,17	800-808	01:57	51°27,26	11°45,19	**807**	01:57	51°27,26	11°45,20	02:14	51°27,26	11°45,17	BWS 7;8
209	CTD/Ro	5	BMP: Galway	23.04.04	02:29	51°27,10	11°45,14	797-813	02:48	51°27,09	11°45,12	**786**	02:49	51°27,09	11°45,13	03:05	51°27,09	11°45,14	BWS 9;10
210	CTD/Ro	6	BMP: Galway	23.04.04	03:20	51°26,92	11°45,14	865-870	03:41	51°26,92	11°45,13	**834**	03:42	51°26,92	11°45,13	03:59	51°26,92	11°45,16	BWS 11;12
211	CTD/Ro	7	BMP: Galway	23.04.04	04:11	51°26,79	11°45,19	886-890	04:31	51°26,80	11°45,19	**865**	04:32	51°26,80	11°45,19	04:49	51°29,79	11°45,21	BWS 13;14
212	CTD/Ro	8	BMP: Galway	23.04.04	05.00	51°26,67	11°45,15	893-895	05:22	51°26,69	11°45,18	**886**	05:23	51°26,69	11°45,19	05:41	51°26,68	11°45,18	BWS 15;16
213	CTD/Ro	9	BMP: Little Galway	23.04.04	05:54	51°26,52	11°45,43	873-884	06:13	51°26,53	11°45,42	**880**	06:14	51^26,53	11°45,42	06:30	51°26,52	11°45,43	BWS 19;20
214	CTD/Ro	10	BMP: Little Galway	23.04.04	06:45	51°26,39	11°45,51	917-927	07:05	51°26,38	11°45,48	**880**	07:06	51°26,38	11°45,49	07:23	51°26,38	11°45,51	BWS 17;18
215	BG	1	BMP: Castor	23.04.04	07:55	51°26,26	11°47,28	986-1003	08:27	51°26,25	11°47,20	**994**	08:29	51°26,25	11°47,20	08:48	51°26,25	11°47,20	
216	BG	2	BMP: Therese	23.04.04	09:18	51°25,72	11°46,26	892-904	09:47	51°25,72	11°46,26	**898**	09:48	51°25,72	11°46,26	10:06	51°25,72	11°46,26	
217	BG	3	BMP: Little Therese	23.04.04	10:34	51°26,03	11°45,88	886-902	10:54	51°26,03	11°45,88	**888**	10:55	51°26,03	11°45,88	11:14	51°26,03	11°45,88	*Acanthogorgia*
218	BG	4	BMP: Little Galway	23.04.04	11:38	51°26,51	11°45,43	871-881	12:03	51°26,51	11°45,43	**871**	12:04	51°26,51	11°45,43	12:22	51°26,51	11°45,43	
219	ROBIO	1	Belgica	23.04.04	16:17	51°09,90	11°39,73	919-918	16:25	51°09,90	11°39,73	**919**	16:26	51°09,90	11°37,73	17:10	51°09,90	11°37,73	release lander
220	BCL	1	Belgica	23.04.04	12:50	51°27,37	11°45,13	860	13:29	51°27,37	11°45,13		13:30	51°27,37	11°45,13	13:50	51°27,37	11°45,13	
221	GKG	1	BMP: Castor (N)	23:04:04	19:26	51°26,47	11°47,22	1058	19:55	51°26,47	11°47,22	**1059**	19:56	51°26,47	11°47,22	20:21	51°26,47	11°47,22	dropstone;dead coral fragments
222	GKG	2	BMP: Castor (Top)	23:04:04	20:52	51°26,16	11°47,29	958-975	21:17	51°26,16	11°47,29	**975**	21:18	51°26,16	11°47,29	21:39	51°26,16	11°47,29	
223	GKG	3	BMP: Castor (SW)	23:04:04	22:05	51°25,87	11°47,39	1029	22.55	51°25,87	11°47,39	**1029**	22:56	51°25,87	11°47,39	23:20	51°25,87	11°47,39	12cm recovery
224	GKG	4	BMP: Pollux	23:04:04	23:56	51°25,26	11°45,60	981	00.28	51°25,26	11°45,60	**981**	00:29	51°25,26	11°45,60	00:50	51°25,26	11°45,60	
225	GKG	5	BMP: Pollux(Top)	24.04.04	01:17	51°24,99	11°45,71	912-914	01:40	51°24,99	11°45,71	**912**	01:41	51°24,99	11°45,71	02:00	51°24,99	11°45,71	
226	GKG	6	BMP: Pollux	24.04.04	02:23	51°24,82	11°45,61	949-950	02:45	51°24,82	11°45,61	**950**	02:46	51°24,82	11°45,61	03:05	51°24,82	11°45,61	
227	CTD/Ro	11	BMP: Galway	24.04.04	03:54	51°27,18	11°44,47	924	04:17	51°27,17	11°44,43	**924**	04:18	51°27,17	11°44,43	04:38	51°27,16	11°44,45	924m BWS 21
228	CTD/Ro	12	BMP: Galway	24.04.04	04:55	51°27,14	11°44,88	886-888	05:17	51°27,13	11°44,91	**888**	05:18	51°27,13	11°44,91	05:34	151°27,12	11°44,91	888m BWS 22

Stat. No.	Gear	No.	Area	Date	Start	Coordinates			at depth	Coordinates			off bottom	Coordinates		end stat.	Coordinates		Observations and subsam-ples
					Time (UTC)	Lat. °N	Long. °W	depth (m)	Time (UTC)	Lat. °N	Long. °W	sampling depth (m)	Time (UTC)	Lat. °N	Long. °W	Time (UTC)	Lat. °N	Long. °W	
229	CTD/Ro	13	BMP: Galway	24.04.04	05:45	51°27,09	11°45,13	804-817	06:05	51°27,08	11°45,14	**804**	06:06	51°27,08	11°45,14	06:22	51°27,09	11°45,14	804m BWS 23
230	CTD/Ro	14	BMP: Galway	24.04.04	06:32	51°27,07	11°45,32	839-900	06:57	51°27,10	11°45,29	**839**	06:58	51°27,10	11°45,29	07:15	51°27,07	11°45,31	839m BWS 24
231	CTD/Ro	15	BMP: Galway	24.04.04	07:41	51°27,07	11°45,61	956-960	08:05	51°27,08	11°45,63	**946**	08:06	51°27,09	11°45,63	08:25	51°27,06	11°45,61	946m BWS 25
232	CTD/Ro	16	BMP: Galway	24.04.04	08:54	51°27,10	11°45,36	984-985	09:16	51°27,11	11°45,37	**973**	09:17	51°27,17	11°45,37	09:37	51°27,10	11°45,39	973m BWS 26
233	CTD/Ro	17	BMP: Galway	24.04.04	11:21	51°26,72	11°48,54	1040-1070	11:49	51°27,02	11°48,95	**1066**	11:51	51°27,03	11°49,00	12:22	51°27,40	11°49,39	1066m BWS 27
234	MOC	1	Belgica	24.04.04	13:55	51°29,83	11°42,10	845-1016				**845**				17:32	51°22,75	11°48,94	
235	BCL	1	Belgica	24.04.04	18:10	51°27,78	11°44,81	926	18:10	51°27,78	11°44,81	**926**	18:10	51°27,78	11°44,81	18:19	51°27,78	11°44,81	send signals: 18:10 ; relea-sing lander
236	MOC	2	Belgica	24.04.04	19:35	51°29,67	11°45,08	935-1037				**935**				22:49	51°22,65	11°45,58	
237	MOC	3	Belgica	25.04.04	00:22	51°30,35	11°45,05	972				**890**				02:54	51°25,14	11°45,42	
238	BG	5	Belgica	25.04.04	03:40	51°29,47	11°43,21	912	04:05	51°29,47	11°43,21	**912**	04:06	51°29,47	11°43,21	04:25	51°29,47	11°43,21	
239	BG	6	Belgica	25.04.04	04:39	51°29,11	11°43,32	814-847	05:02	51°29,11	11°43,32	**818**	05:03	51°29,11	11°43,32	05:20	51°29,11	11°43,32	
240	BG	7	Belgica	25.04.04	05:40	51°28,27	11°44,94	898-901	06:05	51°28,27	11°44,94	**900**	06:06	51°28,27	11°44,94	06:24	51°28,27	11°44,94	
241	BG	8	Belgica	25.04.04	06:48	51°27,31	11°44,06	863-899	07:13	51°27,31	11°44,06	**878**	07:13	51°27,31	11°44,06	07:32	51°27,31	11°44,06	
242	BG	9	Belgica	25.04.04	07:56	51°26,93	11°42,99	881	08:20	51°26,93	11°42,99	**881**	08:21	51°26,93	11°42,99	08:38	51°26,93	11°42,99	
243	BG	10	Belgica	25.04.04	08:56	51°26,69	11°42,66	778	09:22	51°26,69	11°42,66	**778**	09:23	51°26,69	11°42,66	09:39	51°26,69	11°42,66	
244	MOC	4	Belgica	25.04.04	11:01	51°29,47	11°45,06	942-966				**942**				13:55	51°24,93	11°45,38	
245	DOS	1	Belgica	25.04.04	15:50	51°27,34	11°45,15	806-848	16:26	51°27,28	11°45,23	**806**				17:05			
246	ROBIO	2	Belgica	25.04.04	17:30	51°25,07	11°45,52	963		51°25,07	11°45,52	**963**		51°25,07	11°45,52	17:44	51°25,07	11°45,52	
247	OFOS	3	BMP: Erik	25.04.04	18:24	51°29,39	11°42,97	845-904	18:47	51°29,41	11°42,97	**904**	20:15	51°28,85	11°43,43	20:34	51°28,81	11°43,57	
248	OFOS	4	Belgica	25.04.04	21:57	51°24,73	11°41,27	675-764	22:19	51°24,75	11°41,28	**764**	23:23	51°24,15	11°41,17	23:41	51°24,08	11°41,13	
249	CTD/Ro	18	BMP: Thérèse	26.04.04	00:18	51°25,14	11°46,32	10061009	00:42	51°25,15	11°46,32	**995**	00:44	51°25,15	11°46,32	01:05	51°25,14	11°46,32	995m BWS 40
250	CTD/Ro	19	BMP: Thérèse	26.04.04	01:20	51°25,37	11°46,35	978-979	01:45	51°25,37	11°46,34	**960**	01:46	51°25,36	11°46,34	02:04	51°25,36	11°46,35	960m BWS 41
251	CTD/Ro	20	BMP: Thérèse	26.04.04	02:23	51°25,53	11°46,38	943-947	02:46	51°25,52	11°46,34	**919**	02:47	51°25,52	11°46,34	03:05	51°25,52	11°46,33	919m BWS 42
252	CTD/Ro	21	BMP: Thérèse	26.04.04	03:21	51°25,70	11°46,27	878-930	03:44	51°25,70	11°46,29	**850**	03:45	51°25,70	11°46,29	04:02	51°25,71	11°46,28	850m BWS 43
253	CTD/Ro	22	BMP: Thérèse	26.04.04	04:18	51°25,82	11°46,24	891-906	04:44	51°25,82	11°46,31	**910**	04:45	51°25,82	11°46,31	05:04	51°25,82	11°46,31	910m BWS 44
254	CTD/Ro	23	BMP: Thérèse	26.04.04	05:14	51°25,94	11°46,25	914-916	05:37	51°25,94	11°46,23	**907**	05:38	51°25,94	11°46,23	05:55	51°25,94	11°46,25	907m BWS 45
255	CTD/Ro	24	BMP: Thérèse	26.04.04	06:12	51°26,14	11°46,20	990-997	06:36	51°26,15	11°46,27	**989**	06:36	51°26,14	11°46,26	06:55	51°26,15	11°46,21	989m BWS 46
256	CTD/Ro	25	BMP: Thérèse	26.04.04	07:12	51°26,46	11°46,16	992	07:35	51°26,45	11°46,16	**992**	07:36	51°26,46	11°46,17	07:55	51°26,47	11°46,14	Not released

Stat. No.	Gear	No.	Area	Date	Start	Coordinates			at depth	Coordinates			off bottom	Coordinates		end stat.	Coordinates		Observations and subsam-ples
					Time (UTC)	Lat. °N	Long. °W	depth (m)	Time (UTC)	Lat. °N	Long. °W	sampling depth (m)	Time (UTC)	Lat. °N	Long. °W	Time (UTC)	Lat. °N	Long. °W	
257	BCL	2	Belgica	26.04.04	09:55	51°27,07	11°46,36	986	10:40	51°27,07	11°46,36	**986**	10:43	51°27,07	11°46,36	11:11	51°27,06	11°46,38	
258	ROBIO	2	Belgica	26.04.04	12:40	51°24,60	11°45,29	948-977				**977**	12:41	51°24,60	11°45,29	13:35	51°25,08	11°45,61	
259	BG	11	BMP: Galway	26.04.04	13:12	51°27,30	11°45,26	850-867	13:40	51°27,30	11°45,26	**858**	13:41	51°27,30	11°45,26	13:59	51°27,30	11°45,26	
260	TVG	1	Belgica	26.04.04	14:36	51°24,28	11°41,21	636-673	15:01	51°24,31	11°41,19	**636**	16:11	51°24,35	11°41,33	16:29	51°24,35	11°41,33	
261	MOC	5	Belgica	26.04.04	18:38	51°24,93	11°45,68	857-971				**971**				21:12	51°30,99	11°45,05	
262	MOC	6	Belgica	26.04.04	23:11	51°25,18	11°45,08	854-972				**972**				02:04	51°31,14	11°45,15	
263	BG	12	Belgica	27.04.04	02:56	51°26,48	11°42,67	777-808	03:15	51°26,48	11°42,67	**789**	03:16	51°26,48	11°42,67	03:38	51°26,48	11°42,67	
264	BG	13	Belgica	27.04.04	04:03	51°26,08	11°42,06	678-721	04:26	51°26,08	11°42,06	**694**	04:27	51°26,08	11°42,06	04:43	51°26,08	11°42,06	
265	BG	14	Belgica	27.04.04	05:03	51°25,85	11°41,86	705-733	05:24	51°25,85	11°41,86	**733**	05:25	51°25,85	11°41,86	05:40	51°25,85	11°41,86	
266	BG	15	Belgica	27.04.04	05:58	51°25,56	11°42,21	763-795	06:24	51°25,56	11°42,21	**764**	06:25	51°25,56	11°42,21	06:43	51°25,56	11°42,21	
267	MOC	7	Belgica	27.04.04	07:17	51°25,05	11°45,03	947-970				**970**				09:54	51°30,08	11°45,15	
268	MOC	8	Belgica	27.04.04	11:36	51°25,23	11°45,09	974-859				**974**				14:26	51°30,96	11°45,13	
269	BCL	3	Belgica	27.04.04	15:39	51°26,54	11°46,45	1012	15:20	51°26,54	11°46,45	**1012**	15:25	51°26,54	11°46,45	15:55	51°26,54	11°46,45	
270	SL-3m	1	Belgica	27.04.04	16:35	51°25,00	11°45,74	933-962	16:56	51°24,99	11°45,74	**934**	16:57	51°24,99	11°45,74	17:22	51°24,06	11°45,74	Penetr.: 3,5m; Recov. 277cm
271	SL-6m	2	Belgica	27.04.04	17:49	51°24,99	11°45,67	927-934	18:11	51°25,00	11°45,71	**932**	18:12	51°25,00	11°45,71	18:35	51°25,00	11°45,74	Penetr.: 6m; Recov. 405cm
272	GKG	7	Belgica	27.04.04	19:59	51°20,20	11°14,18	812-813	20:18	51°20,20	11°41,19	**813**	20:19	51°20,20	11°41,19	20.39	51°20,21	11°41,21	
273	GKG	8	Belgica	27.04.04	21:09	51°20,22	11°41,59	761-763	21:26	51°20,21	11°41,58	**763**	21:07	51°20,21	11°41,58	21:46	51°20,21	11°41,59	
274	GKG	9	Belgica	27.04.04	22:40	51°24,23	11°41,39	646-655	22:56	51°24,24	11°41,28	**646**	22:57	51°24,24	11°41,28	23:16	51°24,26	11°41,33	
275	GKG	10	Belgica	27.04.04	23:38	51°24,74	11°41,65	785	23:58	51°24,73	11°41,65	**785**	23:59	51°24,73	11°41,66	00:22	51°24,74	11°41,67	
276	GKG	11	Belgica	28.04.04	00:54	51°27,15	11°43,61	905	01:21	51°27,16	11°43,61	**905**	01:22	51°27,16	11°43,61	01:46	51°27,14	11°43,62	
277	GKG	12	Belgica	28.04.04	02:07	51°28,34	11°44,80	900-902	02:37	51°28,33	11°44,78	**901**	02:38	51°28,33	11°44,78	03:02	51°28,32	11°44,79	
278	CTD/Ro	26	BMP: N' Castor	28.04.04	03:44	51°26,46	11°47,24	1064	04:25	51°26,47	11°47,24	**1058**	04:26	51°26,47	11°47,24	04:47	51°26,47	11°47,25	BWS 47
279	CTD/Ro	27	BMP: Pollux	28.04.04	05:22	51°24,97	11°45,70	924-932	05:42	51°24,97	11°45,97	**905**	05:43	51°24,71	11°45,71	06:01	51°24,99	44°45,72	BWS 48
280/1	CTD/Ro	28	BMP: Escarpment S' Poseidon	28.04.04	06:37	51°24,93	11°41,33	681-710	06:53	51°24,33	11°41,40		06:59	51°24,33	11°41,40	08:13	51°24,38	11°41,40	Not released
280/2	CTD/Ro	28-b	BMP: Escarpment S' Poseidon	28.04.04	07:42	51°24,35	11°41,37	692-711	07:55	51°24,36	11°41,36	**680**	07:56	51°24,36	11°41,36	08:13	51°24,38	11°41,38	BWS 49, 48,
281	SL-6m	3	Belgica	28.04.04	08:39	51°24,18	11°41,21	658-662	08:57	51°24,20	11°41,19	**658**		51°24,19	11°41,19	10:50	51°24,20	11°41,20	Penetr. 6m; Recov. 512cm
282	SL-3m	4	Belgica	28.04.04	11:08	51°28,26	11°45,03	906-908	11:27	51°28,27	11°45,04	**907**	11:28	51°28,27	11°45,04	11:47	51°28,27	11°45,01	
283	MUC	1	Belgica	28.04.04	13:08	51°23,87	11°48,59	1160	13,39	51°23,86	11°48,57	**1160**	13,41	51°23,86	11°48,58	14.20	51°23,88	11°48,61	

Stat. No.	Gear	No.	Area	Date	Start	Coordinates			at depth	Coordinates			off bottom	Coordinates		end stat.	Coordinates		Observations and subsam-ples
					Time (UTC)	Lat. °N	Long. °W	depth (m)	Time (UTC)	Lat. °N	Long. °W	sampling depth (m)	Time (UTC)	Lat. °N	Long. °W	Time (UTC)	Lat. °N	Long. °W	
283/1	CTD/Ro	29	BMP: SW' Galway	28.04.04	14:22	51°23,88	11°48,61	1160	14:50	51°23,89	11°48,61	**1160**	14:52	51°23,89	11°48,61	15:15	51°23,88	11°48,60	Not released
283/2	CTD/Ro	29b	BMP: SW' Galway	28.04.04	15:29	51°23,86	11°48,56	1165	15:57	51°23,86	11°48,58	**1155**	15:58	51°23,86	11°48,57	16:26	51°23,87	11°48,60	BWS 50
284	MB/PS	1	Kiel Mount - WRP	30.04.04	07:34	56°40,40	17°33,55	837-1102				**1102**				08:12	56°40,43	17°24,440	
284	MB/PS	2	Kiel Mount - WRP	30.04.04	08:21	51°41,090	17°24,520	843-1118				**843**				08:58	56°41,25	17°33,59	
284	MB/PS	3	Kiel Mount - WRP	30.04.04	09:15	56°41,91	17°33,55	855-1112				**1112**				09:53	56°42,01	17°24,430	
284	MB/PS	4	Kiel Mount - WRP	30.04.04	10:12	56°42,770	17°24,331	892-1140				**892**				10:48	56°42,83	17°33,55	
284	MB/PS	5	Kiel Mount - WRP	30.04.04	10:58	56°43,64	17°35,49	894-1177				**1177**				11:37	56°43,71	17°24,404	
285	BCL	3	Kiel Mount - WRP	30.04.04	12:12	56°39,82	17°29,86	975	12:55	56°39,82	17°29,86	**975**	12:56	56°39,82	17°29,86	13:25	56°39,82	17°29,86	
286	ROBIO	3	Kiel Mount - WRP	30.04.04	13:50	56°40,03	17°27,94	934				**934**				14:08	56°40,03	17°27,94	
287	OFOS	5	Kiel Mount - WRP	30.04.04	14:39	56°41,47	17°30,57	902-1067	15:01	56°41,46	17°30,55	**904**	16:58	56°42,87	17°29,83	17:21	56°43,25	17°29,78	
288	OFOS	6	West. Rockall Bank	30.04.04	17:58	56°40,38	17°32,36	927-1060	18:24	56°40,41	17°31,95	**1049**	21:03	56°41,86	17°31,75	21:25	56°41,90	17°32,01	
289/1	CTD/Ro	30	Kiel Mount - WRP	30.04.04	22:00	56°40,29	17°31,47	1023	22:54	56°40,29	17°31,43	**1022**	22:55	56°40,29	17°31,43	23:17	56°40,30	17°31,44	abort at 300m
289/2	CTD/Ro	31	Kiel Mount - WRP	30.04.04	22:30	56°40,29	17°31,43	1021	22:54	56°40,29	17°31,43	**1005**	22:55	56°40,29	17°31,43	23:17	56°40,30	17°31,44	BWS 57
290	CTD/Ro	32	Kiel Mount - WRP	30.04.04	23:33	56°41,18	17°31,26	912-916	23:53	56°41,17	17°31,24	**897**	23:54	56°41,18	17°31,25	00:11	56°41,18	17°31,25	897m BWS 58
291	CTD/Ro	33	Kiel Mount - WRP	01.05.04	00:25	56°41,85	17°31,26	840-842	00:47	56°41,85	17°31,27	**842**	00:48	56°41,85	17°31,27	01:05	56°41,85	17°31,28	BWS 59
292	CTD/Ro	34	Kiel Mount - WRP	01.05.04	01:20	56°42,66	17°31,06	954-956	01:41	56°42,63	17°31,05	**942**	01:42	56°42,63	17°31,05	02:02	56°42,63	17°31,06	942m BWS 60
293	CTD/Ro	35	Kiel Mount - WRP	01.05.04	02:16	56°43,41	17°30,95	1091	02:41	56°43,37	17°31,00	**1076**	02:42	56°43,37	17°31,00	03:03	56°43,39	17°31,00	BWS 61
294/1	CTD/Ro	36	Kiel Mount - WRP	01.05.04	03:29	56°42,45	17°34,53	1160								03:50	56°42,40	17°34,53	abort at 300m
294/2	CTD/Ro	36	Kiel Mount - WRP	01.05.04	04:03	56°42,40	17°34,53	1161	04:28	56°42,44	17°34,53	**1145**	04:29	56°42,44	17°34,53	04:56	56°42,42	17°34,52	BWS 62
295	CTD/Ro	37	Kiel Mount - WRP	01.05.04	05:16	56°42,05	17°32,19	959-961	05:37	56°42,03	17°32,20	**947**	05:38	56°42,03	17°32,20	05:56	56°42,01	17°32,21	947m BWS 69
296	CTD/Ro	38	Kiel Mount - WRP	01.05.04	06:20	56°41,61	17°30,05	904-905	06:40	56°41,60	17°30,04	**888**	06:41	56°41,60	17°30,04	07.00	56°41,61	17°30,03	888m BWS 70
297	CTD/Ro	39	Kiel Mount - WRP	01.05.04	07:27	56°40,96	17°27,73	942	07:48	56°40,94	17°27,71	**924**	07:49	56°40,94	17°27,71	08:08	56°40,97	17°27,70	924m BWS 71
298	BCL	3	West. Rockall Bank	01.05.04	08:27	56°39,60	17°29,02	951				**951**	08:31	56°39,60	17°29,02	08:58	56°39,60	17°29,02	recovery
299	ROBIO	3	West. Rockall Bank	01.05.04	09:16	56°39,71	17°27,35	909-917				**917**	09:16	56°39,71	17°27,35	1020	56°41,23	17°29,77	recovery
300	TVG	2	Kiel Mount - WRP	01.05.04	10:45	56°41,74	17°30,77	847-864	11:11	56°41,76	17°30,97	**863**	11:41	56°41,78	17°31,27	12:03	56°41,79	17°31,37	
301	TVG	3	Kiel Mount - WRP	01.05.04	12:23	56°41,75	17°31,18	853-904	13:49	56°41,77	17°31,17	**854**	13:30	56°41,94	17°31,46	13:51	56°41,95	17°31,45	
302	MB/PS	6	Kiel Mount - WRP	01.05.04	15:04	56'30,57	17'28,52	968-608				**968**				16:26	56'30,57	17'28,52	
302	MB/PS	7	Kiel Mount - WRP	01.05.04	16:40	56'29,75	17'09,17	610-963				**610**				18:04	56'29,75	17'09,17	
302	MB/PS	8	Kiel Mount - WRP	01.05.04	18:28	56°28,96	17°28,70	607-979				**979**				19:57	56°29,02	17°08,66	
303	OFOS	5	Franken Mound	01.05.04	20:52	56°29,22	17°17,84	678-683	21:10	56°29,29	17°17,91	**678**	00:31	56°30,59	17°18,53	00:49	56°30,57	17°18,54	

Stat. No.	Gear	No.	Area	Date	Start	Coordinates			at depth	Coordinates			off bottom	Coordinates		end stat.	Coordinates		Observations and subsamples
					Time (UTC)	Lat. °N	Long. °W	depth (m)	Time (UTC)	Lat. °N	Long. °W	sampling depth (m)	Time (UTC)	Lat. °N	Long. °W	Time (UTC)	Lat. °N	Long. °W	
304	BG	16	Kiel Mount - WRP	02.05.04	02:15	56°41,22	17°31,32	912-917	02:43	56°41,23	17°31,39	**913**	02:44	56°41,23	17°31,39	03:05	56°41,27	17°31,36	
305	BG	17	Kiel Mount - WRP	02.05.04	03:19	56°41,85	17°31,38	837-854	03:44	56°41,82	17°31,38	**854**	03:45	56°41,82	17°31,38	04:05	56°41,85	17°31,29	
306	BG	18	Kiel Mount - WRP	02.05.04	04:08	56°41,83	17°31,27	834-838	04:29	56°41,85	17°31,30	**837**	04:30	56°41,85	17°31,30	04:48	56°41,81	17°31,30	
307	BG	19	Kiel Mount - WRP	02.05.04	05:03	56°42,07	17°30,69	833-839	05:33	56°42,08	17°30,69	**839**	05:34	56°42,08	17°30,69	05:51	56°42,11	17°30,48	
308	BG	20	Kiel Mount - WRP	02.05.04	05:52	56°42,11	17°30,48	829-840	06:15	56°42,11	17°30,50	**831**	06:16	56°42,11	17°30,50	06:33	56°42,15	17°30,56	
309	BG	21	Kiel Mount - WRP	02.05.04	06:34	56°42,15	17°30,57	838-842	06:56	56°42,15	17°30,58	**840**	06:57	56°42,15	17°30,58	07:15	56°42,14	17°30,59	
310	GKG	13	Kiel Mount - WRP	02.05.04	08:26	56°40,50	17°31,71	1026-1029	08:49	56°40,49	17°31,74	**1029**	08:50	56°40,49	17°31,74	09:34	56°40,48	17°31,74	
311	GKG	14	Kiel Mount - WRP	02.05.04	10:05	56°39,80	17°29,82	968-975	10:26	56°39,81	17°29,80	**971**	10:27	56°39,81	17°29,80	10:52	56°39,78	17°29,95	
312	SL	5	Kiel Mount - WRP	02.05.04	11:30	56°39,82	17°29,82	970-972	11:58	56°39,83	17°29,82	**972**	11:59	56°39,83	17°29,83	12:23	56°39,81	17°29,80	no recovery (banana)
313	GKG	15	Kiel Mount - WRP	02.05.04	13:15	56°42,36	17°29,99	883-904	13:46	56°42,44	17°30,01	**902**	13:47	56°42,44	17°30,01	14:12	56°42,46	17°30,09	
314	CTD/Ro	40	Franken Mound	02.05.04	16:01	56°29,86	17°18,25	670-683	16:22	56°29,90	17°18,43	**682**	16:23	56°29,91	17°18,43	16:38	56°29,91	17°18,52	BWS
315	BG	22	Franken Mound	02.05.04	17:00	56°29,64	17°18,00	663-669	17:21	56°29,64	17°18,05	**665**	17:22	56°29,64	17°18,06	17:38	56°29,69	17°17,97	
316	BG	23	Franken Mound	02.05.04	17:39	56°29,69	17°17,97	665-669	17°58	56°29,72	17°18,01	**667**	17:59	56°29,71	17°18,00	18:13	56°29,72	17°18,09	
317	BG	24	Franken Mound	02.05.04	18:19	56°29,80	659-665	659-665	18:39	56°29,82	17°18,29	**665**	18:40	56°29,82	17°18,27	18:54	56°29,85	17°18,16	
318	BG	25	Franken Mound	02.05.04	18:56	56°29,84	17°18,15	645-662	19:17	56°29,90	17°18,19	**645**	19:18	56°29,90	17°18,19	19:29	56°29,90	17°18,23	
319	BG	26	Franken Mound	02.05.04	19:32	56°29,90	17°18,24	652-686	19:55	56°29,83	17°18,36	**676**	19:56	56°29,83	17°18,36	20:11	56°29,86	17°18,45	
320	BG	27	Franken Mound	02.05.04	20:12	56°29,86	17°18,44	665-682	20:30	56°29,82	17°18,31	**668**	20:31	56°29,83	17°18,31	20:44	56°29,80	17°18,20	
321	BG	28	Franken Mound	02.05.04	20:45	56°29,79	17°18,30	655-667	21:02	56°29,79	17°18,35	**667**	21:03	56°29,79	17°18,35	21:18	56°29,75	17°18,33	
322	BG	29	Franken Mound	02.05.04	21:26	56°29,83	17°18,54	675-694	21:49	56°29,85	17°18,76	**693**	21:50	56°29,85	17°18,77	22:04	56°29,85	17°18,86	

Abbrevations

Gear:
Robio - RObust BIOdiversity lander
OFOS – Ocean Floor Observing System
CTD/RO – CTD and Rosette water sampler
BG – grab sampler
BCL – BC-Lander
GKG – Giant box corer
MOC – Mocness
DOS – Deep-Sea Observation System

Gear:
TVG – TV-grab
SL – gravity corer
MB/PS – Multibeam/

Area:
BMP – Belgica Mound Province
WRP – Western Rockall Plateau

Observations:
BWS – bottom water sample

1.7 References

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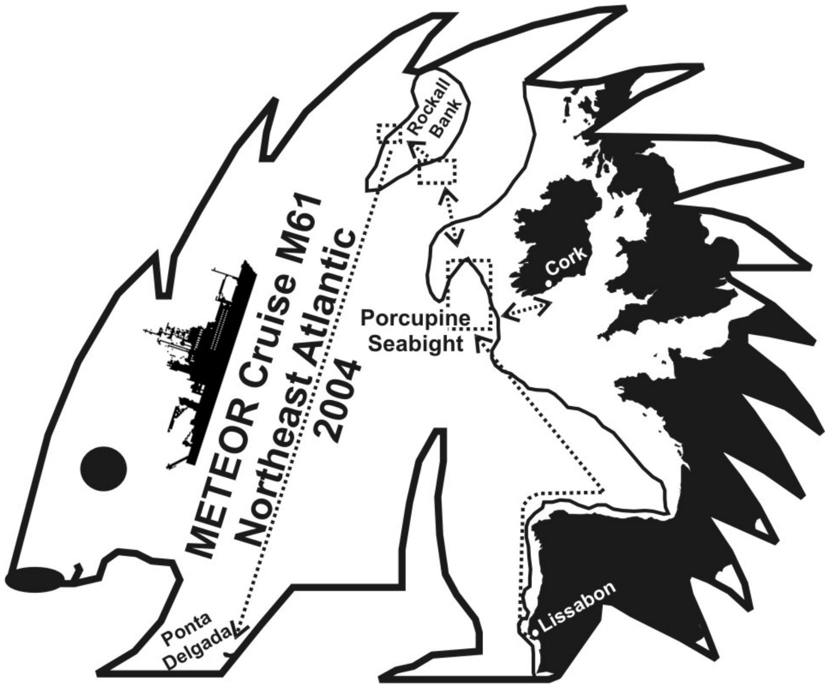
METEOR-Berichte 06-2

Northeast Atlantic 2004

Cruise No. 61, Leg 2

May 8 to May 31, 2004, Cork – Cork



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

Reston, T., Baxmann, M., Brunn, W., Chabert, A., Fekete, N., Gernigon, L., Hasenclever, J., Ingenfeld, R., Ivanova, A., Jones, S., Klein, G., Kriwanek, S., Liersch, P., Neiss, H., Ochsenhirt, W.T., Rogers, E., Steffen, K.P., Thierer, P., Thurow, U., Wagner, G., Weiland, H.

Table of Contents

2.1 Participants

Tab. 2.1 List of Participants on Leg M61-2

Name	Task	Institute
1. Prof. Dr. Tim Reston	Chief scientist	IfM-GEOMAR
2. Dr. Gerald Klein	Processing + Archive	IfM-GEOMAR
3. Noemi Fekete	Processing + Archive	CAU
4. Peter Thierer	OBH/S	IfM-GEOMAR
5. Petra Liersch	OBH/S	IfG, Hamburg
6. Holger Neiss	OBH/S	IfM-GEOMAR
7. Alexandra Ivanova	OBH/S	IfM-GEOMAR
8. Marc Baxmann	OBH/S	IfM-GEOMAR
9. Jörg Hasenclever	OBH/S	CAU
10. Sonja Kriwanek	Parasound + Hydrosweep	CAU
11. Gerlind Wagner	Watchkeeper	CAU
12. Wiebke Brunn	Watchkeeper	CAU
13. Rolf Ingenfeld	Watchkeeper	IfM-GEOMAR
14. Ute Thurow	Watchkeeper	CAU
15. Klaus-Peter Steffen	Airguns	KUM
16. Hans Weiland	Meteorology	DWD
17. Wolf-Thilo Ochsenhirt	Meteorology	DWD
18. Dr. Steve Jones	Guest	TCD Ireland
19. Eloise Rogers	Guest	TCD Ireland
20. Anne Chabert	Guest	DIAS, Ireland
21. Dr. Laurent Gernigon	Guest	DIAS, Ireland

Partner institutions

IFM-GEOMAR: Leibniz-Institut für Meereswissenschaften, Dienstgebäude Ostufer, Wischhofstrasse 1-3, D-24148 Kiel

CAU: Christian Albrechts Universität, Olshausenstr. 40, D-24098 Kiel

KUM Umwelt- und Meerestechnik Kiel GmbH, Wischhofstr. 1-3, Geb. D5, D-24148 Kiel

IfG, Hamburg Institut für Geophysik, Universität Hamburg, Bundesstrasse 55, D-20146 Hamburg

DWD Deutscher Wetterdienst, Geschäftsfeld Seeschiffahrt, Bernhard-Nocht-Straße 76, D-20359 Hamburg

DIAS: School of Cosmic Physics, Dublin Institute for Advanced Studies, 5 Merrion Sq. Dublin 2, Ireland

TCD: Dept of Geology, Trinity College, Dublin 2, Ireland

2.2 Research Program

Scientific Objectives

The Porcupine Basin west of Ireland (Fig. 2.1) provides a natural laboratory for the study of extensional processes. First, both sides of the basin can be investigated, allowing questions about the symmetry of the rifting process to be addressed. Second, the axial stretching factor (Fig. 2.1) – a measure of the amount of subsidence associated with extension - 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 similar ot the North Sea (northern portion of the Porcupine basin) to a rifted continental margin (southern Porcupine 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 cruise was to concentrate on the following:

- determination of the crustal thickness and as a result the actual stretching factor. Until now the stretching factor has 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, we determine the true stretching factor and so refine models of the development of the Porcupine Basin
- determination at which stretching factor (if at all) voluminous magmatic intrusions and/or serpentinisation takes place. This will allow existing models of melting and of mantle serpentinisation to be tested.
- investigation of the P deep crustal reflection (Fig. 2.1) beneath the centre of the basin. P may be a detachment fault (Reston et al., 2001, Reston et al., 2004), but as it is represented by a strong reflection must also represent a major seismic discontinuity of the same form.
- investigation of the Porcupine Median Volcanic Ridge (PMVR – Tate et al., 1993) along the middle of the basin. It is quite possible that this structure is not magmatic in origin but rather is composed of low velocity serpentinites (Reston et al., 2001). The nature of this ridge has important consequences for the tectonic evolution of the basin.

Work Programme

These aims were addressed by collecting several wide-angle seismic profiles across the basin at different latitudes. These profiles follow existing deep seismic reflection lines that cross the basin where the axial stretching factor (from subsidence) is estimated to be 2.5, 4 and > 5. The profiles (Fig 2.1) run from the Irish continental shelf over the basin and onto the shelf of the Porcupine Bank and will reveal the changes in crustal structure at different latitudes and thus the temporal evolution of a rifted margin from initial rifting to final break-up. In addition a north-south oriented profile along the axis of the basin was collected to reveal changes in crustal and mantle structure along the basin axis and in particular the onset of serpentinisation and/or magmatic intrusion.

As we worked along existing reflection profiles, we will be able to incorporate the tilted block structure of the basin. The reflection profiles will provide a template for the interpretation of the wide-angle data and so improve the determination of the deep crustal structure.

Data was recorded both by ocean bottom instruments and by landstations deployed by colleagues from Dublin.

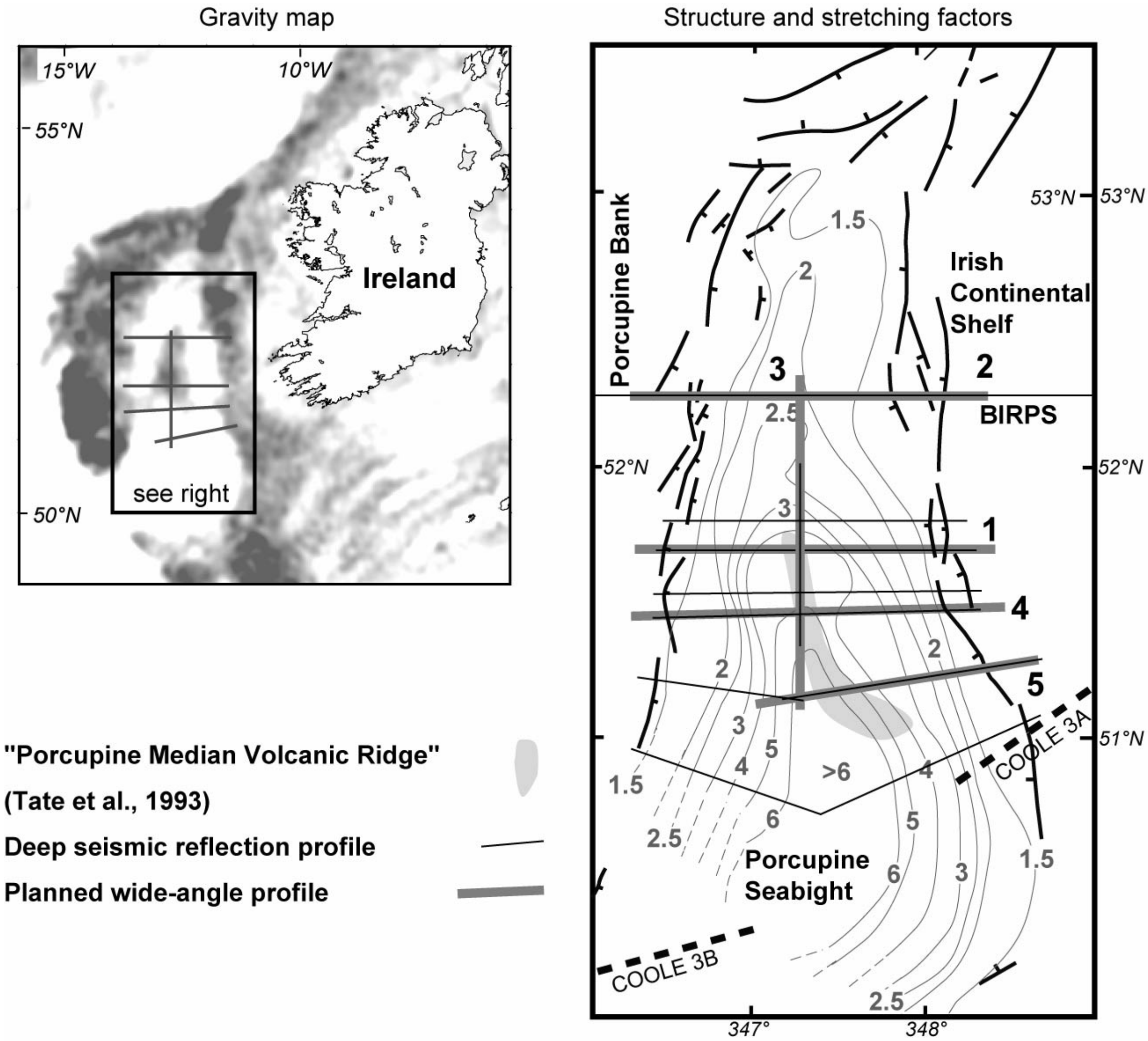


Fig. 2.1: Map of Porcupine Basin showing the profiles #1 to #5. Top left: gravity map (Sandwell and Smith, 1995), showing the basin as a large V-shaped gravity low, opening out to the south. Right: map of stretching factors (derived from subsidence - after Tate et al., 1993), showing how subsidence increases to the south. Fine lines are existing deep penetration MCS data; grey lines are profiles #1 to #5 that were planned to be obtained during M61-2. The "Porcupine Median Volcanic Ridge" is marked in grey; Reston et al. (2004) suggest that this may be a structure of serpentinised mantle.

2.3 Narrative

We left Cork on the 8th of May at 19:00 and headed for the study area approximately 120 miles away. That night at 23:00 local time we started deploying our ocean bottom instruments in a water depth ranging between 200m near the coast to 1600 m in the centre of the basin and shallowing to about 400 m on the Porcupine Ridge.

A total of 25 instruments were deployed on the first line; 10 ocean bottom hydrophones, and 15 ocean bottom seismometers of two different designs (see section 2.4). The average instrument spacing was 4.5 nm. In the deep water at the middle of the line we also performed a CTD profile and a successful test of new acoustic releases.

Deployment finished at 03:00 on the morning of the 10th of May, and was followed by the disturbing news that a large seismic vessel (RAMFORM VALIANT, operated by the Norwegian company PGS) had arrived in the area during the night. RAMFORM VALIANT is equipped with twelve 6 km long streamers and a 3000 + cu in array (about 40 litres). Enquiries to Dublin revealed that the RAMFORM VALIANT was planning to shoot a 3D grid of data through to the beginning of June right at the junction of two of our planned profiles, very close to two others and within range of the others.

We started shooting profile 1 (at 07:30 local time at co-ordinates 51°25´N, 14°51´W, having negotiated (with the help of colleagues in Ireland) with the RAMFORM VALIANT to cease shooting when within 80 km of the Meteor, with the hope that at greater distances the shot noise from the RAMFORM VALIANT would either not prove too troublesome or could be removed by processing.

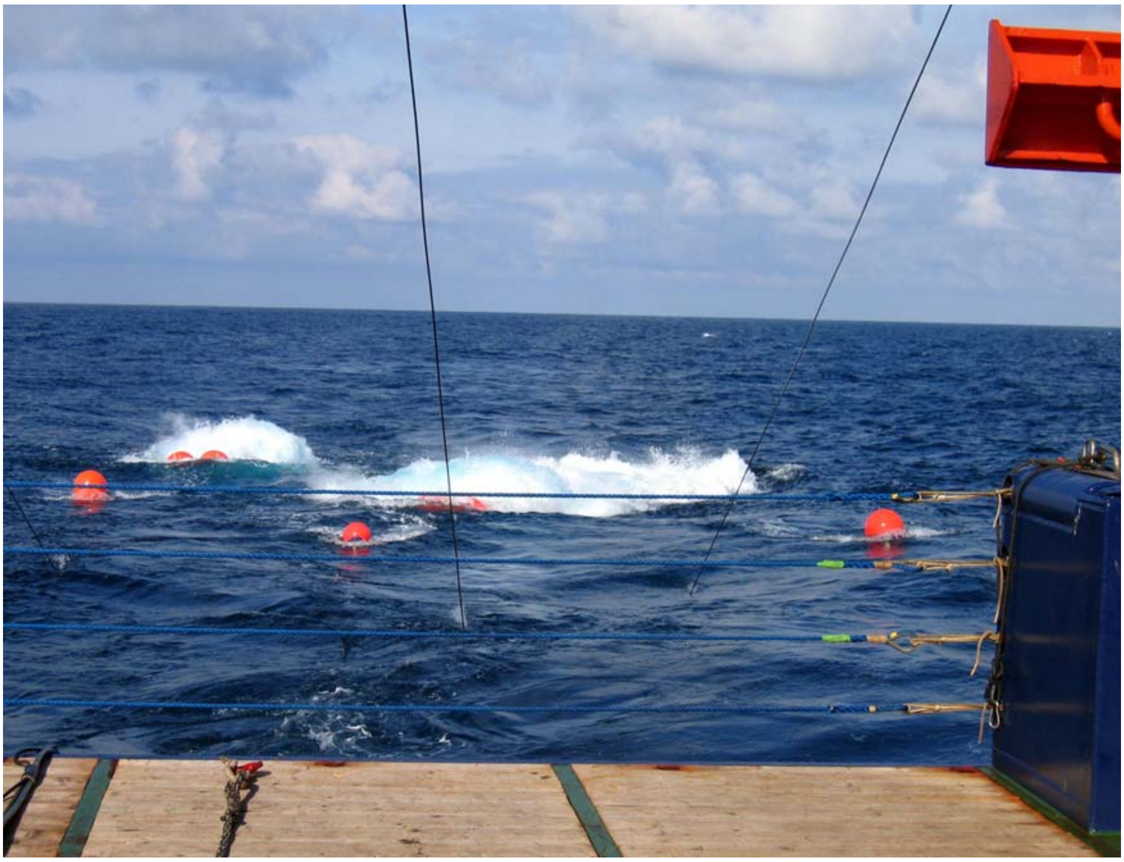


Fig. 2.2: Shooting during Profile 1. Note the perfect weather conditions for seismic work.

We finished shooting (Fig. 2.2) the line at 01:30 on the 12th May and started operations to recover the instruments. Recovery proceeded smoothly and was completed at 03:00 on the 13th. However analysis of the ocean bottom instruments records showed that water-borne noise from the RAMFORM VALIANT posed a severe problem at offsets even over 100 km.

As a result as we deployed instruments along our second profile at a latitude of 51°45´N, we negotiated with the RAMFORM VALIANT a time-sharing agreement in which we shoot for 12 hours continuously and then break off for 8 hours while they shoot two short profiles. In this way, a line which would normally take 36 hours to complete would take a total of 52 hours. While we deployed or recovered instruments, the RAMFORM VALIANT was free to operate as desired. Given the explicit statement in our permit from the Irish government that our work was not to interfere with any ongoing exploration activity, this agreement was better than we might have expected.

On the basis of this agreement we started shooting at 11:00 local time on the 14th May within site of the west coast of Ireland, and broke off at 23:00, with a restart scheduled for 07:00 on the 15th. The extended shooting time was compensated by the excellent weather that had drawn the RAMFORM VALIANT to the region in the first place. This weather has also allowed rapid deployment and recovery of the instruments so far.

Rapid progress continued to be obtained during the second week of the cruise. Profile 2 was completed earlier than expected at 07:40 on the 16th May. As the 2-3 meter swell generated more noise than could be tolerated by the commercial vessel RAMFORM VALIANT, allowing Meteor to shoot through. Instrument recovery proceeded smoothly in good weather conditions until the second last instrument on the line, which although responding to our release signal did not pop-up. As there was heavy fishing traffic in the area (despite a NAVTEX warning) we suspected that the instrument had been disturbed by trawling operations. After recovering the last instrument we returned to the station, located the instrument by determining its distance acoustically, surveyed the seafloor with Parasound (no obvious outcrops or amplitude anomalies) as preparation for dredging. A partly open loop of wire was laid on the seafloor around the instrument, and then drawn in on the instrument by heaving. Shortly after the operation began, the instrument popped-up to the surface, completely intact and still recording and was recovered using the ship's inflatable boat (Fig. 2.3). Inspection quickly revealed that the motor that released the hook was no longer turning properly (although as always this was checked before deployment), possibly because the instrument had been tipped over by one of the many trawlers operating in the area, and the motor had been pushing against a partially open hook. The release unit was withdrawn from further deployments pending repairs.

After the dredging operations, line 3 was deployed in rapid time in very good weather conditions. Shooting started on the morning of the 18th at a speed of 4 knots, higher than optimal, but a necessary compromise if we were to finish the line in three 12 hours stints. Just as we were finishing our first 12 hour stint, the RAMFORM VALIANT called in that the conditions had again become too noisy for their tolerances, allowing us to continue shooting until 06:00 on the morning of the 19th. After a short break while RAMFORM VALIANT shot, we shot for another 6 hours, and then after another break, to finish the profile on the night of the 19th-20th, the halfway point of the cruise.

Fig. 2.3: Recovery of the“Walze” OBS. The instrument was successfully dredged with a cable and recovered by boat

Recovery of instruments along line 3 progressed smoothly until the early hours of the 21st, when the flashlight of one of our OBH was spotted by a sharp-eyed student apparently moving rapidly away! After a chase the instrument was found floating free: the instrument was probably tempora

rily caught in the gear or nets of a fishing boat (again considerable fishing activity has taken place around our lines), but broke free. Apart from a broken flagpole, the instruments were in fine working order.

The next line to be deployed was Line 4, the only N-S line to be shot. Deployment of a reduced number of instruments started promptly at lunchtime on the 21st, was completed by late that same night. 18 instruments were deployed on this line and 6 on Profile 5 (a reshoot of part of profile 1 where the data were compromised by the RAMFORM VALIANT´s shooting.

The RAMFORM VALIANT itself came within 3 miles of us on the morning of the 22nd, allowing a clear view of a modern seismic vessel (Fig. 2.4). Although not shooting, the paravanes, the twelve 6 km streamers and their corresponding tailbuoys could all be seen.

Fig. 2.4: Photograph of the RAMFORM VALIANT, about 3 miles away. The 12 streamers (each 6 km long) can be seen at the stern – the tailbuoys were also clearly visible from Meteor

Profiles 4 and 5 (Fig. 2.5) were completed shortly before midnight on the 24th, and instrument recovery began immediately. All went smoothly until station 86 was reached: the OBH deployed there did not respond to our acoustic release signal. After a brief search using the radio direction finder we picked up the remaining three instruments and then at night plotted a search course to the north of the instrument (the direction of a stiff breeze), reasoning that the flashlight and radio beacon offered a far better chance of finding the instrument than visual sighting of the flag. At one stage we thought we had sighted it, but soon realised that the flashlight we could see was that of the RAMFORM VALIANT ´s chase boat, approximately 12 miles to the west. However the instrument popped up on time at the end of our cruise, still recording, but with a defective acoustic release unit.

A large storm off Greenland was expected to produce a 4 m swell to be followed by gale force winds as the depression moved east. As a result we decided to shoot only a shortened Profile 6 over the "Porcupine Median Volcanic Ridge" where this is at its broadest. Nevertheless this was one profile more than we had hoped for given the weather we had expected. After the recovery of the instruments we hoped that the weather would either hold off or improve rapidly enough to allow us to shoot a dedicated line into the land-stations manned by colleagues in Ireland.

Profile 6 was completed at 02:30 UTC on Thursday 27th May, within 13 hours of the start of shooting. However as instrument recovery proceeded, the swell first increased to 4 m from the west and then became choppier as waves generated by a stiff southerly breeze arrived. The last instrument was brought onboard at 15:00 UTC on the same day, after which a search pattern for the missing OBH was initiated, with the Meteor steaming a series of EW tracks as best allowed by the sea-state. This remained too rough to allow the redeployment of the guns, so further shooting into the land-stations during the remaining time was impossible.

The final event of the cruise was the recovery of OBH 86 after it the time release worked according to plan. It popped up about 200 m in front of the ship right at the time expected and was brought on board with the recorder still working.

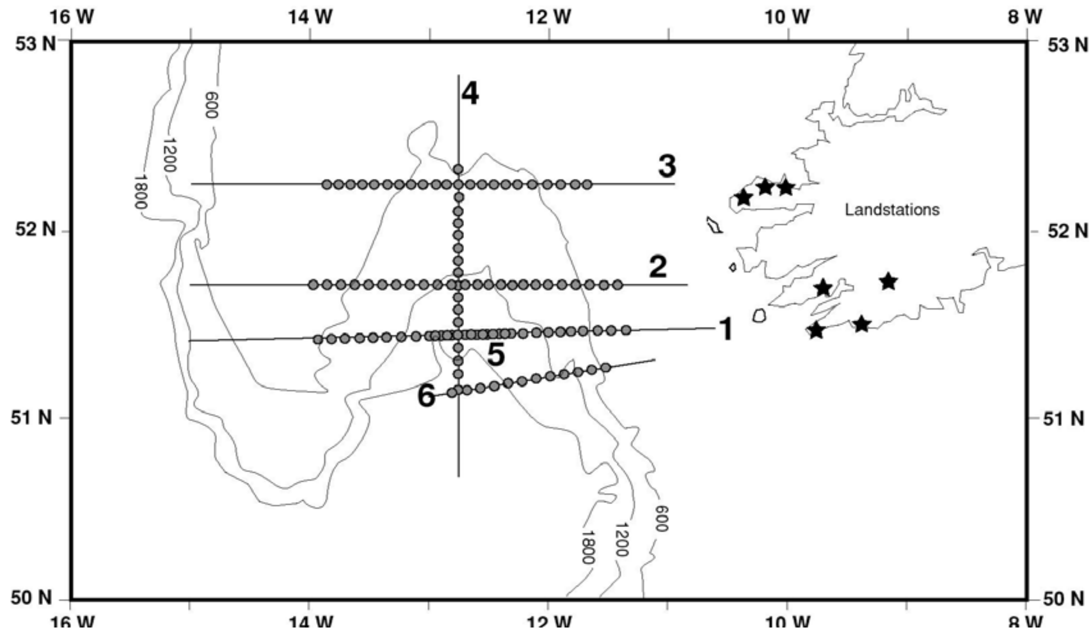


Fig. 2.5: Bathymetric map showing actual data acquisition. Circles are OBH-OBS, lines are shooting profiles; stars are land stations deployed by colleagues in Dublin.

2.4 Equipment Used

2.4.1 GEOMAR Ocean Bottom Hydrophone (OBH)

The first GEOMAR Ocean Bottom Hydrophone was built in 1991 and tested at sea in January 1992 and has since proved highly reliable. A total of 10 OBH instruments were available for M61-2. This type of instrument has proven to be highly reliable; more than 2000 successful deployments of the OBH or the similar OBS (below) have been carried out since.

The principle design of the instrument is illustrated in a photograph showing the instrument upon deployment during M61-2 (Fig. 2.6). The design is described in further detail by Flueh and Bialas (1996). Construction of the OBH is centered around a steel pipe, to which the system components are mounted. At the top of the pipe is a flotation buoy made of syntactic foam that is rated, as are all other components of the system, for a water depth of 6000 m. Attached to the buoy are a radio beacon, a strobe light, a flag and a floating line to aid in retrieval. The hydrophone for the acoustic release is mounted on to a model RT661CE release transponder (MORS Technology) beneath the flotation buoy. Communication with the instrument is possible through the ship's transducer system, allowing successful release and range commands even at 5 kn. speeds and distances of 7 to 9 km. Attached opposite the release transponder is an E-2PD hydrophone sensor from OAS Inc., and in its own pressure tube an MBS recorder from SEND GmbH with D-cells or rechargeable batteries. Finally, suspended approximately 1 m below the steel pipe is an anchor, constructed from pieces of railway tracks weighing about 40 kg each.

Fig. 2.6: Deployment of an OBH during M61-2

2.4.2 GEOMAR Tripod Ocean Bottom Seismometer (TOBS)

Construction of the Tripod Ocean Bottom Seismometer (TOBS) (Bialas and Flueh, 1999) is based on the GEOMAR OBH, with a few minor changes (Fig. 2.7). In contrast to the OBH, the OBS has three legs around a center post to which the anchor weight is attached. When deployed, the OBS is positioned directly on the sea bottom to avoid collisions between the seismometer cable and the anchor. A larger flotation buoy is used to compensate for the heavier payload of instruments and the seismometer release lever. During this cruise a short period seismometer without a gimbal mechanism was used, using a simple stick as deployment lever. A burn wire is used as release of the sensor. This burn works without a clock. A battery is stored water proof and depth resistant inside a copper tube, which at one end offers a corroding wire as a hook. Once deployed into the water a current will establish between copper tube and wire, which results in corroding of the wire. Selection of the size of the wire controls the amount of time (2 hours) needed to release the connected payload. The seismometers are equipped with I/O 4.5 Hz sensors. All three channels are preamplified within the seismometer housing and recorded by the standard Methusalem recorder as used in the OBH units. Parallel to these three channels the standard hydrophone is recorded on the fourth channel. For system compatibility the acoustic release, pressure tubes, and the hydrophone are identical to those used for the OBH. Ten of these instruments were used during M61-2; all were deployed and recovered successfully.

Fig. 2.7: Tripod OBS after recovery being readied for next deployment

2.4.3 GEOMAR "Roller" OBS

In addition to the 10 Tripod OBS, five OBS of a different design were available (Fig. 2.8). These are designed to lie flat on the seafloor (hence reducing risk of being dredged by fishing boats and reducing the noise due to near bottom currents. In the design, the instrument lies flat on a triangular anchor, with the release cylinder vertical but the recording cylinder horizontal and parallel to the flotation tubes, and the flag, flashlight and radio beacon all sticking out horizontally at one end of the instrument, and the geophone arm sticking out horizontally at the other end. The recording cylinder is mounted horizontally across the instrument at the geophone end i.e. at 90 degrees to the line of the flag and geophone.

Upon release, the instrument detaches from the weight and rotates to a more upright position, with the pressure cylinder and geophone at the bottom, and the flag, flash and radio beacons all at the top. The release of one instrument malfunctioned during the cruise, after which only four were deployed further.

Fig. 2.8: Deployment of "Walze" ("Roller") ocean bottom seismometer. These instruments are designed to lie flat on the seafloor (reducing noise from currents), but to rotate to vertical when released. The geophone arm can be seen to the bottom right.

2.4.4 Marine Broadband Seismic Recorder (MBS)

The so-called Marine Broadband Seismic recorder (MBS; Bialas and Flueh, 1999), manufactured by SEND GmbH, was developed based upon experience with the DAT based recording unit Methusalem (Flueh and Bialas, 1996) over the last few years. PCMCIA technology enables static flash memory cards to be used as unpowered storage media, avoiding a mechanically driven recording media and read/write errors due to failure in tape handling operations. In addition, a data compression algorithm is implemented to increase data capacity. Redesign of the electronic layout enables a decreased power consumption (1.5 W) of about 25% compared to the Methusalem system. Data output can be in 16 to 18 bit signed data, depending on the sampling rate. Based on digital decimation filtering, the system was developed to serve a variety of seismic recording requirements. Therefore, the bandwidth reaches from 0.1 Hz for seismological observations to the 50 Hz range for refraction seismic experiments and up to 10 kHz for high resolution seismic surveys. The basic system is adapted to the required frequency range by setting up the appropriate analog front module. Alternatively, 1, 2, 3 or 4 analogue input channels may be processed. Operational handling of the recording unit is similar to the Methusalem system or by loading a file via command or automatically after power-on. The time base is kept on a temperature-compensated DTCXO with a 0.05 PPM accuracy. Setting and synchronizing the time as well as monitoring the drift is carried out automatically by synchronization signals (DCF77 format) from a GPS-based coded time signal generator. Clock synchronization and drift are checked after recovery and compared with the original GPS units. After software preamplification, the signals are low-pass filtered using a 5-pole Bessel filter with a -3 dB corner frequency of 10 kHz. Then each channel is digitized using a sigma-delta A/D converter at a resolution of 22 bits producing 32-bit signed digital data. After delta modulation and Huffman coding the samples are saved on PCMCIA storage cards together with timing information. Up to 4 storage cards may be used, with up to 2 GB per card available. Data compression allows more than 2 GB data capacity. Recently, technical specifications of flashdisks (disk drives of PCMCIA technology) have been modified to operate below 10°C, making 2 GB drives available for data storage. The flashcards need to be copied to a PC workstation after recording. During this transcription the data are decompressed and data files from a maximum of 4 flash memory cards are combined into one data set and formatted according to the PASSCAL data scheme used by the Methusalem system. This enables full compatibility with the established processing system. While the Methusalem system did provide 16 bit integer data, the 18 bit data resolution of the MBS can be fully utilized using a 32 bit data format.

2.4.5 GEOMAR Mini-Streamer

A mini-streamer was onboard to record reflection seismic events. This streamer was manufactured by SIG (Service et Instruments de Geophysique, France) The system comprises several parts: four 50 m long active sections with 20 hydrophones spaced at 2.50 m, two 2.50 m long lead in sections separating the depth transducer (Philips P30) in the tail and the depth transducer and preamplifier in the head from the active sections. The lead in cable is 150 m, and a 50 m long deck cable can be laid out to connect the winch to the lab. The individual hydrophones are omnidirectional and have a flat frequency response from 10 to 1000 Hz. The sensitivity is –90db, re 1V/µbar, +-1 dB. The hydrophones are mounted in an oil filled polyurethane pipe of 34 mm diameter, with a nominal density of 1.12 gr/cm^3. The lead-in cable can be trimmed to the required depth using air and seawater. A control unit provides power to the preamplifier, displays the depths of the head and tail depth transducers and provides the analogue signals of the four channels. A selector enables to choose different preamplifications, either each channel by its own, two neighbouring channels added, or all four channels added. We used the amplification of each single channel. The depth readings are also available on RS232 interfaces for storage on a PC.

The signals recorded by the streamer were stored on a four-channel MBS recorder, identical to those used in the ocean bottom seismic recorders. The streamer winch was placed amidships about 8 m away from the aft of the vessel (Fig. 2.9) and was deployed to provide information on the depth to top basement in a few places where we had no coincident MCS reflection data.

Fig. 2.9: Deployment of the mini-streamer

2.4.6 Seismic Source

Up to three 32 l Bolt airguns were operated simultaneously during the wide angle experiments. The guns were fired through a LongShot airgun controller operating on external trigger signals.

External Trigger

For wide angle and surface streamer profiling the trigger signal was supplied from the ship's Ashtech GG24 GPS/Glonass receiver, which can provide a 1 ms long 5 V-TTL pulse at intervals between 0.2 and 999 s. The impulse should be stable to within the accuracy of the GPS Time, which is 70 ns. Shot breaks, necessary for subsequent data processing and instrument location, were stored on a MBS recorder and displayed in real time for quality control. For this process, the same procedure as for the OBHs was used (see section 2.4.1) and the trigger signal was converted into a 5 V TTL pulse of 300 ms length by a circuit provided from the ship's technical support staff (WTD). The pulse was delivered to the Real Time Systems LongShot Seismic Source Controller and the MBS recording units. As the LongShot triggered on the falling flank the ships trigger signal was inverted. The source controller verifies that all guns are fired at the pre-selected aim point after the external trigger is detected. The ignition pulse is send out to each gun according to the trigger delay time prior to this aim point. Exact position calculation for the shot time was done by post-processing using shot time and UTC time values stored with D-GPS coordinates in the ship's database. From earlier cruises it was known that the coordinates stored within the database were provided by the Atlas ANP 2000 system, which does not copy the exact GPS time values, but adds time stamps of its internal uncontrolled clock to the high precision coordinates of the D-GPS system. Accuracy of the time values mainly depends on the operator's ability to manually set the ANP clock to GPS time. This is clearly a somewhat biased method compared to the efforts of precise positioning.

32L BOLT-Gun

The seismic signals were generated by up to three Model 800 CT BOLT airguns (one on loan from UTIG); a photo of one of the guns is shown in Fig. 2.10. Each gun has a volume of 32 l (2000 in^3), and generates a signal with a main frequency centered around 6 to 8 Hz, including higher harmonics. The pier winches at port and starboard side towed one gun each, while the third gun was towed by the deep sea cable through the center of the A-frame. On port side the towing wire was attached to a block on the A-frame, while on starboard side the extension of the small crane was used. Trigger cables and airhoses were deployed manually. Each gun was suspended on two fenders with an additional float attached to the supply lines to prevent contact between the gun and the towing wire. The guns were towed 60 m behind the vessel and operated at 140 bar in a 7 to 8 m depth. Due to the extension on the starboard crane all three guns could be towed at the same distance behind the vessel.

All three guns were used on the first profile. However the need for repairs to the electrical cables and air tubes, as well as the servicing of the gun meant that on later profiles it was preferred to deploy just two guns and to keep the third on standby to replace any that ceased firing. Gun handling and compressor operation went smoothly over the entire cruise.

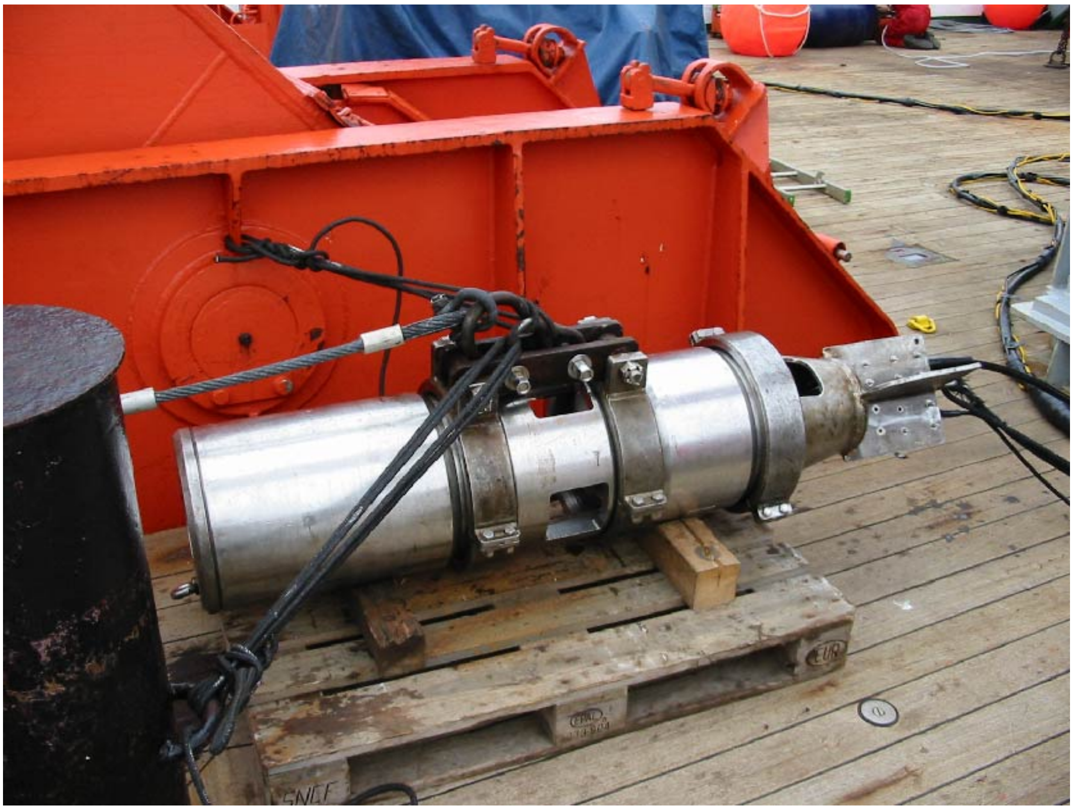


Fig. 2.10: One of the 32 litre guns on deck

2.4.7 Seismic Data Processing and Archiving

During cruise M61-2 six seismic profiles were collected, using ocean bottom recorders, and in places a four channel streamer. As source 1-3 32 litre airguns were used. All instruments are described in sections 2.4.1 – 2.4.6. In the following, the data processing and archiving is described.

Seismic Processing: OBH/OBS Wide Angle Data and Reflection Data

The OBH/S data recorded in continuous mode on the MBS units have to be converted into standard trace-based SEG-Y format for further processing. The necessary program structure was mainly taken from the existing REFTEK routines and modified for the MBS requirements and IFM-GEOMAR´s hardware platforms. The flow chart shown in Fig. 2.11 illustrates the processing scheme applied to the raw data. A detailed description of the main programs follows below:

send2pas

For the PC-cards used with the MBS recorders, data expansion and format conversion into REFTEK data format is performed using a DOS/Windows based PC. The program send2pas reads data from the flashcards used during recording. Decompressed data are written onto the PC's hard disk using PASSCAL data format. Either 16 or 32 bit storage is available. After ftp transmission to a SUN workstation, ref2segy and all other software can be used to handle and process the data files and store them as SEG-Y traces.

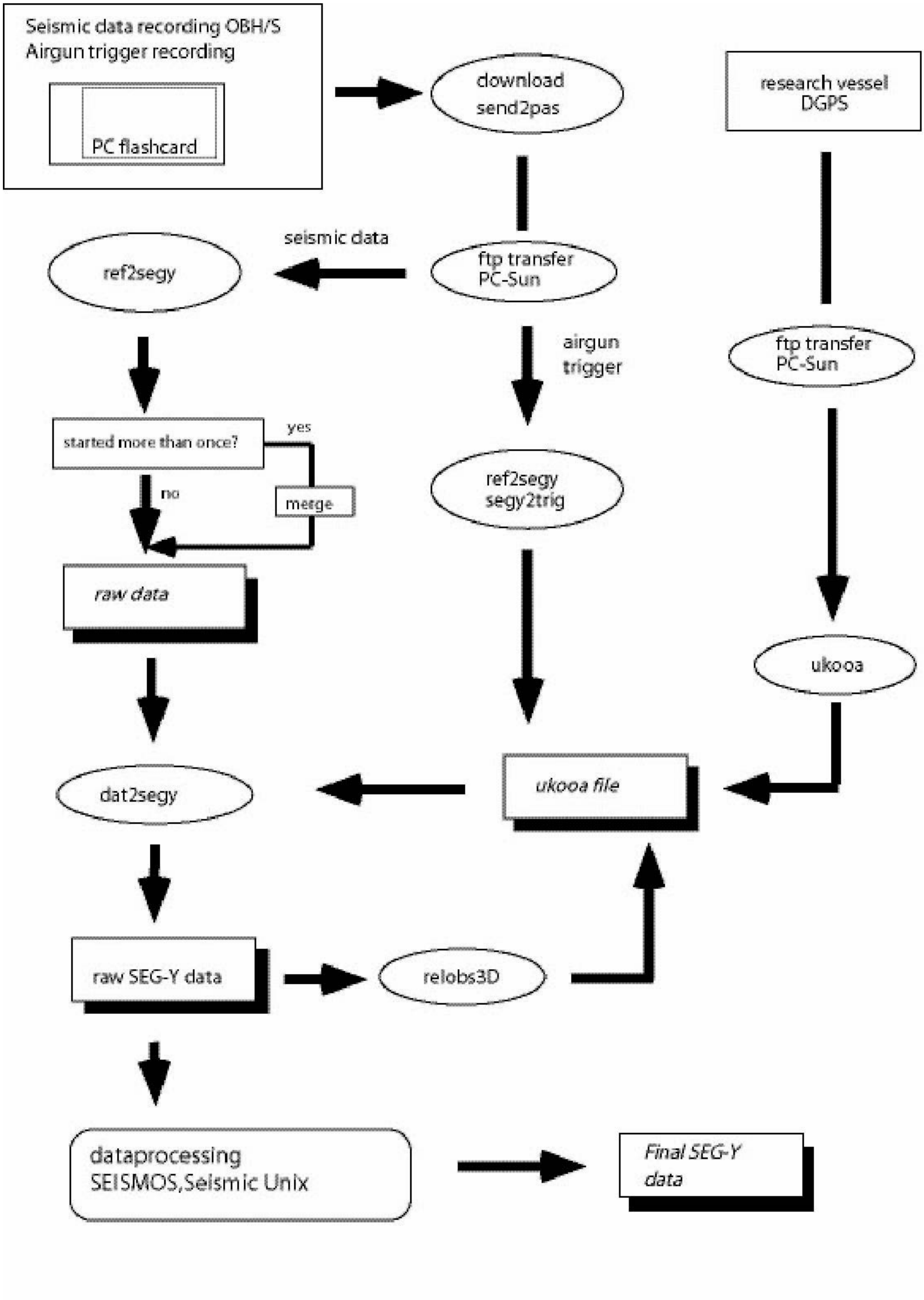


Fig. 2.11: Flowchart of seismic data reformatting and conversion to SEGY.

ref2segy

The ref2segy program converts the output of send2pas to a pseudo SEG-Y trace consisting of one header and a continuous data trace containing all samples, as used by the PASSCAL suite of seismic utility programs. For each channel (normally pressure, vertical velocity, and velocity along two mutually perpendicular horizontal directions for OBS; pressure for OBH) one file is created with the name derived from the start time, the serial number of the Methusalem system, and the channel number. The file size of the pseudo-SEGY file is directly related to the recording time. For instance, a recording time of one hour sampled at 200 Hz (16 Bit) will produce a file size of 1.44 MB per channel. A record with two channels and a recording time of two days will produce a total data volume of 70 MB.

merge146

If an error occurs during the download process, the ref2segy program has to be restarted. This may lead to several data files with different start times. Merging these files into a single file is performed by the merge program. Gaps between the last sample and the first sample of the consecutive data traces are filled with zeros. Overlapping parts are cut out.

segy2trig

The trigger signal, provided by the airgun control system, is recorded on an additional MBS unit during the shooting period. The trigger data are treated similarly to regular seismic data and downloaded to the hard disk via the send2pas and ref2segy programs. Then, the segy2trig program detects the shot times in the data stream by identifying the trigger signal through a given slope steepness, duration and threshold of the trigger pulse. The output is an ASCII table consisting of the shot number and the shot time. Accuracy of the shot time is one of the most crucial matters in seismic wide-angle work, and must be reproduced with a precision of a few ms. Due to this demand the shot times have to be corrected with the shift of the internal recorder clock. Additionally, the trigger file contains the profile number, the start/end time of the profile and the trigger recording. The shot times are part of the ukooa file, which links them with the coordinates of the source and the hydrophones.

ukooa

The ukooa program is used to establish the geometric database by calculating the positions of sources at any given shot time and offset from the ship. The source is placed on the ship track using simple degree/meter conversions and then written to a file in UKOOA-P84/1 format. Corrections for offsets between antenna and airguns as well as consistency checks are included. This file will be used when creating a SEG-Y section via the dat2segy program. The program requires the trigger file to contain the shot times, the ship's navigation, and a Parameter file containing information for the UKOOA file header as basic input information.

dat2segy

The dat2segy program produces standard SEG-Y records either in a 16 or 32 bit integer format by cutting the single SEG-Y trace (the ref2segy output) into traces with a defined time length based on the geometry and shooting time information in the ukooa file. In addition, the user can set several parameters for controlling the output. These parameters are information about the profile and the receiver station, number of shots to be used, trace length, time offset of the trace and reduction velocity (to determine the time of the first sample within a record). Also the clock drift of the recorder (skew) is taken into account and corrected for. The final SEG-Y format consists of the file header followed by the traces. Each trace is built up by a trace header followed by the data samples. The output of the dat2segy program can be used as input for further processing with SEISMOS or Seismic Unix (SU).

relobs

Because of drifting of the OBH and OBS instruments during deployment and inaccuracies in the ship's GPS navigation system, the OBH positions may be mislocated by up to several 100 m. Since this error leads to asymmetry and incorrect traveltime information in the record section, it has to be corrected. This is accomplished with the program relobs.

For input, the assumed OBH location, shot locations and the picked traveltimes of the direct wave near to its apex are needed. To simplify the picking a static correction with a hyperbolic equation was performed to flatten the direct wave. This yields a much more coherent direct arrival which would normally suffer from strong spatial aliasing in the uncorrected section making it difficult to track. By shifting the OBH position, relobs minimizes the deviation between computed and real travel times using a least mean square fitting algorithm (assuming a constant water velocity). Assuming a towing distance of 40 m behind the vessel gives a distance from the research vessel's GPS position to the center of the airgun array of 95 m for the gun array.

Data Archiving

Data recorded with the MBS recorder on flash discs were transferred via a PC to a SUN workstation. On the workstation they were transformed into a so-called PSEUDO-SEGY format.

After navigation data had been merged and SEGY formatted traces with the appropriate header words had been created, the data were also archived. Finally, a second set was stored and archived after the shipboard processing, as described above, had been applied. All final processed SEGY data were archived on tapes.

Data Exchange

For the exchange of the OBH/OBS data, the SEGY-format on disk with a Sun tar-format was chosen. The raw segy data is in Integer2 format whereas the processed data is stored in IBM-floating point. This is the definition of the segy trace header for the IFM-GEOMAR OBS wide-angle reflection data. The extension of the standard SEGY header from 181 to 240 byte is a layout in order to process the data on the SEISMOS software system. Reading bytes directly into this header will allow access to all of the fields.

Seismic Data Processing

Some basic processing was carried out, mainly using SeismicUnix. This processing consisted of amplitude balancing and frequency filtering and was for display purposes only. More sophisticated processing (e.g. multitrace filtering, deconvolution, true amplitude processing) could not be performed during the cruise due to the limited time available, and in particular the lack of transit time. As a result all sections shown in section 2.5 have only undergone rudimentary processing.

2.4.8 Gravimeter

A Lacoste-Romberg marine gravimeter was loaned from the UK (contact Tony Watts and Christine Peirce) and installed in Cork at the start of the cruise (Fig. 2.12). Although not originally permissioned, we applied for permission to use this while in Cork and received the permission a day later thanks to contacts in Dublin.

The gravimeter was simply left running throughout the cruise – the only necessary maintenance being the changing of the paper when this ran out. The data download will take place after the end of M62-4 when the instrument is dismantled and shipped back to England, although a paper copy of the data was available.

Fig. 2.12: Photograph of the Gravimeter installed in Cork.

2.5 Preliminary Results

Shown in this section are examples of record sections produced on board and as such virtually unprocessed. These serve to document the quality of the data collected.

2.5.1 Profile 1

Recordings made on this profile suffered badly from noise from the shots of the 3D commercial seismic vessel RAMFORM VALIANT. Here we show two data examples, one from just to the west of the basin axis (Fig. 2.13 – OBS 14, hydrophone channel) and one from the eastern flank of the basin (Fig. 2.14 - OBH 7).

The RAMFORM VALIANT's shots are marked by panels of incoherent noise, incoherent as the RAMFORM VALIANT was shooting on distance and not on time and refused to give us the shot times which might have allowed us to remove the noise after making it coherent. Some of these panels are prefaced by coherent noise, which we deduce is where the RAMFORM VALIANT was shooting on time during warm-up. The problem as far as we are concerned is the picking of our coherent energy across their shot noise (e.g. Fig. 2.14). Because of the noise generated by the RAMFORM VALIANT, we both negotiated a time-sharing agreement for all other profiles and reshot part of profile 1 as profile 5 (see Fig. 2.13)

2.5.2 Profile 2

This profile was shot after the successful negotiation of a time-sharing agreement with RAMFORM VALIANT. Here we show just two data examples of the merged shot profiles: one from the middle of the basin (OBS 41 – Fig. 2.15) where the data quality is excellent, and one from near the end of the profile (OBS 29 – Fig. 2.16)

2.5.3 Profile 3

Despite the time-sharing agreement, thin strips of noise from RAMFORM VALIANT's shots can be seen on this profile, corresponding to times when RAMFORM VALIANT either started shooting marginally early or stopped marginally late. Fortunately, the noise strips are narrow enough not to be a problem. Data quality is generally good to very good as can be seen in Fig. 2.17 and 2.18 (OBS 59 and OBH 72 respectively from the middle and end of the profile). Clear arrivals are apparent at offset over 70 km on most instruments, giving complete coverage of the crust beneath the basin.

2.5.4 Profile 4

This north south profile was shot in part with the ministreamer deployed to provide information on water depth and depth to basement where no existing MCS data were available. The traces recorded by one channel are shown in Fig. 2.19.

Data quality is in places superb with clear refraction-reflection-refraction triplications observed for several interfaces. Examples of typical and excellent data are shown in Fig. 2.20 (OBS 74) and 2.21 (OBH 86). The latter it should be noted is the instrument which popped up on time release at the end of the cruise, still recording data.

2.5.5 Profile 5

This was a partial reshoot of Profile 1, where the stations in the middle of the basin had been most affected by RAMFORM VALIANT's shots. Two data examples (OBS 91 and 94 – Fig. 2.22 and 2.23) should be compared with the results from Profile 1 (Fig. 2.13). Once more the data are of text-book quality, showing several triplications, indicating that the velocity structure of the crust will be well constrained.

2.5.6 Profile 6

This was the last profile shot and crossed the Porcupine Median High where this was a broad flat-topped high. The two instruments from the extreme ends of the profile (OBS 96 and OBS 107 illustrate the excellent data quality (Fig. 2.24 and 2.25).

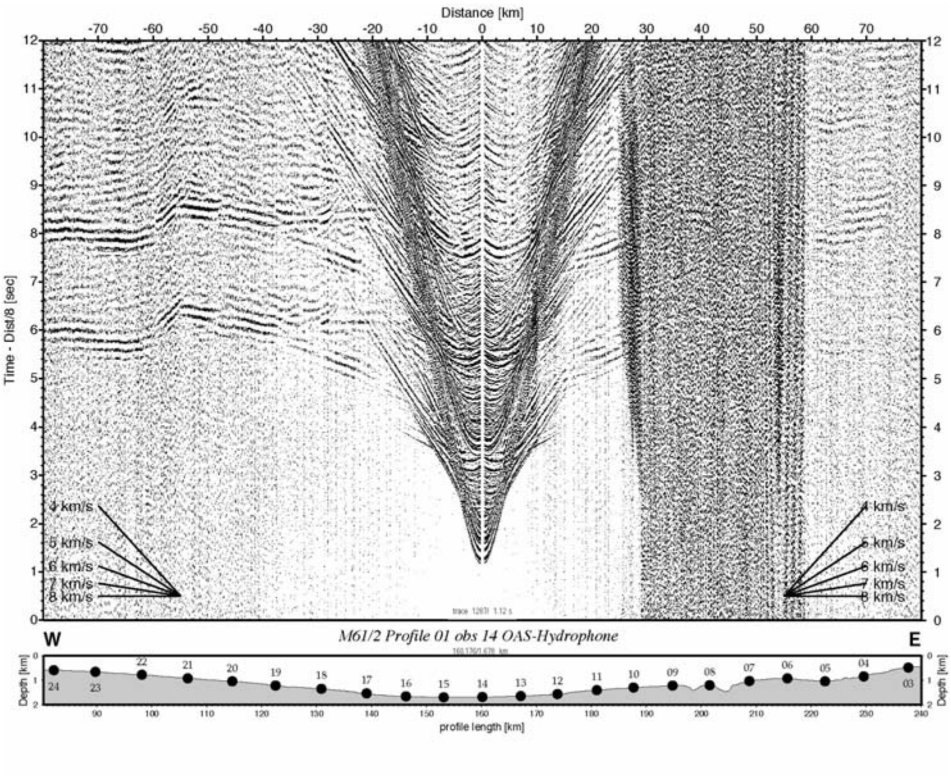


Figure 2.13

Fig. 2.13: Hydrophone channel from OBS14. The band of noise between offsets 28 and 60 km was generated by the RAMFORM VALIANT shooting on distance. Apart from this noise, the data quality is very good. Because of noise problems, we reshot this part of the profile (Profile 5).

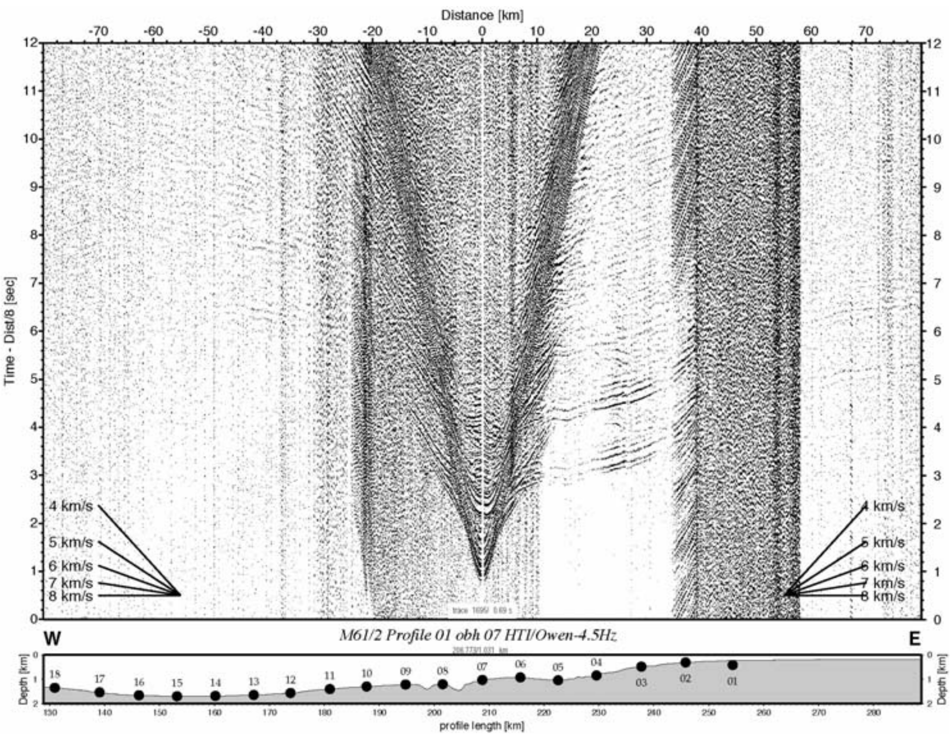


Fig 2.14: Record section from OBH7. Noisy panels between –20 and 15 km and between 35 and 55 km are contaminated by noise from RAMFORM VALIANT's shots. Where this noise is coherent (35-40 km – we believe the RAMFORM VALIANT was shooting on time to warm-up the guns) - processing may be able to remove it.

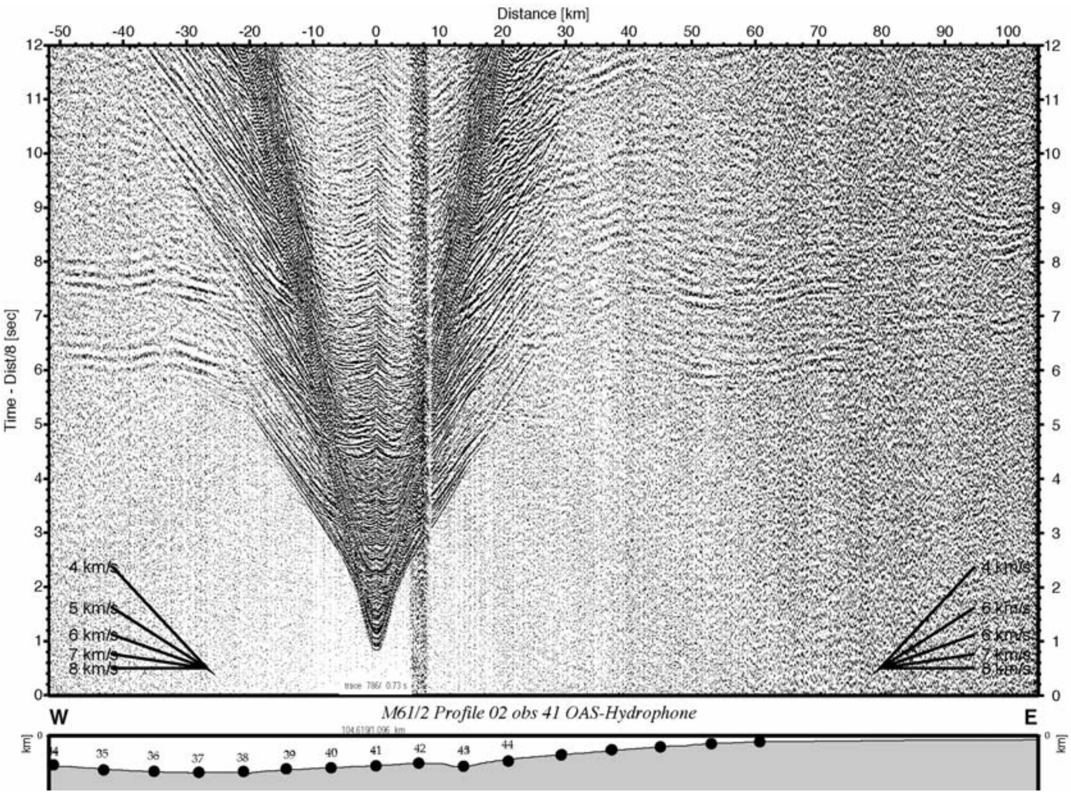


Fig. 2.15: Record section from the vertical component of OBS41 on Profile 2. Note that the data quality is good.

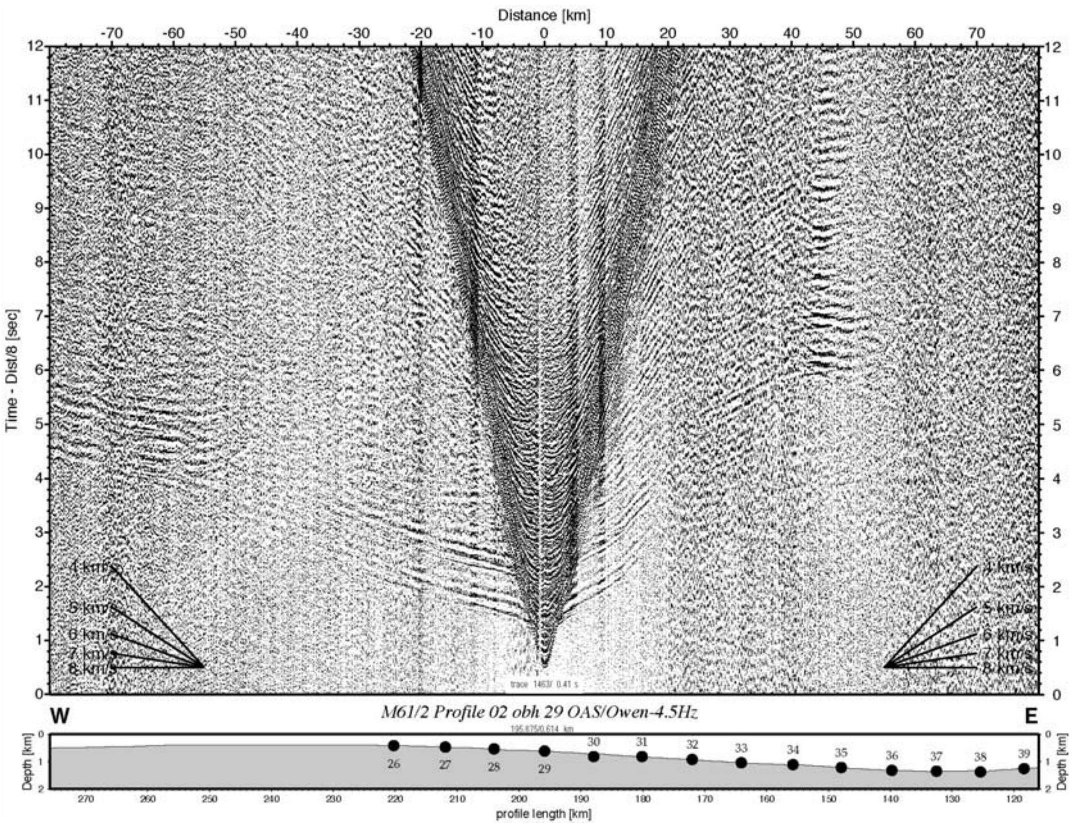


Fig. 2.16: Record section from the hydrophone channel of OBS 29 (near the western end of Profile 2). Data quality is good. The crust of the Porcupine Bank appears far thicker than near the centre of the basin.

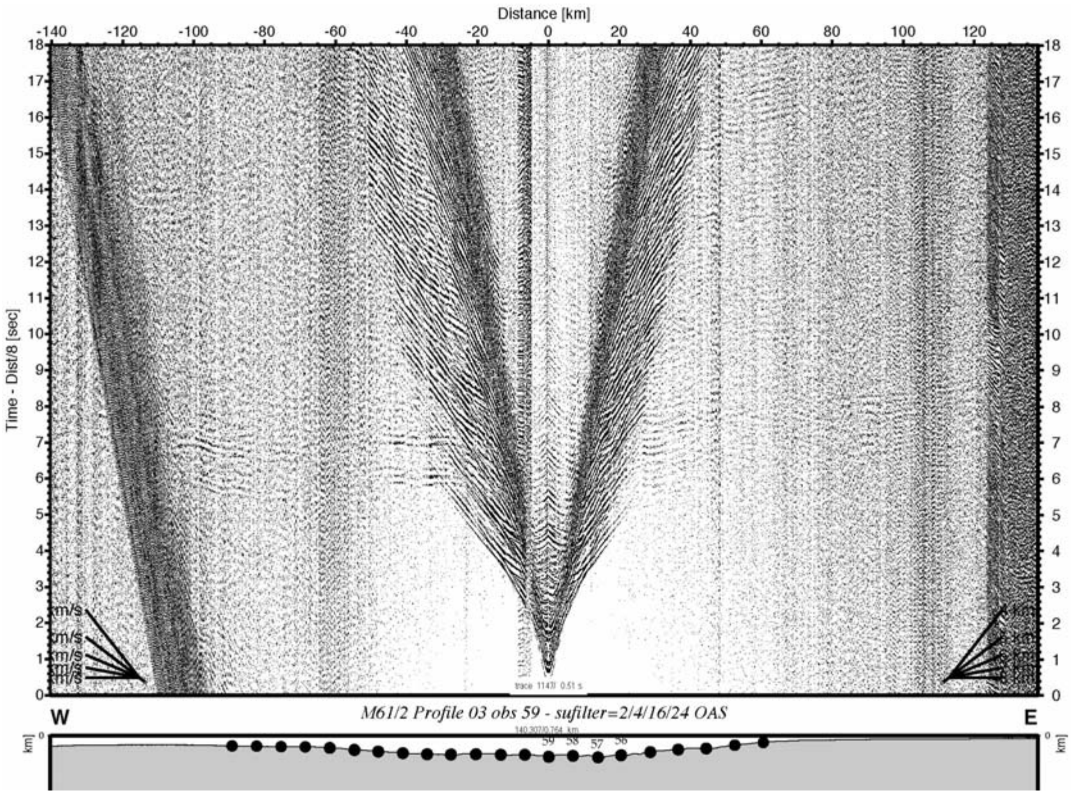


Fig. 2.17: Record section from OBS 59 (from the middle of Profile 3), showing typically good data quality on this profile. Note shots from the entire profile are shown – coherent arrivals are observed out beyond 100 km on both sides.

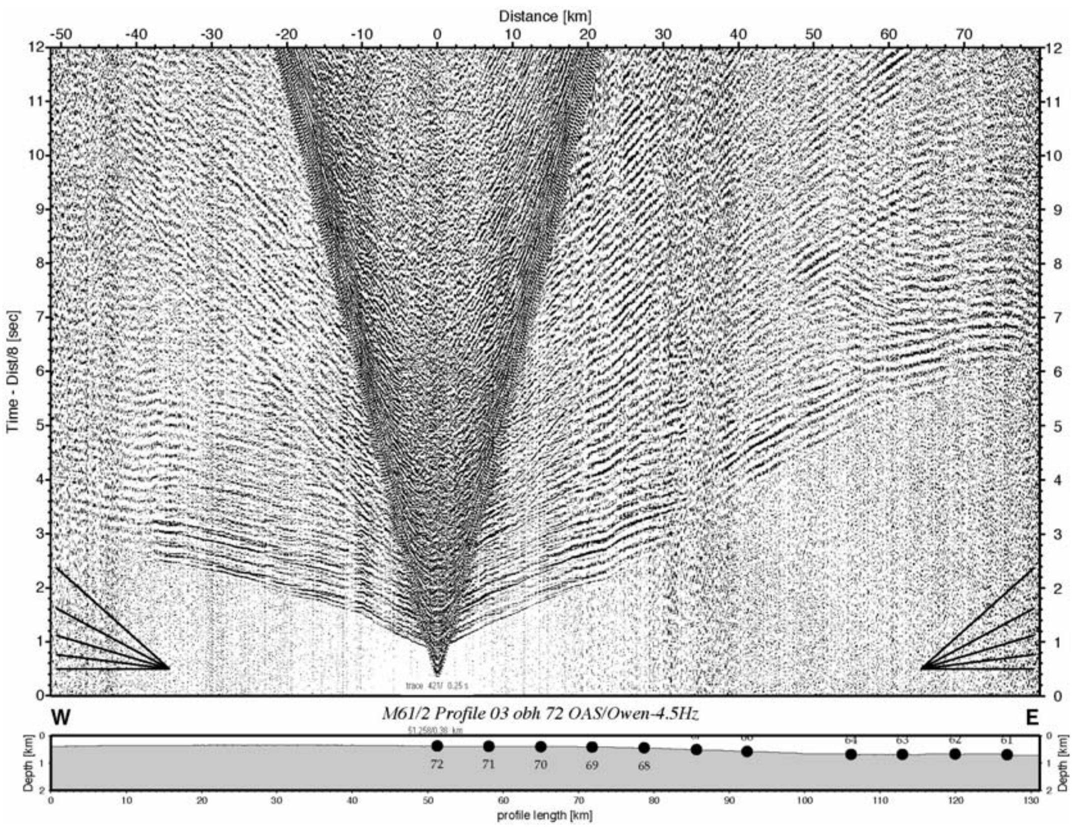


Fig. 2.18: Raw record section from OBH 72 from the end of Profile 3, showing typically good data quality. Arrivals are observed at offsets up to 140 km – in this case Pn.

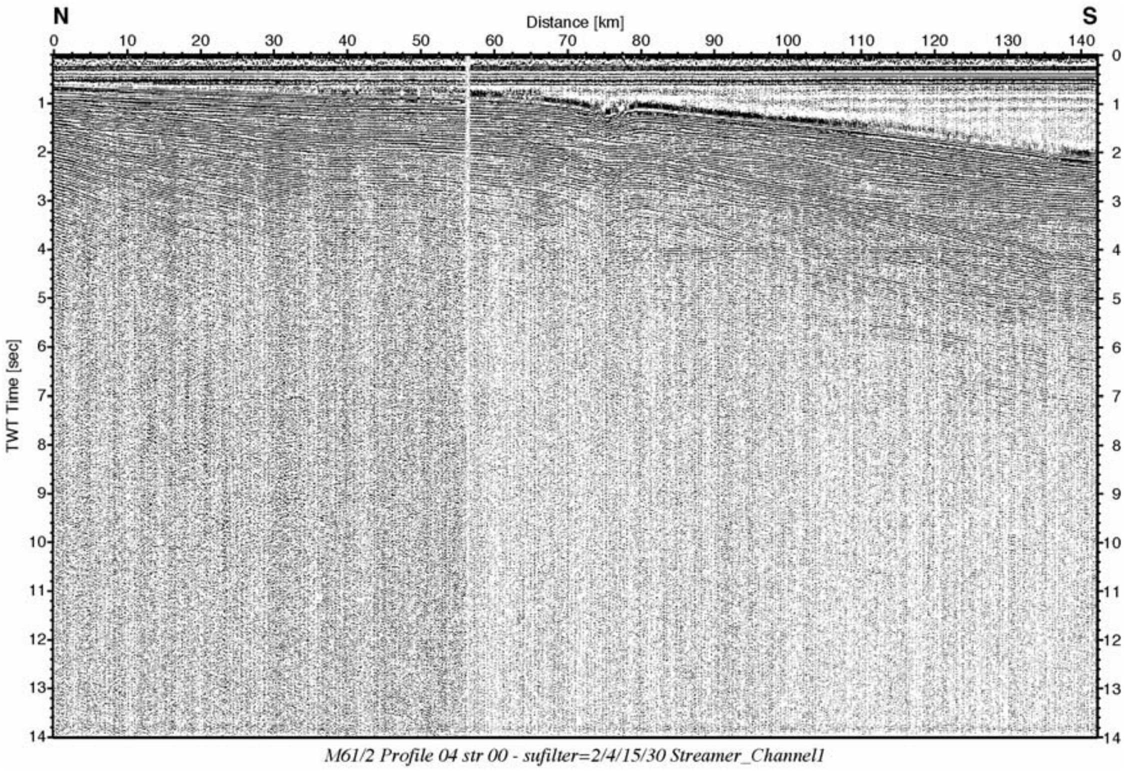


Fig. 2.19: Channel 1 of the mini-streamer used on part of profile 4.

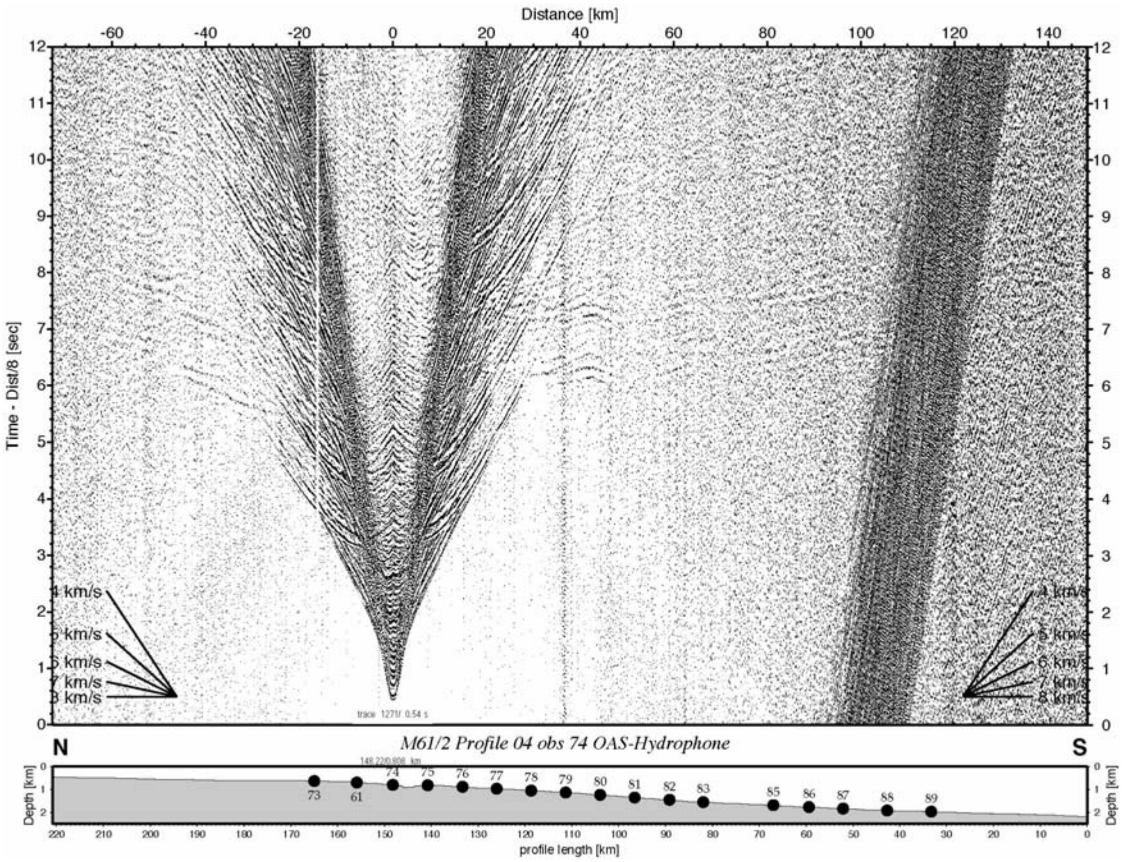


Fig. 2.20: Record section from OBS 74 (Profile 4). Data quality is good. Note arrivals at high apparent velocities.

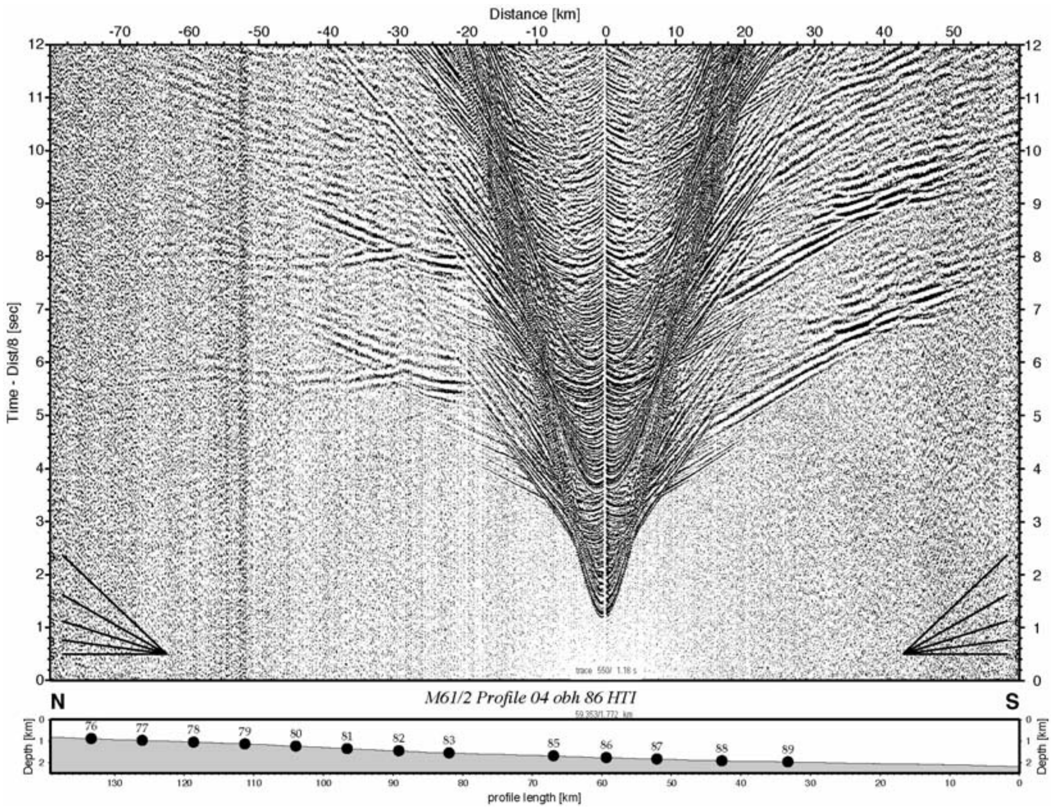


Fig. 2.21: Record section from OBH 86 showing part of the recordings during Profile 4. Data quality is very good. Pn is clearly identifiable to the north and PmP on both sides.

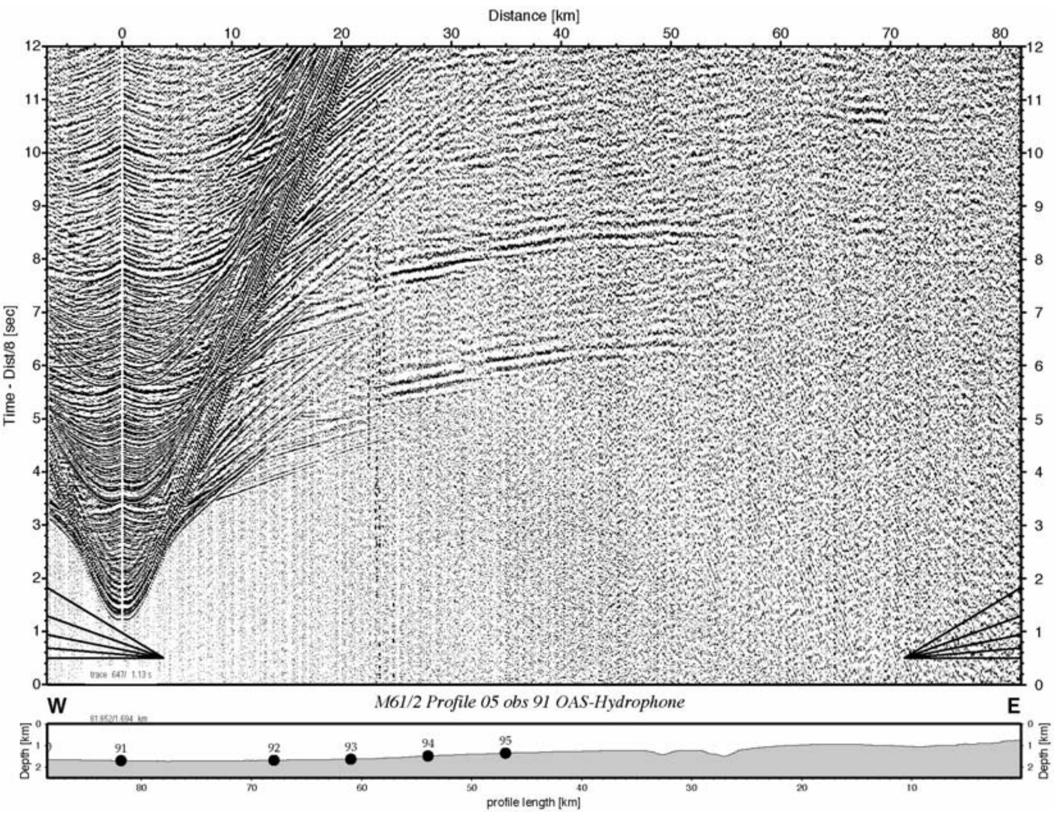


Fig. 2.22: Record section from OBS 91 (Profile 5), located near OBS14 (Fig. 2.13). Data quality is excellent. Note a clear triplication at ca. 8 km, and critical reflections at 25 km offset.

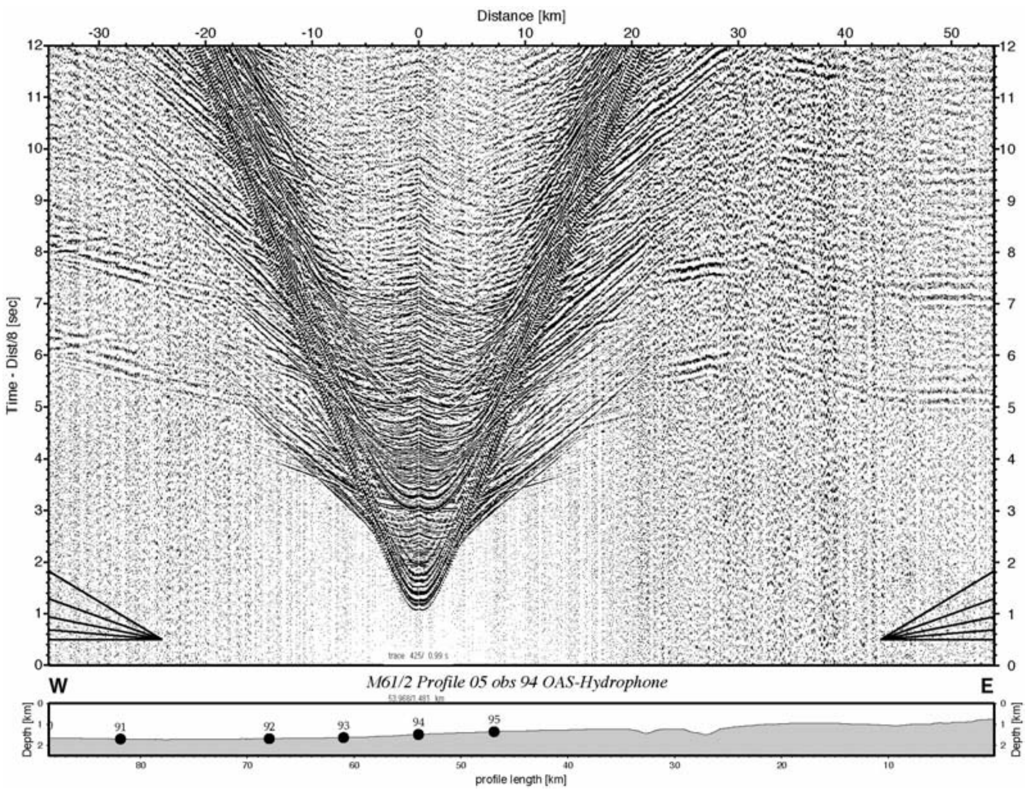


Fig. 2.23: Record section from OBS 94 (Profile 5). Data quality is excellent. Note clear triplications at ca. 8 and –8 km, critical reflections at 28 and –28 km.

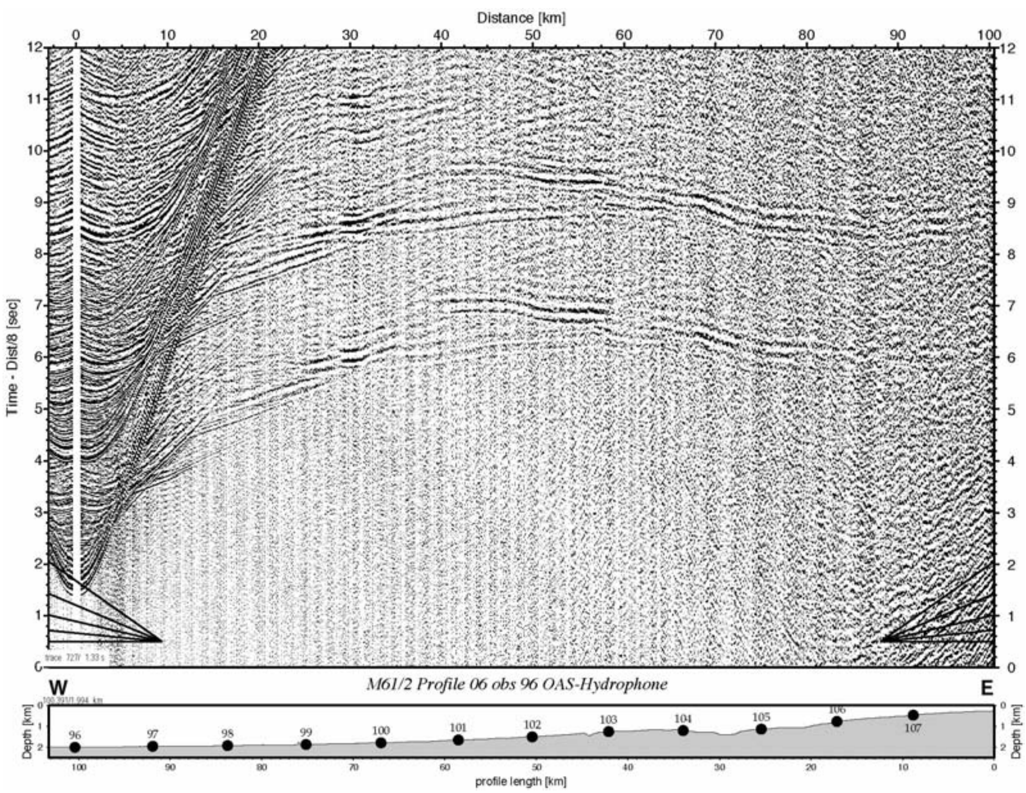


Fig. 2.24: Record section from OBS 96 (western end of Profile 6). Data quality is excellent. Critical reflections at 30 and 55 km may correspond to the top of serpentinised and unserpentinised mantle.

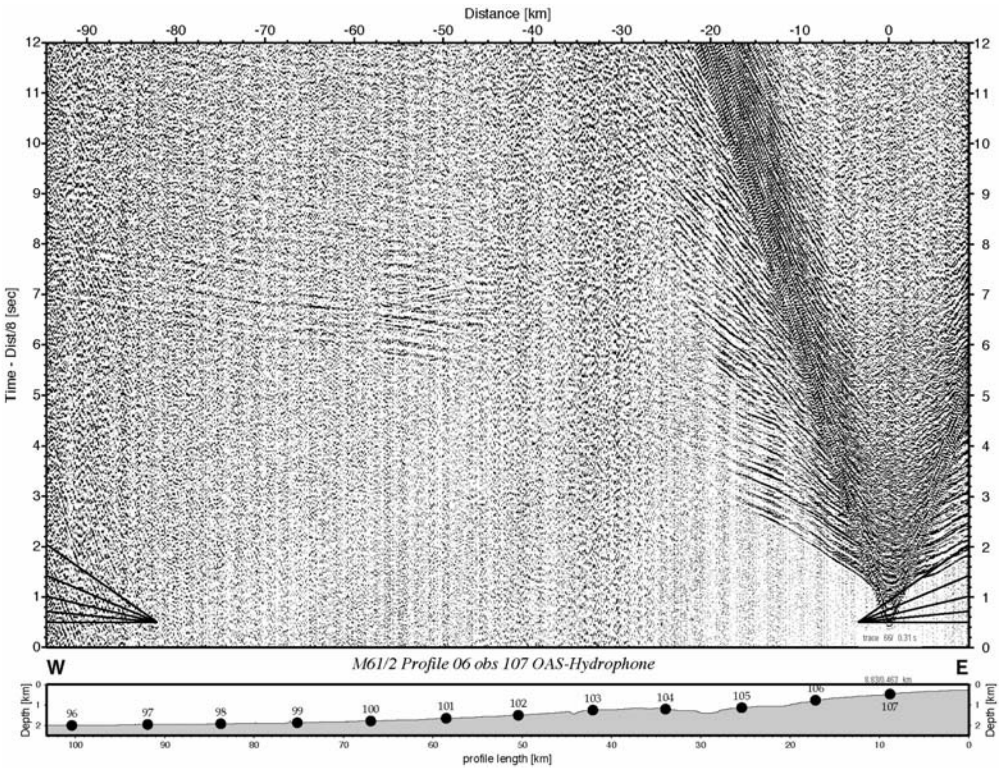


Fig. 2.25: Record section from OBS 107 (eastern end of Profile 6). Data quality is good, with arrivals at the full range of offsets.

2.5.7 Picking of Phases

Although time during the cruise for picking was limited (especially as there was no long transit at the end of the cruise), a first pass pick on profile 2 was carried out towards the end of the cruise. A typical data example showing the picks that were made is shown Fig. 2.26.

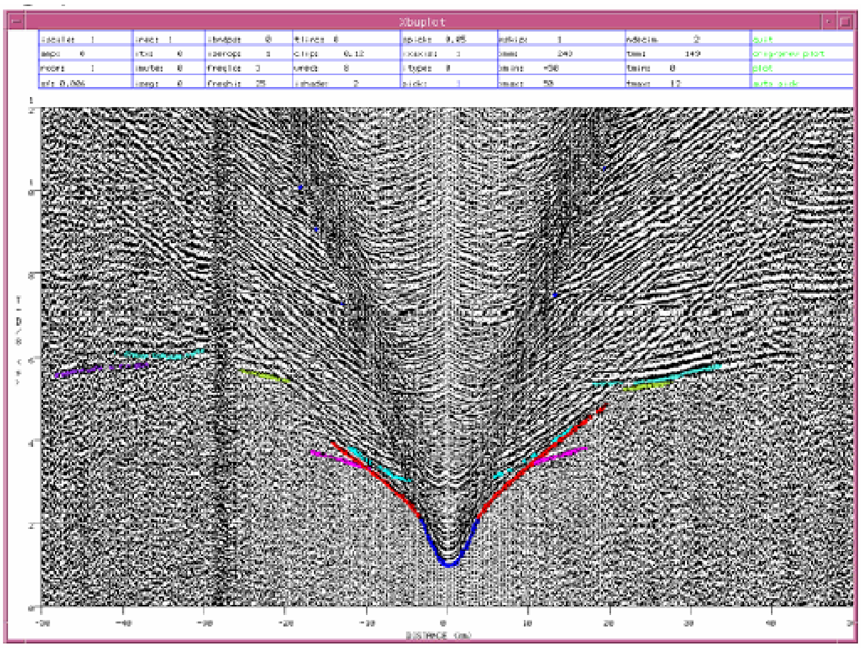


Fig. 2.26: Phases picked from station prior to modelling. Note clear triplications (refraction, reflection, refraction), providing good constraints on velocity structure.

2.6 Station List

Tab. 2.2: Profile 1. Co-ordinates of deployed instruments and shooting line.

Meteor Station	OBH/OBS	Latitude	Longitude	Day+UTC
323	OBS 1 (Walze)	51°28,36´N	11°21´W	
324	OBS 2 (Walze)	51°28,24´N	11°28´W	
325	OBS3 (Walze)	51°28,12 ´N	11°35´W	
326	OBS 4 (Walze)	51°28,00´N	11°42´W	
327	OBH 5	51°27,88´N	11°48´W	
328	OBH 6	51°27,76´N	11°54´W	
329	OBH 7	51°27,64´N	12°00´W	
330	OBH 8	51°27,52´N	12°06´W	
331	OBS 9	51°27,40´N	12°12´W	
332	OBS 10	51°27,28´N	12°18´W	
333	OBS 11	51°27,16´N	12°24´W	
334	OBS12	51°27,04´N	12°30´W	
335	OBS13	51°26,92´N	12°36´W	
336	OBS14	51°26,80´N	12°42´W	
338	OBS16	51°26,56´N	12°54´W	
339	OBS17	51°26,44´N	13°00´W	
340	OBS18	51°26,32´N	13°07´W	
341	OBH19	51°26,20´N	13°14´W	
342	OBH20	51°26,08´N	13°21´W	
343	OBH21	51°25,96´N	13°28´W	
344	OBH22	51°25,84´N	13°35´W	
345	OBH23	51°25,72´N	13°42´W	
346	OBH24	51°25,60´N	13°49´W	
347	OBS25 (Walze)	51°25,48´N	13°56´W	
348	Profile 1 Begin	51°24,80´N	14°50.6´W	10.5.04, 06:34
	Profile 1 End	51°29,30´N	10°35´W	12.5.04, 00:37

Tab. 2.3: Profile 2. Co-ordinates of deployed instruments and shooting line.

Meteor Station	OBH/OBS	Latitude	Longitude	Day+UTC
374	OBS 26 (Walze)	51°43´N	13°58´W	
375	OBH 27	51°43´N	13°51´W	
376	OBH 28	51°43´N	13°44´W	
377	OBH 29	51°43´N	13°37´W	
378	OBH 30	51°43´N	13°30´W	
379	OBS 31	51°43´N	13°23´W	
380	OBS 32	51°43´N	13°16´W	
381	OBS 33	51°43´N	13°09´W	
382	OBS 34	51°43´N	13°02´W	
383	OBS 35	51°43´N	12°55´W	
384	OBS 36	51°43´N	12°48´W	
385	OBS 37	51°43´N	12°42´W	
386	OBS 38	51°43´N	12°36´W	
387	OBS 39	51°43´N	12°30´W	
388	OBS 40	51°43´N	12°24´W	
389	OBH 41	51°43´N	12°18´W	
390	OBH 42	51°43´N	12°12´W	
391	OBH 43	51°43´N	12°06´W	
392	OBH 44	51°43´N	12°00´W	
393	OBH 45	51°43´N	11°53´W	
394	OBH 46	51°43´N	11°46´W	
395	OBS 47 (Walze)	51°43´N	11°39´W	
396	OBS 48 (Walze)	51°43´N	11°32´W	
397	OBS 49 (Walze)	51°43´N	11°25´W	
398	Profile 2-I Begin	51°43´N	10°45´W	14.5.04, 10:08
	Profile 2-I End	51:43´N	12°10'43´W	14.5.04, 22:01
	Profile 2-II Begin	51:43´N	12°11'49´W	15.5.04, 06:00
	Profile 2-II End	51°43´N	15°00.28´W	16.5.04, 06:40

Tab. 2.4: Profile 3. Co-ordinates of deployed instruments and shooting line.

Meteor Station	OBH/OBS	Latitude	Longitude	Day+UTC
425	OBS 51 Walze	52°15´N	11°40´W	
426	OBS 52 Walze	52°15´N	11°47´W	
427	OBS 53 Walze	52°15´N	11°54´W	
428	OBH 54	52°15´N	12°01´W	
429	OBH 55	52°15´N	12°08´W	
430	OBH 56	52°15´N	12°15´W	
431	OBH 57	52°15´N	12°21´W	
432	OBS 58	52°15´N	12°27´W	
433	OBS 59	52°15´N	12°33´W	
434	OBS 60	52°15´N	12°39´W	
435	OBS61	52°15´N	12°45´W	
436	OBS 62	52°15´N	12°51´W	
437	OBS63	52°15´N	12°57´W	
438	OBS64	52°15´N	13°03´W	
439	OBS65	52°15´N	13°09´W	
440	OBS66	52°15´N	13°15´W	
441	OBH67	52°15´N	13°21´W	
442	OBH68	52°15´N	13°27´W	
443	OBH69	52°15´N	13°33´W	
444	OBH70	52°15´N	13°39´W	
445	OBH71	52°15´N	13°45´W	
446	OBH72	52°15´N	13°51´W	
447	Profile 3-I Begin	52°15´N	14°36´W	18.5.04, 11:11
	Profile 3-I End	52°15´N	10°32.4´W	20.5.04, 06:08

Tab. 2.5: Profile 4. Co-ordinates of deployed instruments and shooting line.

Meteor Station	OBH/OBS	Latitude	Longitude	Day+UTC
470	OBS 73 (Walze)	52°20´N	12°45´W	
435	OBS61	52°15´N	12°45´W	
471	OBS 74 (Walze)	52°11´N	12°45´W	
472	OBH 75	52°07´N	12°45´W	
473	OBH 76	52°03´N	12°45´W	
474	OBS 77 (Walze)	51°59´N	12°45´W	
475	OBH 78	51°55´N	12°45´W	
476	OBH 79	51°51´N	12°45´W	
477	OBS 80 (Walze)	51°47´N	12°45´W	
478	OBH 81	51°43´N	12°45´W	
479	OBH 82	51°39´N	12°45´W	
480	OBS 83	51°35´N	12°45´W	
481	OBH 84	51°31´N	12°45´W	
482	OBS 85	51°27´N	12°45´W	
483	OBH 86	51°23´N	12°45´W	
484	OBH 87	51°19´N	12°45´W	
485	OBS 88	51°14´N	12°45´W	
486	OBH 89	51°09´N	12°45´W	
487	Line 4-I Begin	50°51,16´N	12°45´W	21.5.04, 23:41
	Line 4-I End	51° 32.16´N	12°45´W	22.5.04, 11:15
	Line 4-II Begin	51°32.17´N	12°45´W	23.5.04, 17:21
	Line 4-II End	52°19.77´N	12°45´W	24.5.04, 05:05
	Line 4-III Begin	52°19.18´N	12°45´W	24.5.04, 14:18
	Line 4-III End	52°50´N	12°45´W	24.5.04, 21:48

Tab. 2.6: Profile 5. Co-ordinates of deployed instruments and shooting line. Profile 5 was deployed, shot and recovered between Profile 4 parts I and II.

Meteor Station	OBH/OBS	Latitude	Longitude	Day+UTC
488	OBS 90	51°26,5´N	12°57´W	
489	OBS 91	51°26,65´N	12° 51´W	
482	OBS 85	51°27´N	12°45´W	
490	OBS 92	51°26,85´N	12°39´W	
491	OBS 93	51°27,0´N	12°33´W	
492	OBS 94	51°27,1´N	12°27´W	
493	OBS 95	51°27,2´N	12°21´W	
494	First shot	51°28´N	11°40´W	22.5.04, 20:18
	Last shot	51°26,5´N	12°57´W	23.5.04, 08:00

Tab. 2.7: Profile 6. Co-ordinates of deployed instruments and shooting line.

Meteor Station	OBH/OBS	Latitude	Longitude	Day+UTC
510	1	51°17.4´N	11°22´W	
511	2	51°16.5´N	11°30´W	
512	3	51°15.7´N	11°38´W	
513	4	51°14.8´N	11°46´W	
514	5	51°14.0´N	11°54´W	
515	6	51°13.1´N	12°02´W	
516	7	51°12.3´N	12°10´W	
517	8	51°11.5´N	12°18´W	
518	9	51°10.6´N	12°26´W	
519	10	51°09.8´N	12°34´W	
520	11	51°08.7´N	12°42´W	
521	12	51°07.8´N	12°50´W	
522	Profile 6 Begin	51°17.26'N	11°23.49'W	26.5.04, 13:49
	Profile 6 End	51°07.30'N	12°53.1'W	27.5.04, 03:30

2.7 Acknowledgements

We gratefully acknowledge the financial support of the DFG, the political support of colleagues in Ireland and the logistical support of colleagues in IFM-GEOMAR, in particular Ernst Flueh. The work could only be carried out because of the dedication and skill of the captain, officers and crew of the FS Meteor.

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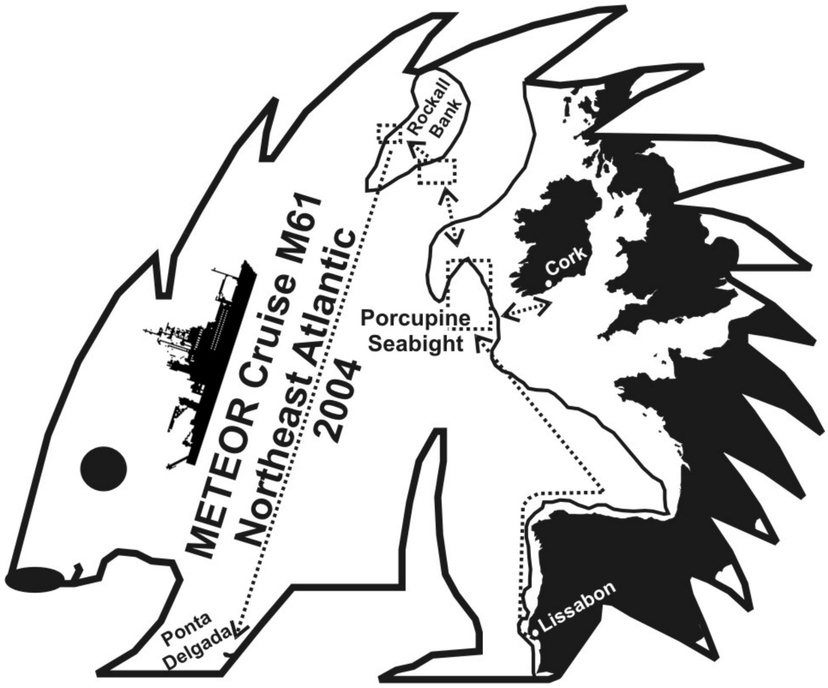
METEOR-Berichte 06-2

Northeast Atlantic 2004

Cruise No. 61, Leg 3

June 4 to June 21, 2004, Cork – Ponta Delgada



Development of Carbonate Mounds on the Celtic Continental Margin

Ratmeyer, V., Beck, T., Belling, R., Bergenthal, M., Beuck, L., Brakel, C., Buhmann, S., Dodds, L., Dorschel, B., Engemann, G., Foubert, A., Gault, J., Grehan, A., Hayn, C., Jurkiw, A., Kahl, G., Kaiser, J., Klar, S., Lutz, M., Noe, S., Papstein, H., Rüggeberg, A., Ruhland, G., Schewe, F., Schmidt, W., Schröder, M., Seiter, C., Truscheit, T., Wienberg, C.

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3.1 Participants

Tab. 3.1 List of Participants on Leg M61-3.

Name	**Discipline**	**Institute**
Beck, Tim, Dipl. Biol.	Benthic Ecology	IPAL
Belling, Reimund	TV-Journalist	NDR-TV
Bergenthal, Markus, Dipl. Phys.	Marine Technology (ROV)	MARUM/RCOM
Beuck, Lydia, Dipl. Geol.	Marine Geology	IPAL
Brakel, Christian	TV-Journalist	MARUM/RCOM
Buhmann, Sitta, TA	Marine Technology (ROV)	MARUM/RCOM
Dodds, Lyndsey A., M.Sc.	Benthic Biology	SAMS
Dorschel, Boris, Dr.	Marine Geology	MARUM/RCOM
Engemann, Greg, M. Eng.	Marine Technology (ROV)	Schilling
Foubert, Anneleen, M.Sc.	Marine Geology	RCMG
Gault, Jeremy	Marine Geology	UCC
Grehan, Anthony, Dr.	Benthic Biology	NIUG
Hayn, Christina, TA	Marine Geology	MARUM/RCOM
Jurkiw, Alexandra, M.Sc.	Marine Geology	MARUM/RCOM
Kahl, Gerhard, Dipl.Met.	Meteorology	DWD
Kaiser, Jerome, M.Sc.	Marine Geochemistry	MARUM/RCOM
Klar, Steffen, TA	Marine Technology (ROV)	MARUM/RCOM
Lutz, Marco, Student	Marine Geology	MARUM/RCOM
Noe, Sibylle, Dr.	Microbiology	IFM-GEOMAR
Papstein, Henning	TV-Journalist	NDR-TV
Ratmeyer, Volker, Dr., Chief Scientist	Marine Geology	MARUM/RCOM
Rüggeberg, Andres, Dr.	Micropaläontology	IFM-GEOMAR
Ruhland, Götz, Dipl. Geol.	Marine Technology (ROV)	MARUM/RCOM
Schewe, Felix, TA	Gear Handling	MARUM/RCOM
Schmidt, Werner, Dipl. Geol.	Marine Technology (ROV)	MARUM/RCOM
Schröder, Marcel, TA	Marine Technology (ROV)	MARUM/RCOM
Seiter, Christian, Dipl. Geol.	Marine Technology (ROV)	MARUM/RCOM
Truscheit, Thorsten	Meteorology	DWD
Wienberg, Claudia, Dr.	Marine Geology	MARUM/RCOM

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D-24148 Kiel / Germany

IPAL Institut für Paläontologie
Universität Erlangen
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MARUM Zentrum für Marine
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Universität Bremen
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D-28359 Bremen / Germany

NDR-TV Norddeutscher Rundfunk
Fernsehen
Oldenburg / Germany

NIUG National University of Ireland
University Road
Galway / Ireland

RCMG Renard Centre of Marine Geology
University of Ghent
Krijgslaan 281 S8
B-9000 Gent / Belgium

RCOM DFG-Forschungszentrum
Ozeanränder
Universität Bremen
Klagenfurterstraße
D-28359 Bremen / Germany

SAMS Scottish Ass. for Marine Sciences
Dunstaffnage Marine Laboratory
Oban, Argyll, PA37 1QA / UK

UCC University College Cork
Donovans Road
Cork / Ireland

3.2 Research Program

3.2.1 Development of Carbonate Mounds Along the Celtic Continental Margin

In the past years, the EU-projects ECOMOUND (*Environmental Controls on Mound Formation along the European Margin*), GEOMOUND (*The Mound Factory - Internal Controls*) and ACES (*Atlantic Coral Ecosystem Study*) have generated many new results concerning the large carbonate mound provinces at the NW-European continental margin. These made clear that particular external environmental factors have a significant influence on the development of the mounds and on the cold water corals living on 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 (*Forcing of Carbonate Mounds and Deep Water Coral Reefs along the NW European Continental Margin*), and which were addressed during leg M61-3:

Which factors control the development of the carbonate mounds?

Possible limiting environmental factors, which have to be considered, are related to 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 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.

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

Video footage from carbonate mounds reports highly diverse faunas consisting of corals, sponges, crinoids and numerous other organism groups. Among these organisms the framework building coral *Lophelia 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 e.g. do not contain any *L. pertusa*. On the base of sediment cores from Propeller Mound investigated in Bremen, a model for mound development has been established to describe 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 along the Celtic Continental margin (e.g. Western Rockall Bank) is unknown at the moment.

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. Another hypothesis claims that bacteria at the sediment surface contribute to the stability of the sediments by e.g. the production of biofilms. Detailed sampling of very steep slope areas is envisaged to solve this question.

In addition there is a great interest to investigate carbonate crusts and hardgrounds, as those are probably also closely related to the growth history of the carbonate mounds. Furthermore, the lithification of the mound sediments will be assessed by the analysis of diagenetic changes in the sediments.

3.2.2 Working Program

The working program during M61-3 focused on the application of the remotely operated vehicle (ROV) QUEST, based at MARUM / Uni Bremen, and the sampling of sediments by box corer and gravity corer, accomplished by CTD casts and hydroacoustic surveys.

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 four different provinces were examined during the M61-3 cruise (Fig. 3.1).

The first location observed was Galway Mound in the Belgica Mound Province (eastern Porcupine Seabight). In summer 2003, seven autonomous sensor units measuring current speed and direction and containing a CTD were placed on this mound. As a major goal of the work program during M61-3, these were successfully located and recovered by Bremen's QUEST ROV after one year of deployment.

The second working area covers Propeller Mound in the Hovland Mound Province (northern Porcupine Seabight). Numerous data already exist from this \`housegarden´ of the Bremen, Kiel and Erlangen teams, making Propeller Mound an ideal place for a sampling campaign to take a number of CTD casts and boxcores with the latter aiming to cover some facies that have so far not been sampled representatively.

The relatively unknown West Rockall Bank was chosen as the third working area. As a fourth working area, the so-called Connaught Mound and an associated terrace structure on the Northern Porcupine Bank were selected after exploring TOBI sidescan images obtained by the Geological Survey of Ireland.

For all of the four working areas (Galway Mound, Propeller Mound, West Rockall Bank, North Porcupine Bank, Fig. 3.1) the working program was based on a similar sampling strategy including (1) an initial hydroacoustic characterisation of the selected structures (Hydrosweep, Parasound), (2) dives with the ROV QUEST, (3) supplemental CTD casts, (4) sampling of sediments with gravity and box corer. Appropriate sediment sampling sites were selected based on site-survey and visual information resulting from the ROV dives. Using QUEST was also essential for a targeted sampling of carbonate crusts, hardgrounds and very steep slopes. Spatial distributions of the faunas on these mounds were video taped during ROV transects over different mound areas (e.g. mound crest, luff and lee flanks, moats).

Although the time budget available for different sampling campaigns at Galway Mound and the West Rockall Bank was limited, information already available from the earlier leg M61-1 allowed an effective planning of sampling campaigns and ROV dives.

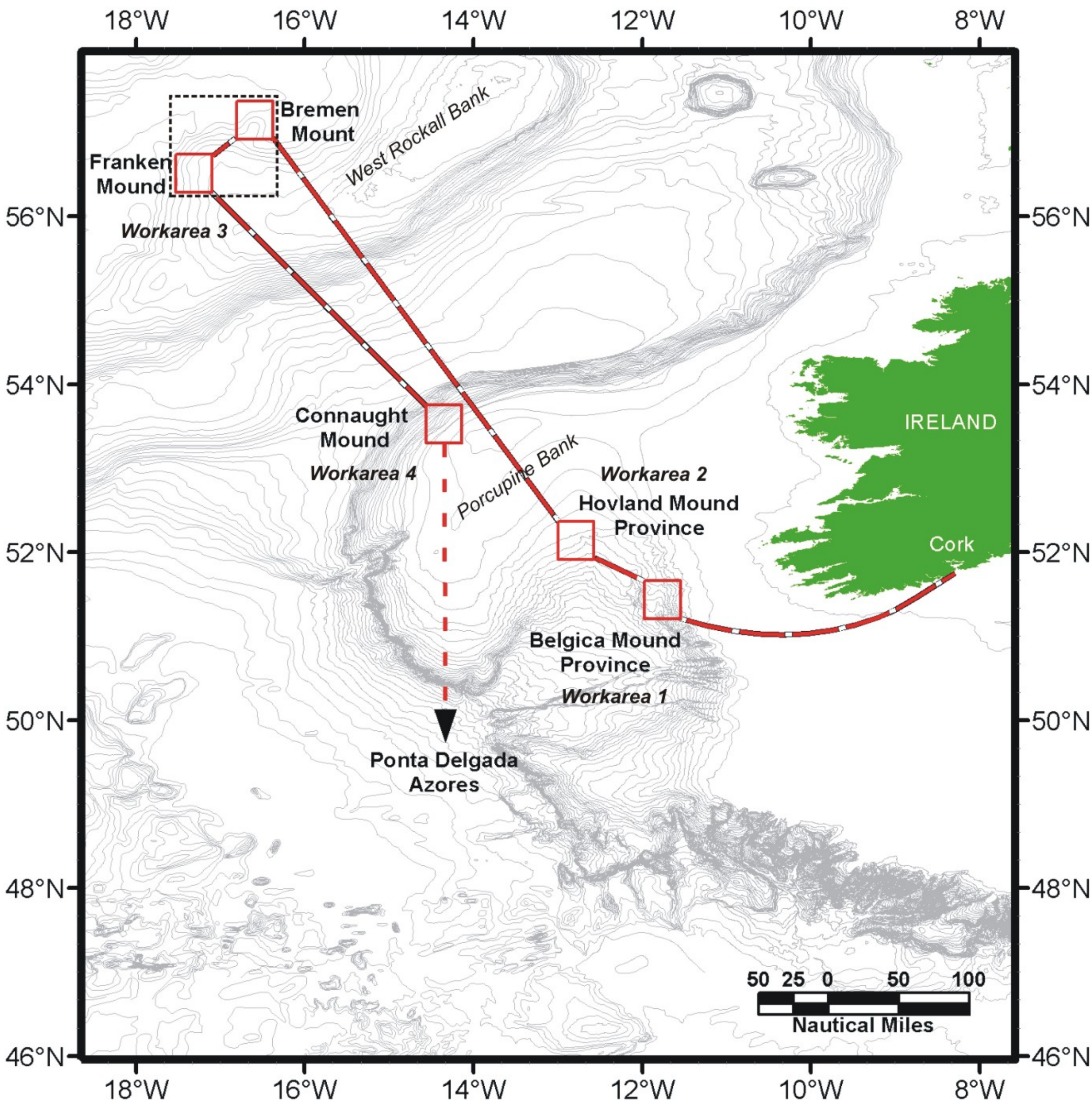

Fig. 3.1 Map of the Celtic continental slope and the four working areas during leg M61-3. Workarea 1 includes Galway and Poseidon Mound, whereas workarea 2 includes Propeller Mound.

3.3 Narrative of the Cruise, Leg M61-3

The third leg of the M 61 cruise lasted 18 days. It started in Cork, Ireland, on June 4th, and ended in Ponta Delgada, Azores Islands, Portugal, on June 21st. After the scientific equipment was loaded aboard RV METEOR, mobilisation of the 4000 m deep diving remotely operated vehicle ROV QUEST of the University of Bremen took place. Beside the vehicle and its scientific payload, a new deployment frame and a new underwater positioning system were installed aboard the vessel. Mobilisation was finished with a successful QUEST dive test at the pier in Cork harbour. RV METEOR departed from Cork in the early afternoon of June 4th, towards the Porcupine Seabight west of Ireland. Sailing down the river Lee provided a scenic background for the first TV-film work of the participating NDR TV-team.

The first working area around Galway Mound (Belgica Mound Province) on the north western edge of the Porcupine Seabight at 51°26.70' N, 11°45.03' W was reached on June 5th, and the scientific program started during night with two CTD profiles and water sampling. Station work continued with the deployment of an elevator-mooring designed for the ROV-based recovery of seven combined CTD/current meter devices. Recovery of these probes, which were set during 2003 with the help of the French ROV VICTOR, was the major goal of two dives with QUEST at Galway Mound. The sensor units, consisting of inductive current meters and CTDs, were deployed on north-south and east-west transects over the structure to collect data on the small scale flow field around Galway Mound. With sampling intervals of 10 minutes, the recorded data are sufficient to provide information on possible tidal influences on the mound. Being installed in the frame of the ESF-project MOUNDFORCE, the main task was to create a data base for the correlation of the current regime at Galway Mound with different biological and geological facies. After successful recovery of these probes, work was followed by a series of boxcorer stations and gravity cores across Galway Mound.

During June 7th, the slightly easterly located Poseidon Mound at 51°26.60' N, 11°41.80' W was sampled with three additional boxcores. A time-series of eight CTD profiles with one-hour interval between each cast indicated the influence of tidal waves at 600–700 m water depth. The detection of such processes is important for the understanding of the deep-water coral ecosystem as the corals take advantage of the strong currents and the pumping dynamics associated to internal waves which both may result in a high nutrient availability for the corals.

After finishing station work in the Belgica Mound Province on June 9th, RV METEOR moved towards West Rockall Bank. On the way, a short stopover at Propeller Mound in the Hovland Mound Province was used to complete previous sampling of surface sediments with the box corer and to take CTD casts across the mound.

First target area in the West Rockall Bank area was an interesting sea floor elevation, discovered previously during RV POSEIDON expedition POS 292. After detailed hydroacoustic mapping the 5th dive with QUEST was scheduled for the evening of June 10th. Since video-observation suggested that the structure was an old volcanic seamount with only very sporadic coral growth, the dive was terminated and RV METEOR moved west towards Franken Mound, a promising structure discovered during M61-1, at 56°29.93' N, 17°18.21' W. A major work program covering nearly the complete mound surface could be performed at this site between June 11th and 13th, including extensive sediment surface and gravity core sampling, CTD casts and four complementary ROV dives. Result of this station work is a complimentary dataset of oceanography, detailed in-situ observations, mapped surface structure extensions and a large variety of sediment and surface samples. Due to changing weather conditions, we decided to spend the remaining time not in the West Rockall Bank area as originally planned, but to move further south towards the Northern Porcupine Bank.

After inspection of TOBI sidescan images provided by the Geol. Survey of Ireland (GSI), a prominent edge structure with a small mound was chosen as next dive and sampling target. At the so-called Connaught Mound at 53°30.92' N, 14°21.16' W, station work lasted from the evening of June 14th through June 16th, providing spectacular video footage (two dives), a variety of lithified carbonate crust samples and coral specimen as well as extensive boxcore, gravity core and water samples. As an important result of the opportunity to sample carbonate crusts with QUEST at different sites, hardground samples recovered from Franken Mound and Connaught Mound can be divided into two major facies: a) poorly to moderately lithified pelagic foraminiferal-nannoplankton oozes, and b) highly lithified fossil coral reef framework.

Station work was finished in the morning of June 16th. In total, 95 stations with 117 deployments were carried out during M61-3. The ROV QUEST could be deployed for nine dives. RV METEOR returned to Ponta Delgada, Azores, in the morning of June 21st, where scientific equipment was unloaded and the scientific crew left the ship.

3.4. Methods

3.4.1 CTD Measurements

(A. Rüggeberg, L. Dodds)

A total of 41 CTD casts were carried out during RV METEOR cruise M61-3. The purpose of these measurements was to perform transects across carbonate mound structures of the Belgica Mound Province at the eastern slope of the Porcupine Seabight, the Propeller Mound within the Hovland Mound Province (northern Porcupine Seabight, the Franken Mound at the western slope of Rockall Bank, discovered during RV METEOR cruise M61-1, and the new Connaught Mound along the Porcupine Bank Margin. Some profiles were measured at the same positions as during cruise M61-1 to determine differences in small-scale variability close to the mounds. Another objective was to investigate the temporal variability of the influence of tidal waves and internal waves at the water mass boundary close to the carbonate mound structures. Therefore, CTD profiles were performed at three stations (west–top–east of a mound) with each measurement being repeated three times.

The CTD system used is a SeaBird Electronics, model 911 plus type, referred to as IFM-GEOMAR serial number 2. The underwater unit was built into a rosette housing capable of holding 24 water sampler bottles. Pre-cruise laboratory calibrations of the temperature and pressure sensors were performed. Both yielded coefficients for a linear fit. The oxygen sensor must be considered unreliable because no in-situ measurements were carried out during the cruise. However, the general downcast trend of dissolved oxygen seems to follow previous studies (e.g. WOCE Global Data, World Ocean Database 2001; Conkright et al., 2002), but due to unrealistic decreasing values during several downcasts (between 0.5-1 ml/l) the absolute values are unreliable.

The overall impression of CTD performance was very positive. The downcast profiles showed virtually no spikes in the data and the recording computer worked without problems. Further processing of the data was performed using software SBE Data Processing, Version 5.30a (ftp://ftp.halcyon.com/pub/seabird/out) and Ocean Data View mp-Version 2.0 (http://www.awi-bremerhaven.de/GEO/ODV) for visualisation**.** Water samples were taken at stations 10 m above the seafloor (bottom alarm) and within the water column for stable isotope analyses (IFM-GEOMAR, Kiel), as well as at selected stations at water depths corresponding to 500 db and 100 db for DIC analyses (SAMS, Oban).

3.4.2 Deployment of the QUEST Remotely Operated Vehicle (ROV) for Video Observation and Sampling

(V. Ratmeyer, M. Bergenthal, G. Engemann, S. Klar, G. Ruhland, C. Seiter, W. Schmidt, M. Schroeder)

The remotely operated deep diving robot QUEST is an electric 4000 m-rated, commercial work-class ROV, operated by MARUM, University of Bremen, since May 2003 (Fig. 3.2). The robot was designed and manufactured by Schilling Robotics, Davis, USA. The whole QUEST system weighs 45 tons (including the vehicle, control van, workshop van, electric winch, 5000-m umbilical, and transportation vans) and can be transported in four 20-foot vans. Using a MacArtney Cormac electric driven storage winch to manage the 5000 m of the 17.6 mm NSW umbilical, no hydraulic connections had to be installed during mobilisation.

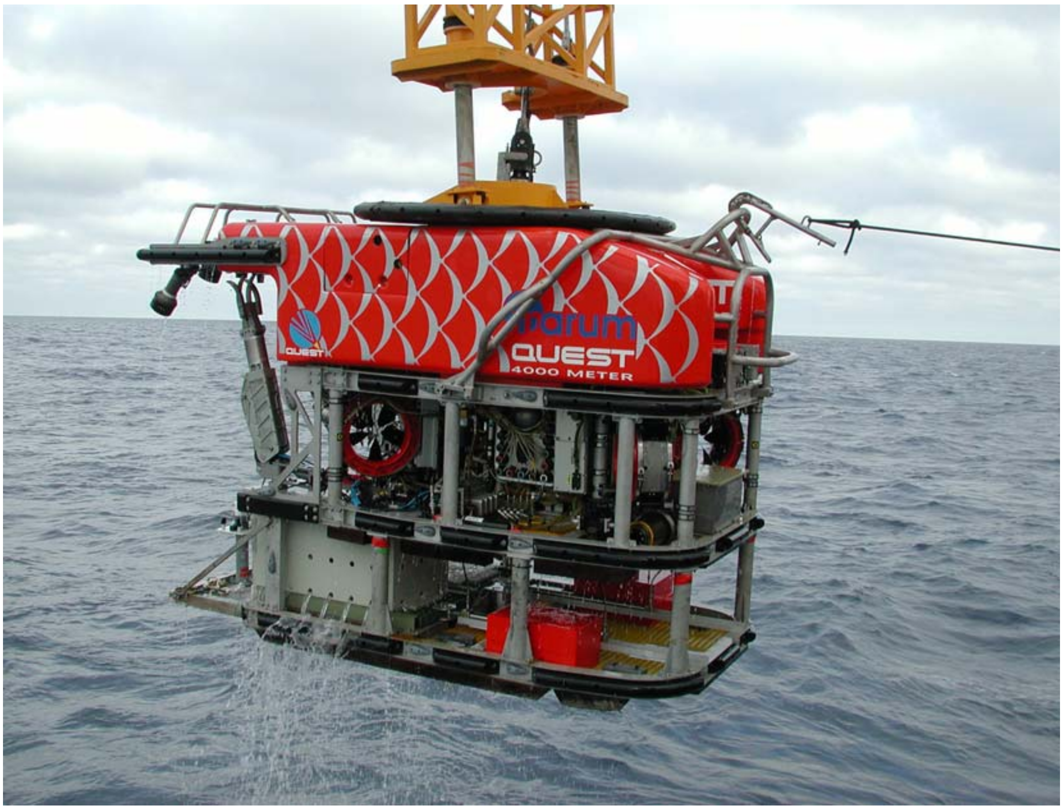

Fig. 3.2 Deployment of the remotely operated vehicle QUEST from RV METEOR during M61-3.

During this cruise, QUEST's technical innovations played a key role to gain operational success aboard RV METEOR and provide a flexible and highly adaptable platform for scientific sampling and observation tasks. A key feature is the reliable and precise positioning capability of the system. QUEST uses a Doppler velocity log (DVL) to perform Station Keep Displacement, automatically controlled 3D positioning, and other auto control functions. Designed and operated as a free-flying vehicle, QUEST system exerts such precise control over the 60-kW electric propulsion system allowing the vehicle to maintain a positioning accuracy within centimetre to decimetre ranges. During M61-3, these functions provided the base for detailed close-up photography and video, as well as for sampling of carbonate hardgrounds with two different robotic arms. In addition to QUEST's standard control features, the vehicle provides lift capacity of up to 250 kg with the RIGMASTER manipulator, as well as a set of different scientific tools and adaptations for biological and geological sampling. A major installation is the advanced camera and lighting suite, consisting of 2.4 kW light power and six different video and still cameras.

The QUEST control system provides transparent access to all RS-232 data and video channels. The scientific data system used at MARUM feeds all ROV- and ship-based science and logging channels into a commercial, adapted real-time database system (DAVIS-ROV). During operation, data and video can be easily distributed over the ship to allow maximum data and video online access by minimizing crowding in the control van. Using the existing ship's communications network, all sensor data can be distributed in real-time via TCP/IP from the control van into various client laboratories, regardless of the original raw-data format and hardware interface. This allows topside processing equipment to perform data interpretation and sensor control from any location on the host ship.

Additionally, the pilot's eight-channel video display can be distributed to up to 16 client stations on the ship via CAT5 cable. This allows the simple setup of detailed, direct communication between the bridge and the ROV control van. Similarly, information from the pilot's display can be distributed to a large number of scientists. During scientific dives where observed phenomena are often unpredictable, having scientists witness a "virtual dive" from a laboratory rather than from a "crowded" control van allows an efficient combination of scientific observation and vehicle control.

During operation, the data distribution setup allows easy access and distribution of data during all stages of the expedition, including the compilation of customized data products for post processing applications after the cruise. Additionally, "dive summaries" containing all data of interest including video and digital still photographs have been compiled. Using the database's export capabilities in combination with the French software product "ADELIE" developed at IFREMER, GIS based plots, data graphs and dive track maps containing time and position-referenced scientific data, video and images are available shortly after or even during the dives.

After the cruise the data will be archived in the information system PANGAEA at the World Data Center for Marine Environmental Sciences (WDC-MARE), which is operated on a long-term base by MARUM, University of Bremen, and the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven (AWI).

During leg M61-3 QUEST has been successfully deployed for 9 dives (Tab. 3.2) encountering sea states up to 4, and winds of up to 6 bft., using the ships stern A-frame in combination with a customized deployment frame. During operation, both ship's and ROV crew were in close contact and could provide a successful handling and navigation to fulfil the scientific tasks required, including instrument search and recovery, digital imagery, video mapping and observation, close up high resolution imaging, specimen sampling and carbonate crust sampling at a variety of locations.

Tab. 3.2 QUEST dives during M61-3. BMP: Belgica Mound Province; WRB: West Rockall Bank; NPB: Northern Porcupine Bank.

Dive No.	Station No.		Area	Date	Time (UTC)		Position at bottom contact		Depth max
QUEST	GeoB	METEOR		(dd/mm/yy)	Begin	End	Lat. °N	Long. °W	(m)
16	9203	550	BMP; Galway Mound	05/06/2004	09:48	20:50	51°26.70'	11°45.03'	892
17	9211-2	558-2	BMP; Galway Mound	06/06/2004	09:38	14:48	51°27.10'	11°45.20'	795
18	9239-1	586-1	BMP; Galway Mound	08/06/2004	07:25	16:30	51°27.10'	11°45.20'	781
19	9240	587	BMP; Poseidon Mound	08/06/2004	17:50	20:54	51°24.30'	11°41.20'	700
20	9249	596	WRB; Bremen Mount	10/06/2004	18:42	00:08	57°06.40'	16°35.30'	803
21	9255-1	602-1	WRB; Franken Mound	11/06/2004	09:46	19:09	56°30.16'	17°18.16'	607
22	9267	614	WRB; Franken Mound	12/06/2004	08:25	18:52	56°30.30'	17°17.30'	685
23	9281-1	628-1	WRB; Franken Mound	13/06/2004	07:59	15:17	56°29.90'	17°18.20'	651
24	9285-1	632-1	NPB; Connaught Mound	15/06/2004	08:10	19:08	53°30.99'	14°22.00'	876

3.4.3 Sediment Surface Sampling with Giant Box Corer

(S. Noé, T. Beck, A. Foubert, A. Grehan)

The main tool used for sediment sampling was the giant box corer, with a sampling area of 50x50 cm and a maximal penetration depth of 50 cm. The giant box corer was deployed at 38 stations during M61-3.

Penetration was highly variable due to the specific types of sediment. At sites dominated by sediments, recovery was on average 20-40 cm with reasonably well preserved surfaces. Areas with a dense coral cover did not allow a penetration depth beyond 20 cm. In total, ten box-corer failed to collect any sediments. Extremely inclined mound flanks as well as exposed hardgrounds prevented any penetration with the giant box corer; instead, these were successfully sampled by the ROV.

The sediment-dominated surfaces mostly comprised light brownish-grey muddy/silty sands, well-sorted sands or poorly sorted muddy silts to coarse sands. In some off-mound areas polymict dropstones of up to 10 cm in diameter were present. Coral-dominated on-mound samples contained mostly coarse-grained sediments underneath the exposed coral framework with high contents of skeletal grains. As these samples have been partly washed out during recovery, however, their composition might be altered.

The sediment column in boxes with a recovery of >20 cm often revealed a significant change in composition and colour in about 5-15 cm depth: at a relatively sharp boundary representing the reduction horizon, colour changed from brownish-grey to olive-grey, while grain sizes decreased to a finer-grained composition and more cohesive properties. Hence, a coarsening-upward succession was observed in many sections. At other stations, however, even bedding and sharp horizons were sometimes blurred by intense bioturbation and burrowing.

In summary, 12 stations of a total of 19 deployments in working area 1 (Belgica Mound Province), 2 stations of 5 in working area 2 (Propeller Mound), 9 stations of 11 in working area 3 (West Rockall Bank), and 3 stations of 3 deployments in working area 4 (Northern Porcupine Bank) yielded good results.

The sampling scheme of the boxcorer samples included high-resolution sampling of the sediment surface and column. Various kinds of samples taken from the individual box corer stations are listed in the detailed box corer protocols, available in form of the internal compilation of the cruise data in digital version.

Surface sampling included two 100 cm^3 sub-samples - one stained with a solution of 1g of rose Bengal in 1 litre ethanol for foraminiferal studies and one unstained for organic matter (TOC) analyses - taken by GeoB as well as sub-samples of varying quantities collected by IFM-GEOMAR, IPAL, RCMG and UCC. The living invertebrate fauna was collected by IPAL for taxonomic investigations. In addition, sub-samples of living *Lophelia* and/or *Madrepora* skeletons were taken by IFM-GEOMAR and SAMS for stable isotope analyses. Temperature measurements were taken immediately after arrival on deck.

The sediment column was sampled by archive liners taken by GeoB and IPAL (10 cm ∅ in each case) and by RCMG (5 cm ∅ at every station and, in addition, 10 cm ∅ at some selected locations). Bulk core sediment at defined horizons was sampled by UCC at every station, while analogous sampling by RCMG focused on working areas 3 and 4. At stations which provided a recovery of more than 30 cm, GeoB sampled the sediment column by two sets of syringes (10 cm^3) at 3 cm levels. In addition, archive boxes were taken by IPAL and RCMG from a few boxes with excellent recovery.

The remaining sediment column was sieved stratigraphically in 10 cm-thick slices (or other, following the sedimentary units) over a series of sieves with > 5,0 mm, 2,0-5,0 mm, 0,5-2,0 mm, 0,2-0,5 mm and < 0,2 mm mesh size. All sieved fractions were kept under seawater. After at least 4 hours in the ships cold room (4°C) all samples were looked through under the microscope. Thereby all animals (or at least a representative number of specimens) have been sorted out. Samples containing a large number of remaining living animals were then preserved in 70% ethanol. Samples from underlying sediments or without any apparent animal life were rinsed and air dried. All living animals were kept alive in the cold room for further documentation. Therefore the IPAL documentation system consisting of a computer-guided digital camera system mounted on a binocular was used. The ANALYSIS software package provided a multitude of different photographic features. Specimens larger than 3 cm have been documented using an ordinary digital camera. After its documentation each specimen was preserved separately in 70% ethanol to allow verification of the preliminary identifications made on board.

3.4.4 Sediment Sampling with Gravity Corer

(C. Hayn, A. Jurkiw, J. Kaiser, M. Lutz, F. Schewe, C. Wienberg)

Sediments were sampled with a gravity corer (SL 6 and SL 12) at 11 stations along the Celtic Continental Margin (Galway Mound, Franken Mound, Northern Porcupine Bank) after detailed surveys with the shipboard PARASOUND system. All details on the core stations are given in Table 3.3 and in the station list (Tab. 3.5). At Galway Mound, seven gravity cores were retrieved. At Franken Mound, we recovered two gravity cores from the top of the mound and off-mound. Additionally, at the Northern Porcupine Bank two gravity cores were retrieved, with the off-mound core not containing any sediments.

To recover longer sediment sequences, a gravity corer with a pipe length of 6 m and a weight of 1.5 tons was used at 9 stations (GeoB 9212, 9213, 9214, 9222-1, 9223, 9282, 9283, 9294-1, 9295) as well as a gravity corer with a pipe length of 12 m and weight of 1.5 tons was used at 2 stations (GeoB 9225, 9226-1). Before using the coring tools, the liners had been marked lengthwise with a straight line in order to retain the orientation of the core. Once on board, the sediment core was cut into 1 m sections, closed with caps on both ends and labeled according to a standard scheme.

Ten cores were retrieved with recoveries between 1.69 and 5.15 m resulting in a total core recovery of 37.80 m. Due to the supposed high content of coral fragments 7 of 10 sediment cores were frozen for 24 hours before opening (Tab. 3.3). All gravity cores were opened on board and 9 of 10 sediment cores were sampled. All cores were cut into an archive and work half. The archive half was used for core description, smear slide sampling, core photography, and color scanning. The work half was sampled with two series of syringes (10 ml) at 5 cm intervals for geochemical, sedimentological and faunal studies. Further analysis of the sediment cores will be done after the cruise at the Department of Geosciences, University of Bremen.

Tab. 3.3 Gravity Corer (SL) stations during M61-3 cruise. BMP: Belgica Mound Province; WRB: West Rockall Bank; NPB: Northern Porcupine Bank.

Stat. No.	Area	Coordinates		Depth	Recovery		Analysis onboard			
GeoB		Lat. °N	Long. °W	(m)	(cm)	corals	description	photo	color-scanning	sampling
9212	BMP; Top Galway Mound	51°27.13’	11°44.99’	847	193	X	X	X	X	X
9213	BMP; Top Galway Mound	51°27.09’	11°45.16’	793	515	X	X	X	X	X
9214	BMP; Galway Mound	51°27.06’	11°45.28’	857	489	X	X	X	X	X
9222-1	BMP; Galway Mound	51°27.48’	11°45.39’	900	376	X	X	X	X	X
9223	BMP; Galway Mound	51°26.90’	11°45.10’	839	465		X	X	X	X
9225	BMP; Galway Mound, off-mound	51°26.76’	11°48.55’	1072	358		X	X	X	X
9226-1	BMP; Galway Mound, off-mound	51°27.75’	11°43.03’	887	251	X	X	X	X	X
9282	WRB; Top Franken Mound	56°30.20’	17°18.31’	642	169		X	X	X	X
9283	WRB; Franken Mound, off-mound	56°29.98’	17°18.65’	683	489		X	X	no data	
9294-1	NPB; Connaught Mound, off-mound	53°31.06’	14°21.80’	871	no recovery					
9295	NPB; Top Connaught Mound	53°30.90’	14°21.10’	723	475	X	X	X	no data	X

The core descriptions shown in the respective regional results sections summarize the most important results of the analysis of each sediment core following ODP convention. The lithological data, indicated in the "Lithology" column, are based on visual analysis and smear slide analysis of the core. In the structure column the intensity of bioturbation together with special features (coral bioclasts, shell fragments, lamination etc.) is shown. The hue and chroma attributes of color were determined by comparison with the Munsell soil color charts and are given in the color column in the Munsell notation.

A Minolta CM-2002TM hand-held spectrophotometer was used to measure percent reflectance values of sediment color at 31 wavelength channels over the visible light range (400-

700 nm). The digital reflectance data of the spectrophotometer readings were routinely obtained from the surface (measured in 2 cm steps) of the split cores (archive half). The color measurements (red-green ratio, blue-yellow ratio and lightness) of each core are shown together with the visual core description for each core.

3.4.5 Plankton Net

(L. Dodds)

Plankton was sampled using a 120 µm plankton net for on-board feeding trials with *Lophelia pertusa* and *Madrepora oculata*. Vertical tows were performed on two occasions during the cruise, at the Rockall Bank and at the Porcupine Bank. Along the transect from the Porcupine Bank to the Azores, plankton was collected for 24 hours from the centrifugal-pumped seawater in the laboratory. Initial analysis suggested high numbers of copepods within the plankton samples, with large numbers of salps (Class: Thaliacea) being collected with each plankton tow. The plankton were used in feeding trials and then preserved in 10% formaldehyde for subsequent analysis.

3.5. General Results

3.5.1 ROV-Based Recovery of Current Meters

(B. Dorschel)

A major task during this cruise was the recovery of seven sensor units (Fig. 3.3) deployed at Galway Mound (Fig. 3.7) in the Belgica Mound Province in June 2003 with the French ROV VICTOR 6000. The sensor units, consisting of inductive current meters and CTDs, had been deployed on north-south and east-west transects over the structure to collect data on the small scale flow field on and around Galway Mound. With sampling intervals of 10 minutes, the recorded data are sufficient to provide information on possible tidal influences on the mound.

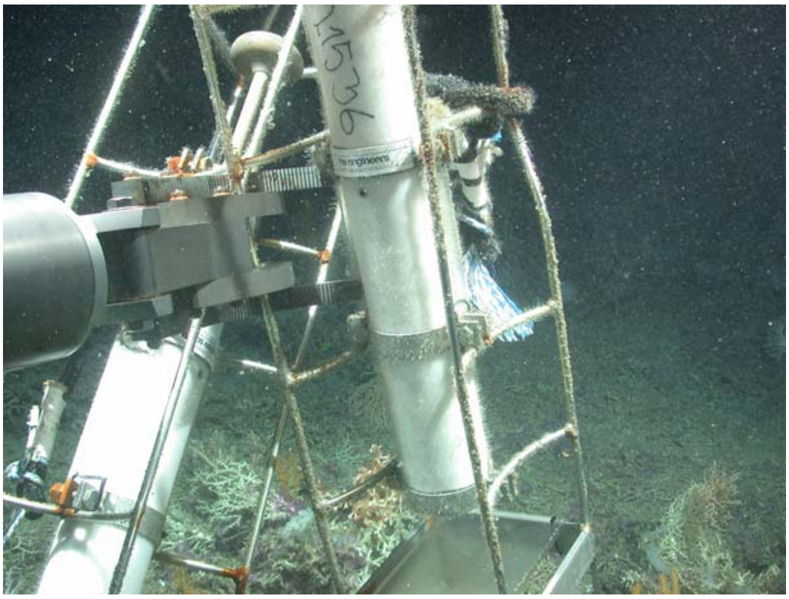

Fig. 3.3 ROV recovery of current meters at Galway Mound.

The sensor units were installed in the frame of the ESF-project MOUNDFORCE and the main task was to analyse the current regime at Galway Mound and to compare these data with different biological and geological facies found on and around this carbonate mound. Earlier work on carbonate mounds in the Porcupine Seabight revealed a close connection between oceanography, the occurrence of coral thickets, the sedimentation and thus the development of carbonate mounds. Therefore, for the first time a carbonate mound had been covered with a grid of sensor units analysing up- and down-stream currents (north-south transect). Two additional sensors were placed in the east and in the west of the top of the mound to obtain a 3D-coverage. First onboard instrument checks indicated that six of seven sensor units were still operating after recovery.

3.5.2 Carbonate Hardgrounds

(S. Noé)

A main objective of RV METEOR cruise M61-3 to the Porcupine-Rockall area was to evaluate which processes are involved in the stabilization and lithification of the steeply inclined flanks of carbonate mounds growing on the continental margins of the Porcupine Bank and Rockall Bank at 600-1000 m water depth. Carbonate samples were collected during ROV dives GeoB 9255-1 and 9267-1 on the western Rockall Bank (Franken Mound) and GeoB 9267-1 on the newly discovered Connaught Mound (Fig. 3.4).

ROV dives along the western flank of Franken Mound (West Rockall Bank) and at the crest of Connaught Mound and a nearby scarp on the Northern Porcupine Bank provided videos of exposed carbonate beds with uneven surfaces that are covered by living and dead coral colonies in certain areas. Cliffs consisting of well-bedded carbonate lithologies of different weathering resistance, which closely resemble alternations of pelagic and hemipelagic sediments, are locally exposed with individual layers measuring several decimetres in thickness. Samples recovered from the rather resistant layers on Franken Mound and Connaught Mound show two major facies: (1) poorly to moderately lithified pelagic foraminiferal-nannoplankton oozes; (2) highly lithified fossil coral reef framework.

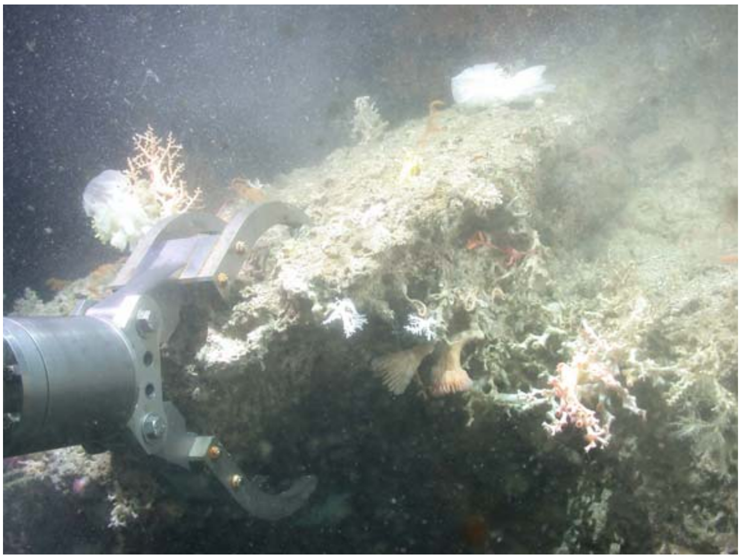

Fig. 3.4 Sampling of carbonate crusts with QUEST's heavy duty Rigmaster manipulator.

Fossil pelagic carbonates

Samples of the well-bedded lithified pelagic oozes show two sub-lithologies: (1) a micritic facies comprising hard, moderately lithified foraminiferal-nannoplankton oozes with very uneven surfaces that are heavily bored, encrusted by sessile invertebrates and Fe/Mn-stained or covered by thin manganese crusts; (2) a chalky facies consisting of soft, poorly lithified nannoplankton-foraminiferal oozes which in the same way shows bioeroded and Fe/Mn-stained surfaces. Both facies are white except for the stained surfaces. Planktic and some admixed benthic foraminifera compose the silt-size fraction, while the clay-size matrix is made up of nannoplankton. The fine-grained pelagites may be admixed with varying amounts of pelagic pteropods, benthic bivalves, and coral fragments which were eroded from coral thickets further upslope.

Fossil coral reef framework

Fossil reef rock consists of scleractinian skeletons (mainly *Lophelia, Madrepora* and some solitary corals) and shells of reef dwellers (bivalves, brachiopods, gastropods etc.). Most part of the framework is clogged by fine-grained calcareous sediments. By analogy to the lithified pelagic oozes, the rock surfaces are strongly bioeroded, encrusted by diverse invertebrates, and Fe/Mn impregnated. The reef rock differs from the pelagic carbonates by having a high portion of autochthonous to parautochthonous sessile invertebrates and a high degree of lithification. Exposed cliffs show multiple stages of vertical coral growth which are separated by thin layers of fine-grained pelagic sediments.

Distribution of carbonate facies

ROV dives and the recovery of carbonate samples revealed that the resistant carbonate lithologies - moderately lithified pelagic oozes and fossil coral framework - construct the steep western flank of Franken Mound on West Rockall Bank and the Connaught Mound on the Northern Porcupine Bank, forming bedded cliffs of up to several meters height. Pelagic micrites form major part of the western flank of Franken Mound, while fossil reef framework shows a patchy distribution on the flank and crest of this mound, documenting long-term coral growth in these areas. On the other hand, poorly lithified chalky beds are restricted to the smoothly inclined eastern flank of Franken Mound, where they are eroded from surrounding current-rippled sandy sediments. This facies distribution clearly reflects the asymmetric shape of Franken Mound.

Genesis of hardgrounds on Rockall and Porcupine banks

Lithification of the pelagic (and hemipelagic?) sediments derives predominantly from physical compaction linked with pore fluid escape in the course of sediment burial, although a possible microbial support by precipitation of automicrites in the tiny pores cannot be ruled out. Duration of burial and depth-related overburden pressure controlled the formation of chalky or micritic carbonates respectively. Major lithification of the fossil reef carbonates took place by reduction of primary growth framework porosity via infill of fine-grained pelagic calcareous oozes and – possibly - microbial automicrite precipitation.

After burial, the lithified carbonate beds were exhumed by currents, forming escarpments or steep cliffs on the sea floor. Subsequently their surfaces were affected by (1) bioerosion as indicated by burrows, and (2) abrasion, documented by furrowed surfaces and Fe/Mn impregnation. These characteristic features of non-deposition/erosion and submarine exposure prove the exposed fossil carbonates to be real hardgrounds which form the steeply inclined flanks of the carbonate mound. Fe/Mn-staining and some manganese crusts argue for a Pleistocene age or older.

Coral colonization of hardgrounds
Hardgrounds exposed in loose sediments of the Rockall/Porcupine continental slope settings are colonized by colonial scleractinians, whereas the dense mesh of coral skeletons surrounded by the sticky coenenchym is a preferential site of fixation of fine-grained pelagic rain. By protecting sediment particles from current transport, the coral framework supports sediment stabilization at the sites of coral growth. After a first stage of patchy colonization, coral colonies gradually amalgamated to coral gardens covering the flanks and ridges of topographic highs, thus forming carbonate mounds with steeply inclined flanks. Internal stratification of the fossil coral framework documents individual stages of coral growth interrupted by periods of pelagic sedimentation. The latter intervals indicate a deterioration of environmental conditions for the corals.

Conclusions
Fossil lithified pelagites and coral reef framework exposed on the flanks and tops of the investigated carbonate mounds represent hardgrounds which are responsible for stabilization of the steep mound flanks and provide a solid substratum for colonization of mound-forming invertebrates in areas of otherwise loose sediment accumulation. A possible microbial control on stabilization and lithification of the investigated carbonate mounds may be based on the formation of biofilms on coral skeletons and hard substrates via sediment binding. In addition, bacterially induced precipitation of automicrite and carbonate cements which are known to occlude major primary porosity in tropical shallow-water reefs may have contributed to porosity reduction and lithification of the deep-water coral reef framework.

Reefal and pelagic hardground facies are strikingly different from bacterially-induced authigenic carbonate precipitates typical of cold seep, mud volcano and gas hydrate settings, such as thin-bedded micritic carbonate crusts and collapse breccias. Their origin is clearly related to local oceanographic conditions, lacking any endogenic control.

3.5.3 Environmental Impacts in Areas of Deep-Water Coral Occurrences

(A. Grehan)

Serious damage to deep-water corals has been observed during ROV investigations of reef areas in Norway. It is estimated that between 30-50% of known reefs have been impacted by the use of deliberate destructive trawling techniques (Fosså et al., 2002). Documentation of this destruction has led the Norwegian Authorities to ban trawling from areas where corals are known to occur. Deep-water corals off the west coast of Ireland are located much deeper than their Norwegian analogues and it was thought that this gave them a degree of protection. Sadly, allegations of Norwegian style damage in Irish waters (Grehan et al., 2003) were substantiated during the R/V ATALANTE CARACOLE cruise in 2001 (Grehan et al., in press) and the subsequent R/V POLARSTERN ARK 3A cruise in 2003 (Grehan et al., 2004).

During M61-3, the QUEST ROV dives offered an opportunity to expand our knowledge of the types and intensity of environmental impacts (particularly from fishing) in Irish waters. This information will help provide the scientific base for decision makers charged with selecting appropriate management measures to ensure that ecological quality objectives established during designation of conservation areas can be effectively met. Ireland is currently at the beginning of the designation process to establish a network of conservation areas (Special Areas of Conservation under the EU Habitat's Directive) to protect deep-water coral reefs.

Environmental impacts observed during the dives can be broadly assigned to two categories: (1) small man-made objects lost/thrown overboard (Tab. 3.4, Fig 3.5A), and (2) gears lost during routine fishing activity (Tab 3.4, Figs. 3.5B-D). In the first category, of interest was the utilization of a piece of man made material in place of the usual antipatharian/gorgonian branch, characteristically carried by a *Paramola* sp. crab, as a defence over it's carapace. In the second category, all of the lost fishing gear was observed on Franken Mound. The images in Fig. 3.5B-D clearly show gill/tangle nets complete with head and ground lines. In Fig. 3.5B, the ground or headline has been colonized by settling epifauna which suggests the gear was not lost recently. In Fig. 3.5C-D, the net is full of coral, and has clearly been dragged in a failed attempt to free it from snags. While some coral may survive in these nets, it is almost certain that many corals died due to the enforced change of location.

The Franken Mound and surrounds, is still an area favoured by fishermen as was evident during the first dive when a longliner (Fig. 3.5A) approached within one nautical mile of R/V METEOR while retrieving previously set gillnets. The skipper confirmed that he was mainly interested in monkfish, blue ling, red crab (Figs. 3.6B-D) and sikki shark.

Deep-water coral areas are fished in Irish waters using both static gears (gill/tangle net and sometimes crab pots) and heavy trawl gear (principally for orange roughy; *Hoplostethus atlanticus*). During M61-3 we saw no evidence of the latter, but once again, we observed the impact that attempted recovery of snagged static gears can have on deep-water corals. It is likely, that in addition to banning trawling, the use of static gears will have to be managed in areas designated for the conservation of deep-water corals. This will require the implementation of appropriate technical conservations measures under the Common Fisheries Policy (Long and Grehan, 2002).

Tab 3.4 Location and description of environmental impacts observed during the M61-3 QUEST dive series.

Event	Station No.	Date	Coordinates		Depth	Dive No.	Time	Tape No.	Observation	Digital Still
	GeoB		Lat. °N	Long. °W	(m)	QUEST	(UTC)			
1	9203	05/06/04	51°26.71'	11°45.03'	887	16	11:56	2	Metallic box	
2	9203	05/06/04	51°26.71'	11°45.03'	891	16	12:00	2	Metallic rubbish	
3	9255-1	11/06/04	56°30.01'	17°18.42'	666	21	11:40	2	Lost tangle net, *Roxania* sp.	
4	9267	12/06/04	56°29.92'	17°17.84'	669	22	11:57	4	*Paramola* sp. with manmade object as cover	
5	9281-1	13/06/04	56°30.30'	17°18.60'	648	23	12:27	5	Lost fishing net (rope) in btw. dead coral and hardground	Fig. 3.5B
6	9281-1	13/06/04	56°30.38'	17°18.63'	651	23	13:27	6	Lost tangle net full of coral, *Roxania* sp. On rope.	Fig. 3.5C, 3.5D
7	9285-2	15/06/04	53°30.92'	14°21.01'	704	24	12:05	5	White plastic rubbish bag	Fig. 3.5A
8	9285-2	15/06/04	53°30.88'	14°20.94'	758	24	12:22	5	Plastic bag	

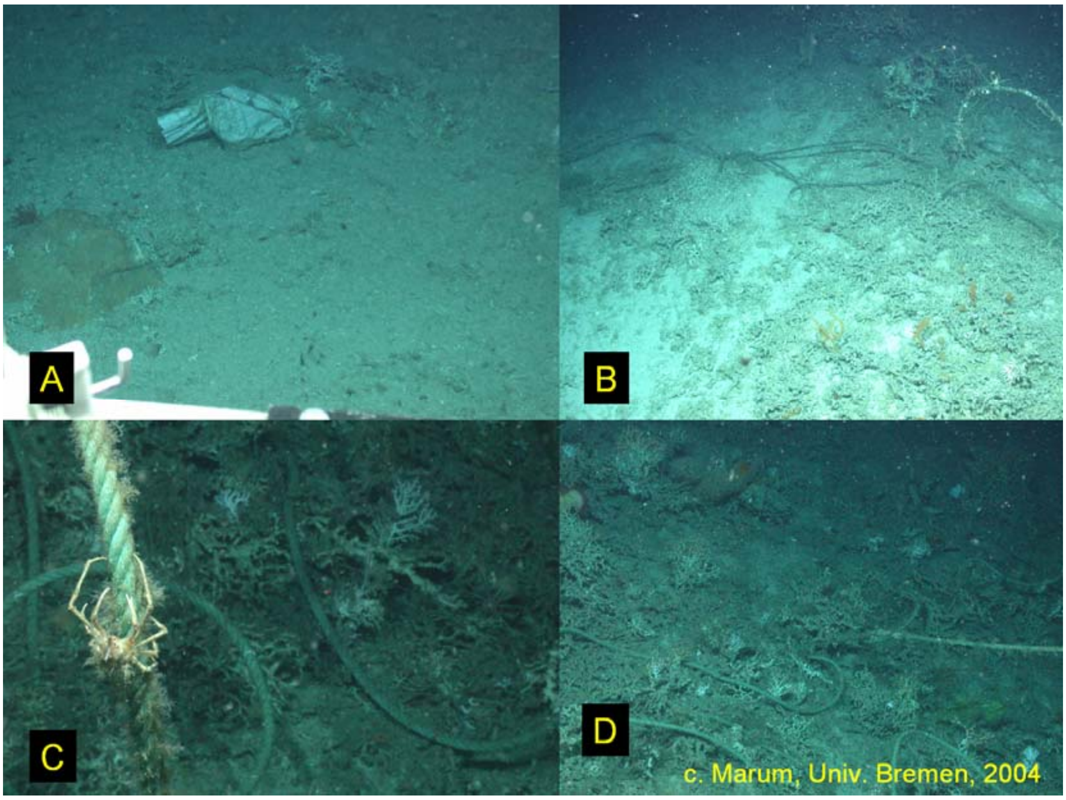

Fig. 3.5 (A) Plastic bag imaged on the Connaught Mound. (B-D) Lost gillnets/tangle-nets on Franken Mound.

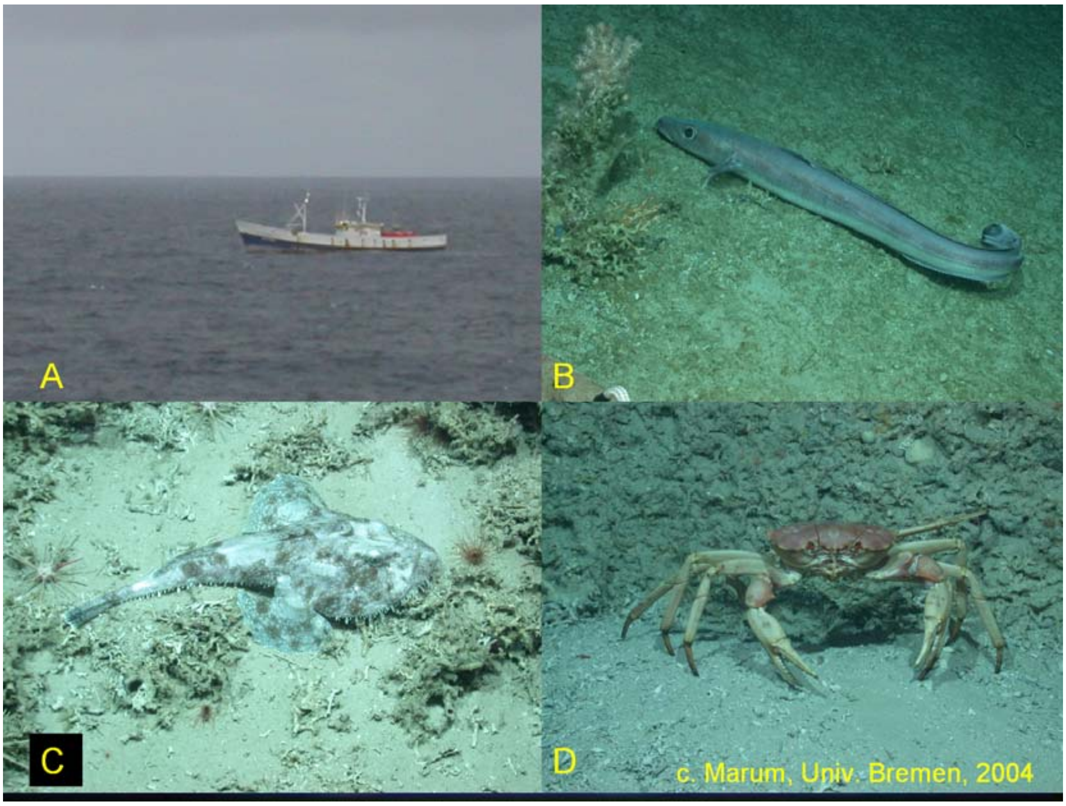

Fig 3.6 (A) Longliner recovering gillnet/tangle net sets from the Franken Mound area. (B) Commercial target species: Molva dypterygia (blue ling), (C) Lophius piscatorius (monkfish), (D) Chaceon affinis (red crab).

3.6 Regional Results

3.6.1 Working Area 1: Belgica Mound Province

3.6.1.1 Bathymetry and Sampling Stations

(A. Foubert, L. Beuck, J. Gault)

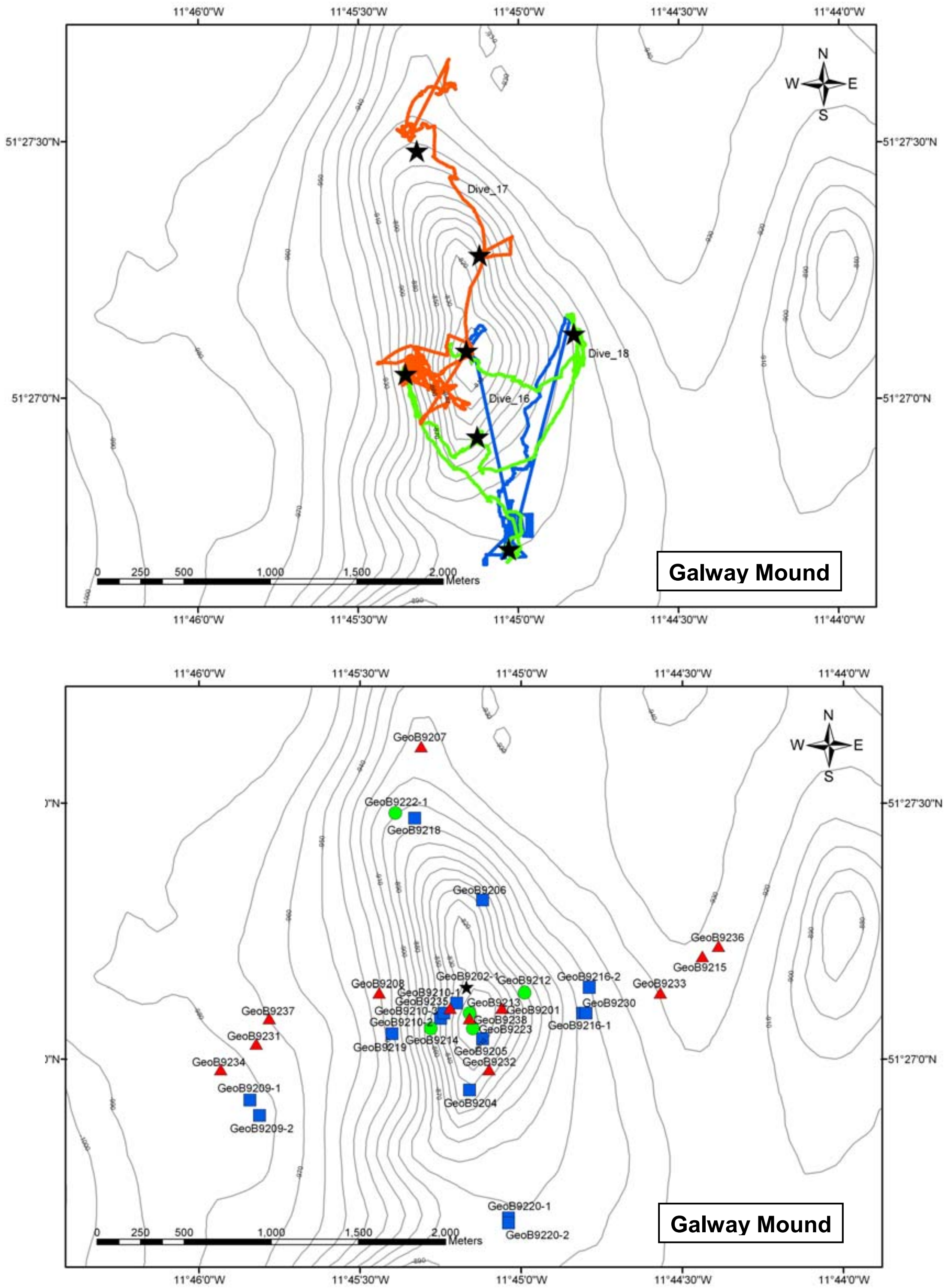

Fig. 3.7 Maps of bathymetry, QUEST dives (top) and sampling stations (bottom) in the Belgica Mound Province. Stars: current meters; circles: gravity corer; squares: box corer; triangles: CTD.

3.6.1.2 Hydrography in the Belgica Mound Province

(A. Rüggeberg, L. Dodds)

Within the Belgica Mound Province 13 CTD profiles were performed, of which 5 profiles covered positions in a NS- and EW-direction across Galway Mound, to compare with measurements taken on cruise M61/1. The distribution of water masses at Galway Mound was typical for the eastern margin of the Porcupine Seabight with a warm surface water mass layer of 40 to 50 m, overlying the Eastern North Atlantic Water, where temperature and salinity decrease to a minimum at ~600 m water depth (Fig. 3.8). Increasing salinity values indicate the occurrence of Mediterranean Outflow Water below ~ 700 m with a coherent decreasing oxygen content.

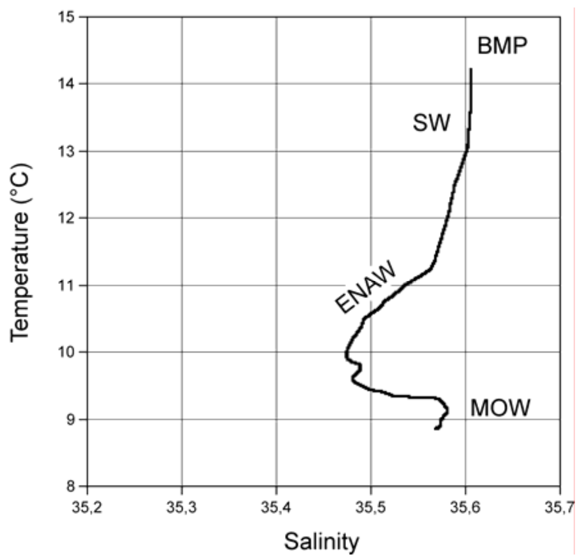

Fig. 3.8 TS-plot of a typical CTD profile in the Belgica Mound Province (BMP; station GeoB 9234-1). SW: Surface Water; ENAW: Eastern North Atlantic Water; MOW: Mediterranean Outflow Water.

To analyse the temporal variation of water mass dynamics in the vicinity of Galway Mound, we established a series of CTD profiles at three positions, west, top and east of Galway Mound and repeated the measurements three times except for the eastern location. The result was a time-series of eight CTD profiles with one-hour interval between each cast, which visually indicates the influence of tidal waves at 600–700 m water depth (Fig. 3.9) as reported by Rice et al. (1990) along the European continental margin and by White (2003) along the eastern slope of the Porcupine Seabight. The salinity minimum appearing from the east may be the result of internal wave reflection at the slope. Additional strong Ekman downwelling induced by the northward flow of the slope current delivers re-suspended organic material into the depth of the carbonate mounds (White, in press). These processes are important for the deep-water coral ecosystem as the corals take advantage of the high nutrient availability, the strong currents and the pumping dynamics of internal waves.

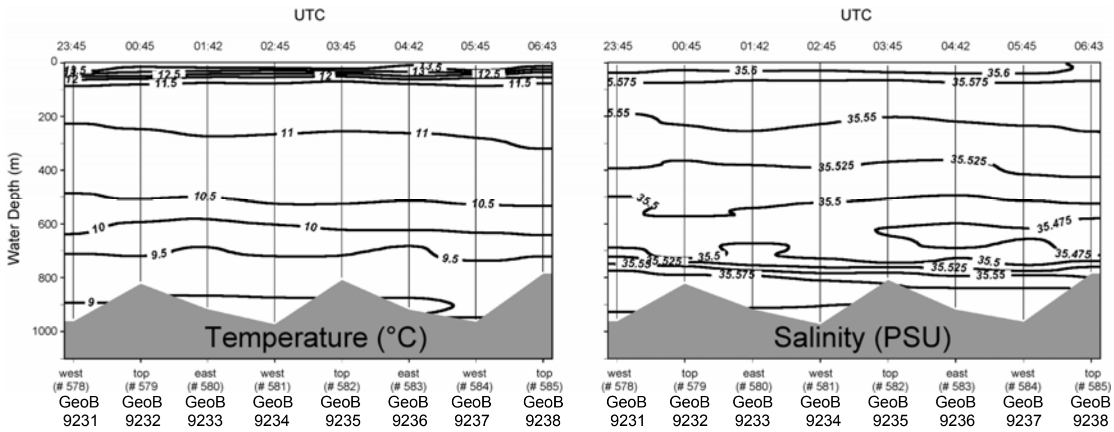

Fig. 3.9 CTD time-series across Galway Mound, Belgica Mound Province. Temperature and salinity indicate the influence of tidal waves at the water mass boundary between Eastern North Atlantic Water (ENAW) and Mediterranean Outflow Water (MOW; 600–700 m) with increasing time (UTC on top, station and GeoB# and position relative to mound on bottom).

3.6.1.3 ROV Video Observations

(B. Dorschel, T. Beck, A. Foubert, J. Gault, A. Grehan, V. Ratmeyer, G. Ruhland)

In total, 4 dives (GeoB 9203-1, 9211-2, 9239-1, 9240-1) were performed in the Belgica Mound province in the Eastern Porcupine Seabight with ~18 hours of video footage recorded (Fig. 3.7, top). Three dives (GeoB 9203-1, 9211-2, 9239-1) were carried out at Galway Mound devoted to the recovery of 7 sensor-packages (current meter, CTD) which have been deployed in June 2003. An additional dive (GeoB 9240-1) targeted an unnamed mound in the Eastern Belgica Mound Province to sample hardgrounds that have been discovered during a ROV survey with the French ROV VICTOR 6000 in June 2003.

The dive tracks for the recovery of the sensor units where chosen to complement existing ROV surveys. Therefore south-north as well as east-west transects over the mounds were selected thus crossing and completing the existing video coverage. During all dives continuous video observations were recorded providing high quality video footage on facies distribution, ecosystems, faunal assemblages and human impacts. In addition sedimentological and biological samples were taken in areas, where standard sampling techniques failed to succeed due to steep slopes and hard substrate.

Description of ROV-dives

Dive GeoB 9203-1 lasted 10h with 9h of ground sight. It started south of Galway Mound, followed a grid at the southern and western base of the mound and than ran over the top to the north. Dive GeoB 9239-1 lasted 9h with 7:20h of ground sight and crossed the mound from east to west further continuing to the south (Fig. 3.7).

The off-mound area south of Galway Mound is characterised by sand waves with several meters wave length. The crest of the sediment waves had often been overgrown by sponges and corals while the troughs contained coarse sands. At the base of the mound the abundance of living corals increased with also the troughs being covered with corals. At the mound flank the wavy structure was still recognisable but being fully overgrown by corals only intercepted by small sand patches. Upslope, increasingly higher abundances of living corals occurred with the largest colonies in the summit area. North of the summit, following the rim of the mound, the amount of living corals decreased and sand patches became more common. The most northerly extension of the survey reached again the 'overgrown sand wave' facies at the lower flank of Galway Mound. Also towards the east of the mound, the living coral facies faded out into the 'overgrown sand wave facies' and further into the 'sand wave facies'. The sand waves showed the characteristic of current induced mega-ripples.

A major task of the ROV-dives at Galway Mound was the recovery of seven sensor packages, which has been performed successfully. The recovery of the sensor packages proofed the capacity of the ROV navigation system to retrieve small objects without the support of acoustic beacons or similar devices. It was possible to locate all seven sensor packages at ~800 m water depth after a one year deployment based on only the deployment coordinates. The sensor packages were picked with a manipulator to remove the stabilising weight with the specially designed 'Krueger Knife' and stored on the porch of the vehicle or kept with the ROV manipulator. Different to earlier plans, all sensor packages were brought on board with the ROV and were not recovered with the elevator mooring. During dive GeoB 9203 three sensor packages and during dive GeoB 9239-1 the additional four sensor packages have been collected and brought to surface by the ROV. Against accidental loss during transport, the sensor units were additionally secured with snap hooks to the ROV.

A surface sediment sample was collected by the ROV (GeoB 9239-1) with a sample bag at the location of the current meter west of Galway Mound. The steep slope of this area cannot be sampled with standard tools (e.g. box corer) thus leaving the ROV as the only tool for collecting sediment samples.

The last dive in the Belgica Mound Province, performed at an unnamed mound structure from the mound chain expanding south of Poseidon Mound, was devoted to the collection of hardgrounds. Unfortunately, the attempt to approach the rim of the mound, where the hardground cropped out, failed due to strong currents. The eastern flank of this mound is covered by a dropstone pavement interfering with sediments consisting purely of barnacle plates.

3.6.1.4 Surface Samples

(S. Noé, T. Beck, A. Foubert, A. Grehan)

Galway Mound

Galway Mound represents one of the largest mound structure of the "deeper line of mounds" of the Belgica Mound Province. This prominent elongated seabed structure with more than 160 m positive relief arising from 920 m to 780 m water depth is characterized by living coral framework covering its flat top and steep flanks, contrasting the fine-grained sediments of the surrounding off-mound areas which contain dead coral framework and rubble derived from the flanks. The density of coral cover increases from the base upslope the flanks, culminating with highest abundance and coral size in the summit area (ROV dive observations).

Facies distribution

Living coral/sponge framework, mostly attached to underlying dead framework, was recovered by the giant box corer on a south-to-north transect across the mound crest (GeoB 9204, GeoB 9205 and GeoB 9206), furthermore on the steeply dipping western mound flank down to a depth of 920 m (GeoB 9219), and on the somewhat less steeply inclined east face down to 890 m depth (GeoB

9216-1; Fig. 3.10). Off-mound areas are characterized by a mega-rippled "sand wave facies" composed of mixed siliciclastic-calcareous sediments containing dead coral framework and rubble with a few living *Madrepora* colonies on top. This facies extends from the southern flank of the mound (GeoB 9220-1/9220-2) around the eastern flank to its northern margin (GeoB9218-1), while in the western off-mound area at 981 m depth (GeoB 9209-2) sand waves are covered by dead coral framework preserved *in situ*, forming an "overgrown sand wave facies" as deduced from ROV observations (Fig. 3.10).

Sediment column

At the coral sites, fine-grained muddy to sandy sediment trapped within the dead framework beneath the living surface was partly washed out during recovery. The thickness of the sediment column rarely exceeded 20 cm, while two box corer deployments did not provide any sediment. The sediment columns of the on-mound and off-mound sites showed even to slightly uneven bedding with a reduction horizon being located 5-10 cm beneath the surface of some box core columns, while other stations did not show any distinct differences in redox conditions throughout the section. Bedding was commonly overprinted by irregular bioturbation and/or distinct worm burrowing.

Composition of coral/sponge framework

Living reef framework collected from the crest and flanks of Galway Mound consists predominantly of *Madrepora oculata* thickets. The healthy living framework is generally devoid of any fine-grained sediment. Dead or subfossil coral framework underneath the living reef-building community is made up of (several morphotypes of) *Lophelia pertusa* that provide the colonization substratum for the corals. Dead framework is generally clogged by mixed fine-grained calcareous-siliciclastic sediments. *Lophelia* skeletons show varying taphonomy from *in situ* arrangement to total disintegration of framework with small fragments being embedded in the sediment. In this case a vertical succession from coral rubble to a zone of dead but well preserved *Lophelia* skeletons to living reef communities may be observed (e.g. at site GeoB 9219; Fig. 3.10).

Aphrocallistes, the dominating hexactinellid sponge of the Belgica Mound Province, was found at all on-mound and flank sites where live specimens are actively involved in framework building. Abundant dead specimens buried beneath living coral framework were found at a site on the western mound flank (GeoB 9219), while at the western off-mound site (GeoB 9209-2) a "sponge mass grave" of dead *Aphrocallistes* specimens appeared beneath dead coral framework.

Biological features

Attached to the skeletons of the colonial scleractinians there are some solitary corals (predominantly *Desmophyllum cristagalli*), abundant hexactinellid sponges (*Aphrocallistes bocagei*), as well as gorgonians (*Acanthogorgia armata*). In some areas on Galway Mound these species are extremely abundant and characterise the living coral habitat on this mound structure. Dead and subfossil specimens of *Aphrocallistes* often served as substrate for other animals like a yellow encrusting sponge (not to confuse with living *Aphrocallistes* which is whitish) and species of Zoantharian which is also very characteristic due to its bright yellow colour. The pink-coloured octocorals *Anthothela grandiflora*, hydroids and encrusting bryozoans of different species are commonly encrusting the dead parts of coral framework. The probably closest associate to the colonial scleractinians, the polychaet *Eunice norvegicus*, was present in or on almost each piece of coral larger than 5 cm. Its characteristic tubes, built up of a thin parchment-like layer, are normally overgrown by the scleractinians and though contribute to the complexity of the coral framework.

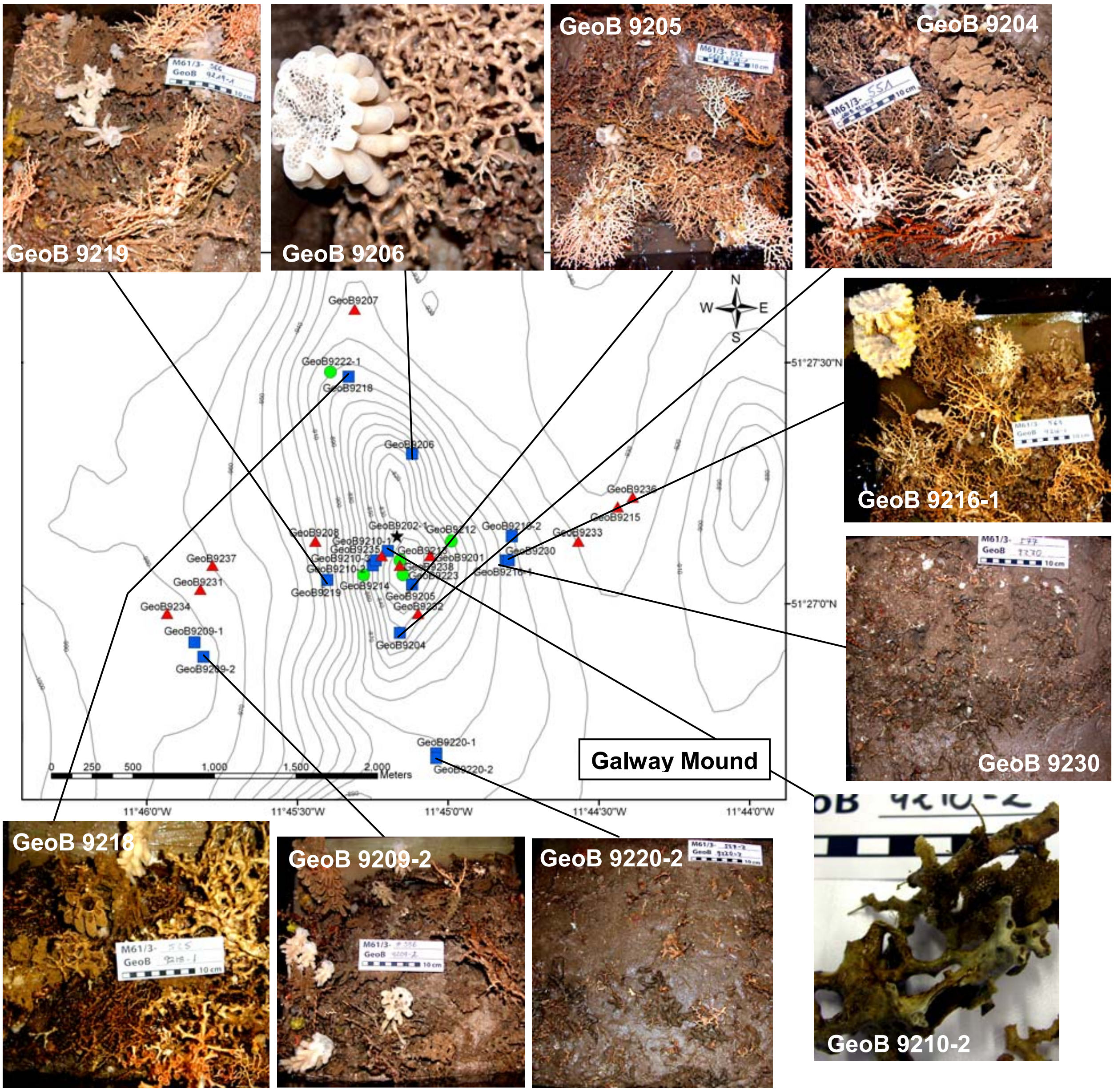

Fig. 3.10 Box core sampling stations and surface sediments in the Galway Mound area. Circles: gravity corer; squares: box corer; triangles: CTD.

A multitude of vagile fauna including ophiuroids, bivalves, gastropods, polychaetes and shrimps (*Palaemon* sp.) has also been sampled. The bivalves are mostly represented by bysally attached species like *Asperarca nodulosa*. A bright red polychaet of the family Hecionidae was almost as abundant as *Eunice norvegicus*. The solitary worm-shaped coral *Stenocyathus vermiformis* was found to be very abundant in a sample from the coral habitat close to the top of Galway Mound (GeoB 9219). Beside the very abundant species *Aphrocallistes* another hexactinellid sponge, ?*Mellonympha velata*, was found in sample GeoB 9204 from the southern slope of Galway Mound. This was the only record for this species during the entire M61-3 cruise. It remains to be investigated if there is a relation to the very low temperature of the sediment at this site. The sediment of sample GeoB 9204 was with 7°C about 3°C colder than all other sediment samples collected during M61-3.

Conclusion

Facies distribution revealed by box coring confirms Galway Mound to represent a still growing mound with a deep-water coral/sponge ecosystem densely covering the flat top and steep flanks down to the seabed. By analogy to the adjacent Therese Mound, Galway Mound therefore clearly represents the catch-up to keep-up stage in the evolution of mound growth in the Porcupine Seabight (ECOMOUND model: Rüggeberg et al., in press).

Poseidon Mound

Poseidon Mound, the most prominent carbonate mound of the "shallower line of mounds" of the Belgica Mound Province, elevates from 850 m (western slope) to 670 m (summit) water depth. Since this mound has been sampled by several gears including giant box corer during RV POSEIDON cruise POS 292, only three box-corer stations were carried out during this cruise.

Facies distribution

One site located at the eastern mound flank (GeoB 9227) revealed a dropstone pavement with barnacle hash, stylasterids and echinoid (*Cidaris*) spines. A similar dropstone facies is exposed in the off-mound area further to the south (GeoB 9229). On the other hand, a box corer deployed on the northeastern flank (GeoB 9228) provided *Madrepora* rubble sticking in well-sorted sands (Fig. 3.11). Penetration depth of the dropstone facies amounting up to 41 cm is conspicuously higher than that of the coral sites.

Box core recovery from POS 292 cruise revealed that the crest and western flank of Poseidon Mound are covered by *Madrepora* rubble with encrusting invertebrates largely embedded in fine-grained sediments, while the eastern flank and off-mound areas are covered by sandy sediments with extended dropstone pavements on top. Hence, the box core sampling of M61-3 cruise fits well to the previously discovered sedimentary pattern of Poseidon Mound.

Biological features

The two samples (GeoB 9227 and 9229) from the dropstone habitat surrounding Poseidon Mound revealed a fauna well adapted to high current velocities. As characteristic features the holothurian *Psolus* sp. and the stylasterid *Pliobothrus symmetricus* were found attached to a dropstone. The barnacle *Bathyplasma* sp. was the only one found alive, although the shell plates of dead *Bathyplasma* sp. are an important feature in the surface sediments.

From a biogeographical point of view sample GeoB 9229 is noteworthy as it contained several species of molluscs which normally occur in more northern and shallower areas like the bivalves *Yoldiella pernula* and *Cuspidaria cuspidata*. As these species were only found as empty shells it is possible that they represent elements of a "cold fauna" representing past, colder conditions. In clear contrast, GeoB 9228 contained several possibly subfossil species with clear Mediterranean affinities (*Putzeysia wiseri, Spondylus gussoni* and *Lima marioni*). With *Coralliophila* sp. only one species was found which possibly feeds on scleractinia. This species is so far not yet reported from the Belgica Mound area.

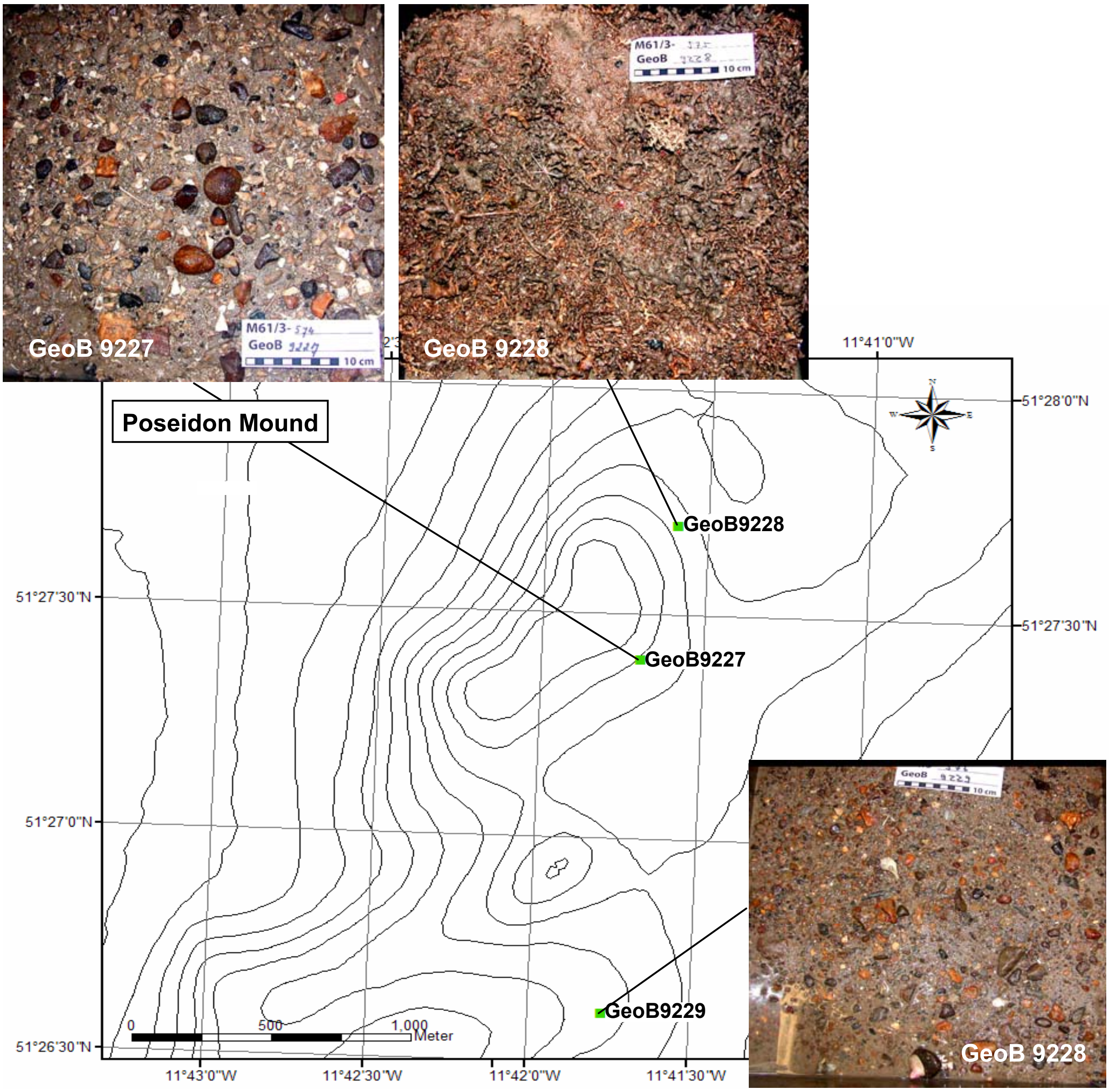

Fig. 3.11 Box core sampling stations and surface sediments in the Poseidon Mound area.

3.6.1.5 Sediment Cores

(C. Hayn, A. Jurkiw, J. Kaiser, M. Lutz, F. Schewe, C. Wienberg)

In the Belgica Mound Province, seven gravity cores were retrieved from Galway Mound. Five cores were retrieved from the top and the flanks of the mound structure (GeoB 9212, 9213, 9214, 9222-1, 9223; Tab. 3.3). These cores are dominated by a silty to fine sandy mud matrix containing abundant bioclasts which are mainly composed of fragments of the coral *Lophelia pertusa* and secondary made up of the coral *Madrepora occulata*, molluscs, echinoid spines, brachiopods as well as benthic and planktic foraminifers. Two cores were retrieved from the off-mound area close to Galway Mound (GeoB 9225, GeoB 9226-1; Tab. 3.3). These cores look completely different compared to the five cores from the top and the flanks. They contain very few fragments of organisms. The sediment is again mainly made up of silty to fine sandy mud and in addition sandy layers occur.

3.6.2 Working Area 2: Hovland Mound Province

3.6.2.1 Bathymetry and Sampling Stations

(A. Foubert, L. Beuck, J. Gault)

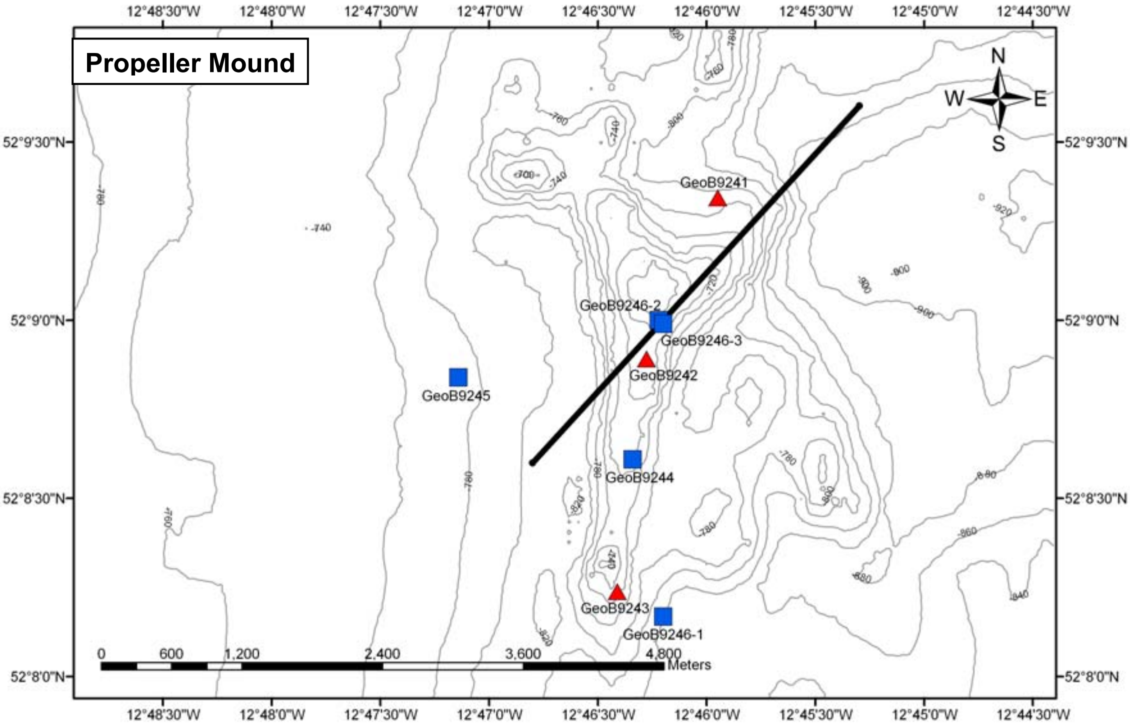

Fig. 3.12 Map of bathymetry and sampling stations around Propeller Mound in the Hovland Mound Province. Squares: box corer; triangles: CTD.

3.6.2.2 Hydrography in the Hovland Mound Province

(A. Rüggeberg, L. Dodds)

In the Hovland Mound Province, northern Porcupine Seabight, three CTD profiles were achieved arranged in a N-S transect across Propeller Mound. The water mass distribution was similar to the Belgica Mound Province with ENAW underlying the surface waters (Fig. 3.13).

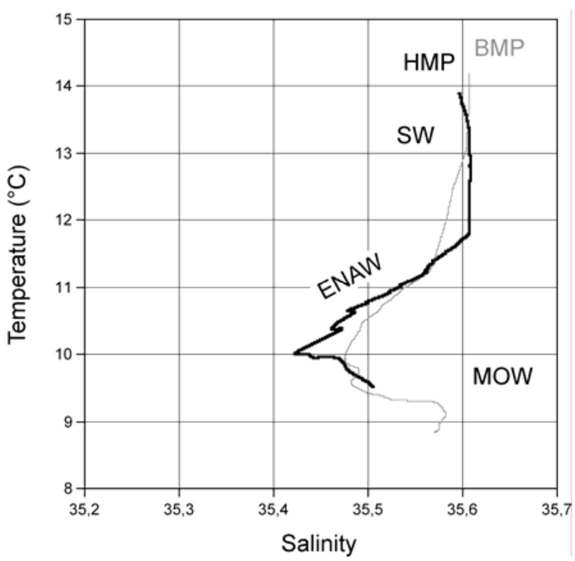

Fig. 3.13 TS-plot of atypical CTD profile in the Hovland Mound Province (HMP; station GeoB 9241). SW: Surface Water; ENAW: Eastern North Atlantic Water; MOW: Mediterranean Outflow Water.

However, the signature of MOW seemed to be little shallower compared to the Belgica Mound Province, which is the result of the northward and up-slope flow of water masses. Previous studies and cruises have shown that the current intensity weakens in the northern Porcupine Seabight and the general flow becomes south-westerly (e.g. Freiwald et al., 2000; White, 2003).

3.6.2.3 ROV Video Observations

No QUEST dives were carried out in the Hovland Mound Province.

3.6.2.4 Surface Samples

(S. Noé, T. Beck, A. Foubert, A. Grehan)

Propeller Mound has been intensively investigated during several previous cruises. Hence, box coring was conducted at only four stations, with two of them showing recovery. One box core taken from a site near the summit (GeoB 9246-3; Fig. 3.14) devoid of living coral framework reveals a poorly sorted, strongly burrow-mottled sediment with some *Madrepora* rubble and a few dropstones.

The dead coral framework was typically colonized by hydrozoans, bryozoans and agglutinating foraminifera and inhabited by a remarkable number of very juvenile *Rochinia carpenteria.* These findings support the previous results that the summit of this mound is locally covered by sediment and shows a reduced density of living corals, hence representing a keep-up stage in mound evolution (ECOMOUND model: Rüggeberg et al., in press).

Another station carried out in the distal western off-mound area (GeoB 9245; Fig. 3.14) provided burrowed siliciclastic silty mud lacking any reef-building skeletons. The sample brought up some characteristic soft-bottom dwellers like ophiuroids, polychaetes and some komokiaceans.

3.6.2.5 Sediment Cores

No gravity cores were collected in working area 2.

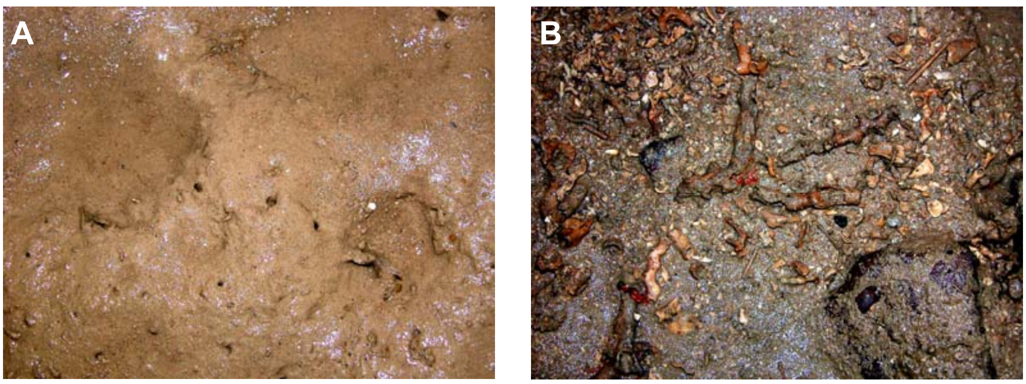

Fig. 3.14 Surface sediments in the Propeller Mound area. (A) Box core surface of GeoB 9245, western off-mound area and (B) GeoB 9246-3, southern margin of summit.

3.6.3 Working Area 3: West Rockall Bank

3.6.3.1 Bathymetry and Sampling Stations

(A. Foubert, L. Beuck, J. Gault)

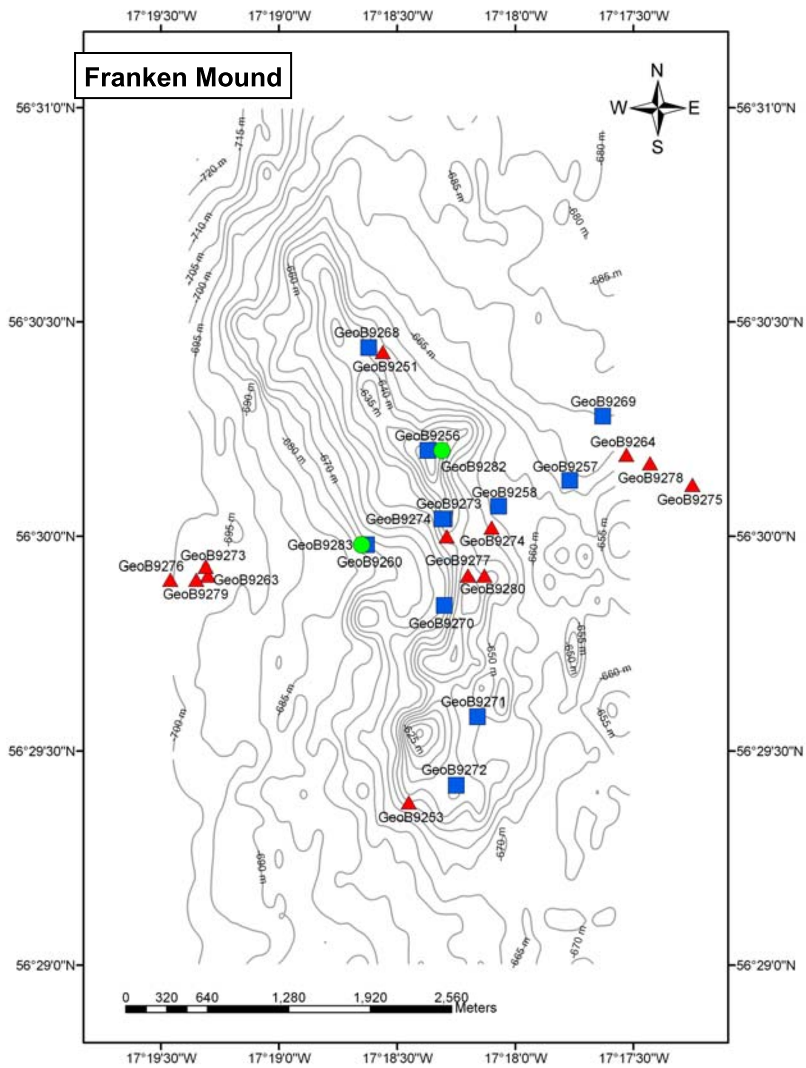

Fig. 3.15 Map of bathymetry and sampling stations at Franken Mound, West Rockall Bank. Circles: gravity corer; squares: box corer; triangles: CTD.

3.6.3.2 Hydrography of the West Rockall Bank Area

(A. Rüggeberg, L. Dodds)

Along the western slope of the Rockall Bank 19 CTD casts were performed at Franken Mound, discovered during cruise M61/1. Eleven profiles were arranged in NS- and EW-transects across Franken Mound in water depths between 640 and 760 m and showed a similar water mass distribution as profiles already performed during cruise M61-1. In comparison to the Porcupine Seabight a typical TS-plot for the West Rockall Bank (Fig. 3.16) showed colder and less saline surface waters. Below the surface waters a continuous and linear TS-relation indicates the occurrence of a colder and less saline water mass, described here as North Atlantic Central Water (NACW) with a different production area compared to the ENAW. Below 600 m a slight increase in salinity may indicate a contribution of MOW or another high saline water mass of southern origin, as the general direction of circulation around Rockall Bank follows a clockwise flow.

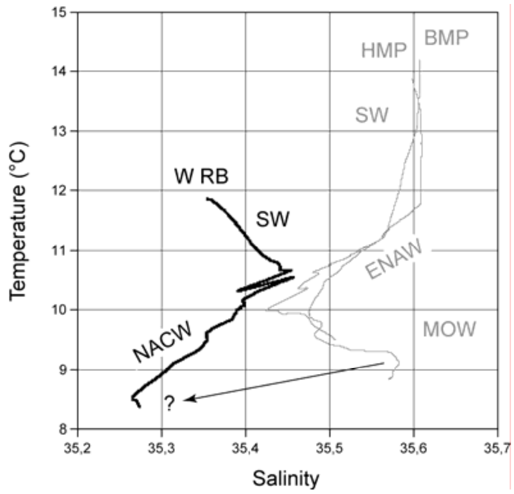

Fig. 3.16 TS-plot of typical CTD profile in the West Rockall Bank area (WRB; station GeoB 9250). SW: Surface Water; NACW: North Atlantic Central Water.

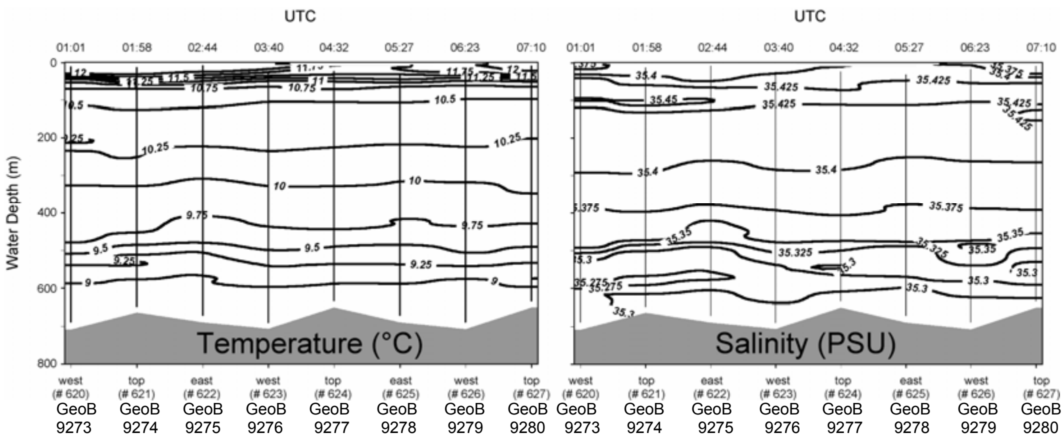

Fig. 3.17 CTD time-series across Franken Mound, West Rockall Bank. Temperature and salinity indicate the influence of tidal waves at the surface and the water mass boundary between NACW and the underlying water mass (~500–600 m) with increasing time (UTC on top, station and GeoB # and position relative to mound on bottom).

A time-series with eight CTD profiles across Franken Mound was achieved in a similar way as in the Belgica Mound Province with three positions (west–top–east), three measurements at each position (except for the eastern one with only two) and approximately 55 minutes interval in between each cast (Fig. 3.17).

The variability of temperature and salinity was similar to the observed variation of the eastern Porcupine Seabight. Salinity showed a minimum at ~580 m water depth at the beginning of the time-series, which vanished at around 4 h UTC and seemed to re-appear at the last station GeoB 9280). The influences of tidal waves, internal wave reflection and Ekman downwelling probably also play an important role as primary processes responsible for coral nourishment at the western Rockall Bank.

3.6.3.3 ROV Video Observations

(B. Dorschel, T. Beck, A. Foubert, J. Gault, A. Grehan, V. Ratmeyer, G. Ruhland)

At the West Rockall Bank, in total 4 dives (GeoB 9249, 9255-1, 9267, 9281-1) were performed. Two mound structures were investigated. The first dive targeted an unexplored structure named Bremen Mount. Three further dives were performed at Franken Mound (Fig. 3.27).

Bremen Mount is a newly discovered circular structure with ca. 3.5 km in diameter at the West Rockall Bank. It was investigated by a ROV transect running up its southern flank (GeoB 9249). The survey revealed that Bremen Mount is rather a seamount than a carbonate mound, with what is supposed to be basalts exposed at its lower flank. Towards the top, the basalt outcrops became covered by hemipelagic sediments. The flat summit area was characterised by hemipelagic sediments with drops stones being common. The occurrence of drop stones on the seafloor indicated that on Bremen Mount Holocene sequences had either not been deposited or were eroded later.

The second target area at the West Rockall Bank was the Franken Mound. Three dives (Fig 3.28) were carried out to explore the curved structure that measured 5.2 km in north-south direction and <1.5 km from east to west. The mound summit is at about 640 m water depth and its base at approximately 680 m water depth.

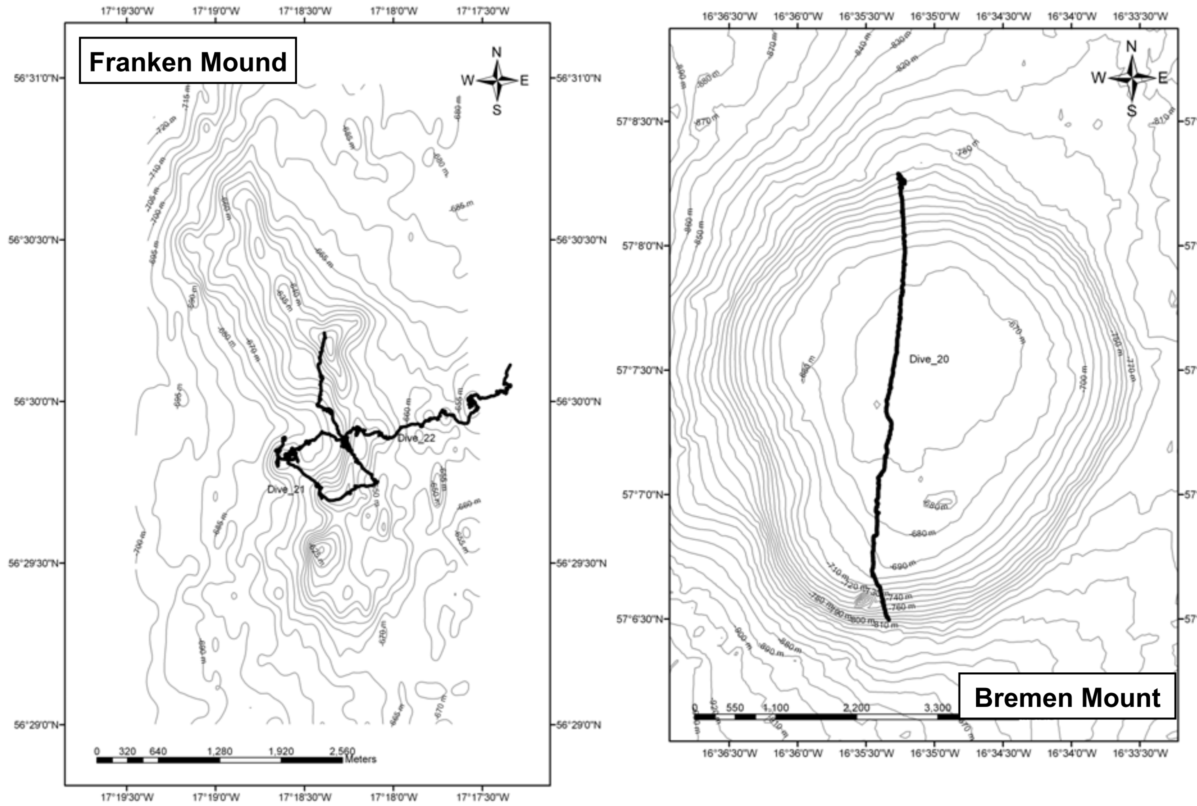

Fig. 3.18 Tracklines of QUEST dives 20 and 21 in the West Rockall Bank area (Franken Mound left, Bremen Mount right).

On Franken Mound ROV-dives of in total 27.25h were performed with dive GeoB 9255-1 lasting 9.5h. It started at the top of Franken Mound crossing its western flank in SW direction, running up the flank in SE direction turning west at the crest following the rim of a west pointing spur. Dive GeoB 9267 (10.5h) crossed the mound on an east west transect.

The last dive, GeoB 9281-2 (7.25h), started at the mounds summit following its crest to the north. Franken Mound is an asymmetric shaped mound with steep flanks facing west and low inclined eastern flanks. The facies distribution also reflects this asymmetry. The western flanks are characterised by large banks of outcropping hardgrounds several meters high that gave this flank a step-like character. In contrast, the east-facing flank was covered by sandy sediments that formed sand ripples and sand waves. Small positive morphological structures further east off Franken Mound appeared to be outcrops of hardgrounds as well.

All observed hardgrounds were overgrown by numerous organisms as for example soft corals, hydrozoans and sponges. Extensive thickets of corals up to several meters high were observed on the hardgrounds east of Franken Mound and in the crest regions. Those thickets were mainly built by *Lophelia pertusa*, but *Madrepora oculata* was also common.

The abundant hardgrounds at Franken Mound and its irregular shape indicate that this mound is an overgrown relict structure rather than an actively growing carbonate mound. An early interpretation sees Franken Mound in a phase of erosion with the exposed hardgrounds providing a settling ground for recolonisation.

3.6.3.4 Surface Samples

(S. Noé, T. Beck, A. Foubert, A. Grehan)

Franken Mound located on an isolated topographic high at the western slope of Rockall Bank was discovered during M61-1 cruise by means of PARASOUND and OFOS surveys. The elongated carbonate mound arises from about 680 to 630 m water depth with an elevation of at least 50 m above the surrounding seabed. It shows a conspicuous asymmetric shape with a steeply inclined western flank forming some kind of steep-faced embayment on the deeper sea floor, and a largely straight, smoothly dipping eastern flank which grades into the surrounding off-mound sediments. ROV dive tracks crossing the mound in a north-south and east-west transect together with crab samples clearly revealed the west face to be composed of moderately to well-lithified hardgrounds consisting of pelagic micrites and of fossil reef framework, both forming steep, thick-bedded cliffs of several meters height. The eastern flank, on the other hand, is made up of poorly lithified nannoplankton oozes forming thin-bedded chalks which are exhumed from rippled calcareous sands largely covering this flank and the adjacent off-mound regions.

Facies distribution

Franken Mound and its surroundings were sampled by 11 box corer deployments, with 9 being successful. Their recovery clearly reflects the asymmetry of the mound and corresponds well with the ROV observations.

<u>Summit and crest:</u> Coral framework occurs on the summit and along the southward dipping crest down to 670 m water depth. The summit is covered by coral thickets (GeoB 9256), made up of dead to subfossil *Lophelia pertusa* and to a minor degree of *Madrepora oculata* (Fig. 3.19). The dead framework with its lower part being clogged by soft, fine-grained sediments is patchily overgrown by living *Madrepora* colonies and solitary corals (*Desmophyllum cristagalli* and *Caryophyllia sarsiae*). The scleractinians represent by far the most important frame builders. Tracing the crest towards the south (GeoB 9270) and

towards the north (GeoB 9268), the same framework of prevailing dead *Lophelia pertusa* and associated *Madrepora oculata* colonized by some living *Lophelia* specimens and solitary corals occurs also at greater water depths (668 or 656 m respectively; Fig. 3.19). Sampling in the area of expended growth of large living coral colonies has been avoided.

The dominance of dead framework on the summit and crest as recovered by selective box corer deployments contrasts the observations gained during three ROV dives and an OFOS survey carried out on M61-1 cruise which clearly revealed extended areas of living corals growing on top of dead corals and exposed hardgrounds on the central part of the crest, while dead framework showing a patchy distribution is restricted to the western flank.

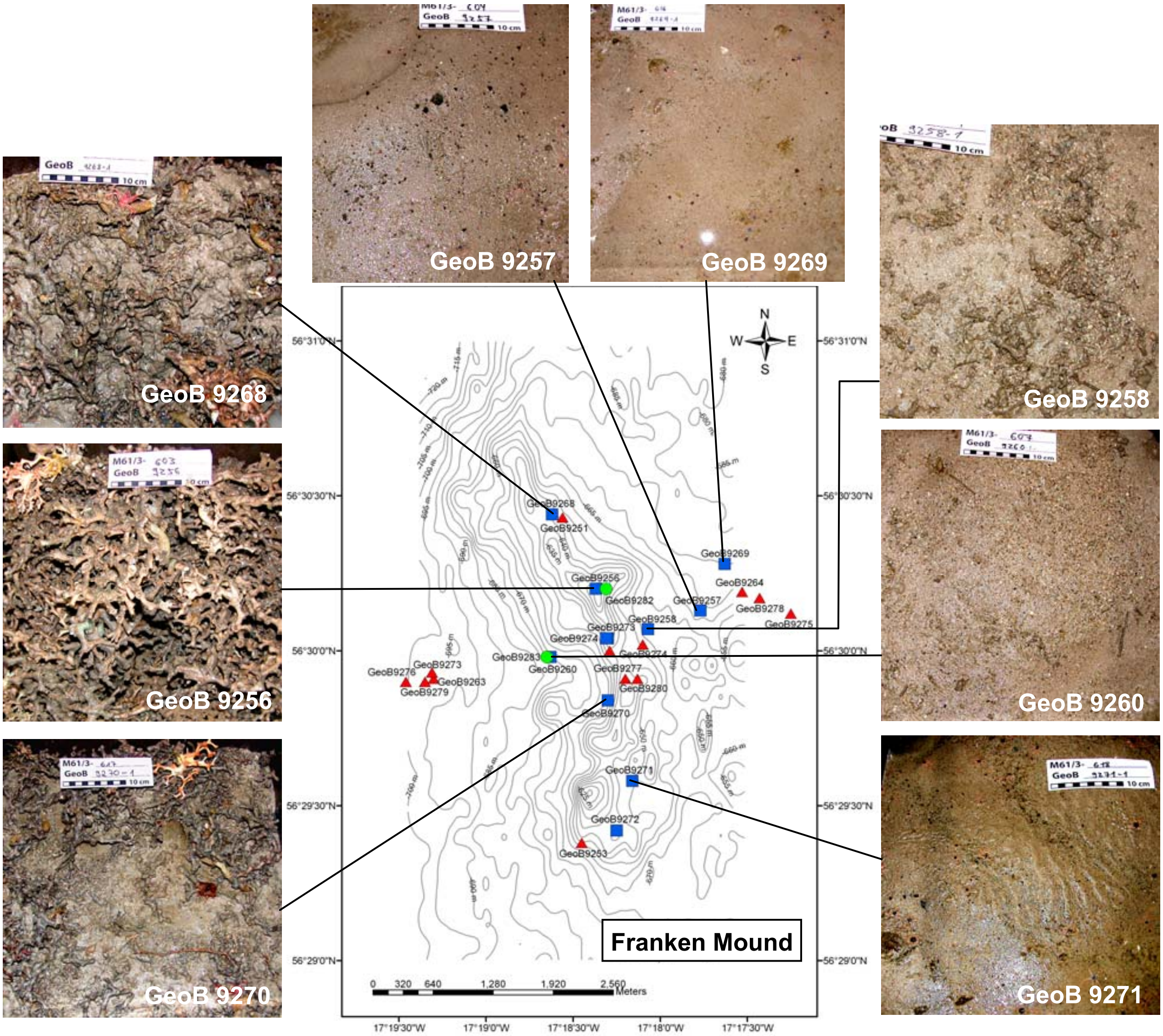

Fig. 3.19 Box core sampling stations and surface sediments in the Franken Mound area. Circles: gravity corer; quares: box corer; triangles: CTD.

Flank deposits: Due to the lack of sediment cover on the steeply dipping west face composed of lithified carbonates, box corers deployed on that flank did not provide any recovery (GeoB 9259-1, 9259-2). At the foot of slope, however, well-sorted calcareous sands containing some subfossil *Lophelia* fragments and carbonate pebbles eroded from the mound were recovered together with a few dropstones (GeoB 9260; Fig. 3.19). This facies type composed of fine-grained carbonate sands, some dropstones and scattered coral rubble largely resembles that of the eastern flank (GeoB 9258); the latter differs, however, by the fact that the coral rubble is composed of subfossil *Madrepora* fragments (Fig. 3.19).

Off-mound areas: Two box corers deployed east (GeoB 9257) and further northeast (GeoB 9269) of the carbonate mound revealed well-sorted calcareous sands with scattered dropstones and admixed shell fragments, serpulids and worm tubes; the sediment surfaces being covered by abundant living ophiuroids (Fig. 3.19). Off-mound sites to the south (GeoB 9271 and 9272) are characterized by well-sorted rippled sands composed of planktic foraminifers with admixed dark lithoclasts derived from dropstones (Fig. 3.19). Ripples showing wave lengths of 1-3 cm and a ripple height of the steep leeward slope of 0.3 cm are asymmetric, slightly curved and locally bifurcated, thus being formed by unidirectional currents. Invertebrate fauna, clearly dominated by ophiuroids, shows a low apparent diversity.

Sediment column

By analogy to the mounds of the Porcupine Seabight, samples taken on the summit and crest of Franken Mound revealed a moderate content of dead coral framework and subfossil coral rubble embedded in fine-grained sediments. Penetration depths of 15-28 cm were generally less than in the sandy facies of the deep mound flanks and off-mound areas which provided a recovery of more than 30 cm. Most sediment columns showed a distinct reduction horizon at 5-13 cm depth, characterized by the change from brownish to olive-grey colours.

The recovery of the coral-dominated on-mound cores taken on the summit and deeper crest revealed oxic and reducing zones in the sediment column. Box cores from the deep-flank and off-mound sites surrounding the carbonate mound showed three to four horizons, characterized by a thick oxic interval following beneath a thin reducing zone. Identified horizons are from top to base: (1) a coarse-grained oxic zone rich in skeletal grains; (2) a finer-grained reducing zone mainly composed of planktic foraminifera following beneath the reduction horizon; (3) a change to oxic Eh conditions documented by reddish-brown slightly cohesive muddy silts with abundant worm burrows blurring the boundary to the overlying reducing zone; (4) a zone of highly liquefied muddy silt of a prevailing oxic environment; this horizon recovered from the southern off-mound site revealed abundant siliceous sponge spicules deriving from the decay of a large hexactinellid sponge.

Biological features

On Franken Mound the framework-building scleractinians *Madrepora oculata* and *Lophelia pertusa* are, similar to the previous stations, associated with stylasterids (here with *Stylaster* sp.), hydroids, bryozoans, and other sessile organisms. In contrast to all other stations from coral habitats sampled during the cruise, the hexactinellid sponge *Aphrocallistes bocagei* does not occur on Franken Mound.

Very distinctive features in the fauna of Franken Mound are several polychaetes. A species of *Chaetopterus* was frequently present with its u-shaped tubes. These tubes are reminding the parchment-like *Eunice* tubes but are recognizable by a clear narrowing towards both ends of the tube and by its typical u-shaped appearance. In the samples GeoB 9256, GeoB 9270 and GeoB 9268 also several specimen of feather-worms (Sabellidae) were found. Feather worms have not been reported from other areas studied during M61-3. The probably most striking characteristic of Franken Mound is the high abundance of bivalves with *Heteranemonia squamula* and *Hiatella arctica* by far dominating the other invertebrate fauna.

A very interesting observation was the finding of a sponge species growing on parts of living *Lophelia* that are normally covered by the mucus layer. The sponge seems to compete with the living tissue of *Lophelia*. In some *Lophelia* specimens an abnormal growth form was observed where that sponge settled on. This yellow encrusting sponge showed to be frequently co-occurring with a small actinian of orange colour which also seemed to be competing with living tissue of *Lophelia*. Some specimens were eve growing into the thecae of living *Lophelia* polyps. These two species have also been found on a piece of *Lophelia* from Bremen Mound (ROV dive 20, GeoB 9249) and in sample GeoB 9287 from Connaught Mound.

Conclusions

Franken Mound formed on a topographic high which may in part be responsible for the strongly asymmetric flanks of the mound structure. Living coral framework was observed to cover wide areas along the crest, whereas the patchy coral cover on the steeply inclined western flank is mostly dead. This is in contrast to the mounds in the Belgica Mound Province, where the crests and flanks are being equally colonized by actively growing coral reef communities.

The flanks of Franken Mound are composed of lithified carbonates showing Fe/Mn-stained and strongly bored surfaces, thus representing real hardgrounds that are indicators of current erosion. Age determination and facies analysis of the sampled hardgrounds will help to answer the question if the outcropping hardgrounds forming the flanks of the structure are constructed by frame-building organisms, which would suggest that they belong to the carbonate mound itself, or if they are part of the topographic high, forming the basement of the actively growing mound. In the latter case they would represent a relict structure of Pleistocene or Tertiary age that was later colonized by mound-forming organisms.

3.6.3.5 Sediment Cores

(C. Hayn, A. Jurkiw, J. Kaiser, M. Lutz, F. Schewe, C. Wienberg)

In the region of the West Rockall Bank, we recovered two gravity cores from Franken Mound; one from the top of the mound (GeoB 9282) and one off-mound (GeoB 9283; Tab. 3.3). The core from the top of Franken Mound is composed of mud containing abundant bioclasts of primarily *Lophelia pertusa* and secondary *Madrepora occulata*, molluscs, echinoids and planktic foraminifers throughout the entire core. The off-mound core is dominated by a white to pale yellow/very pale brown clay with rare organisms (shells, planktic and benthic foraminifers) and occasional bioturbation. In particular, the lower part of the core shows semi-lithification.

3.6.4 Working Area 4: Northern Porcupine Bank

3.6.4.1 Bathymetry and Sampling Stations

(A. Foubert, L. Beuck, J. Gault)

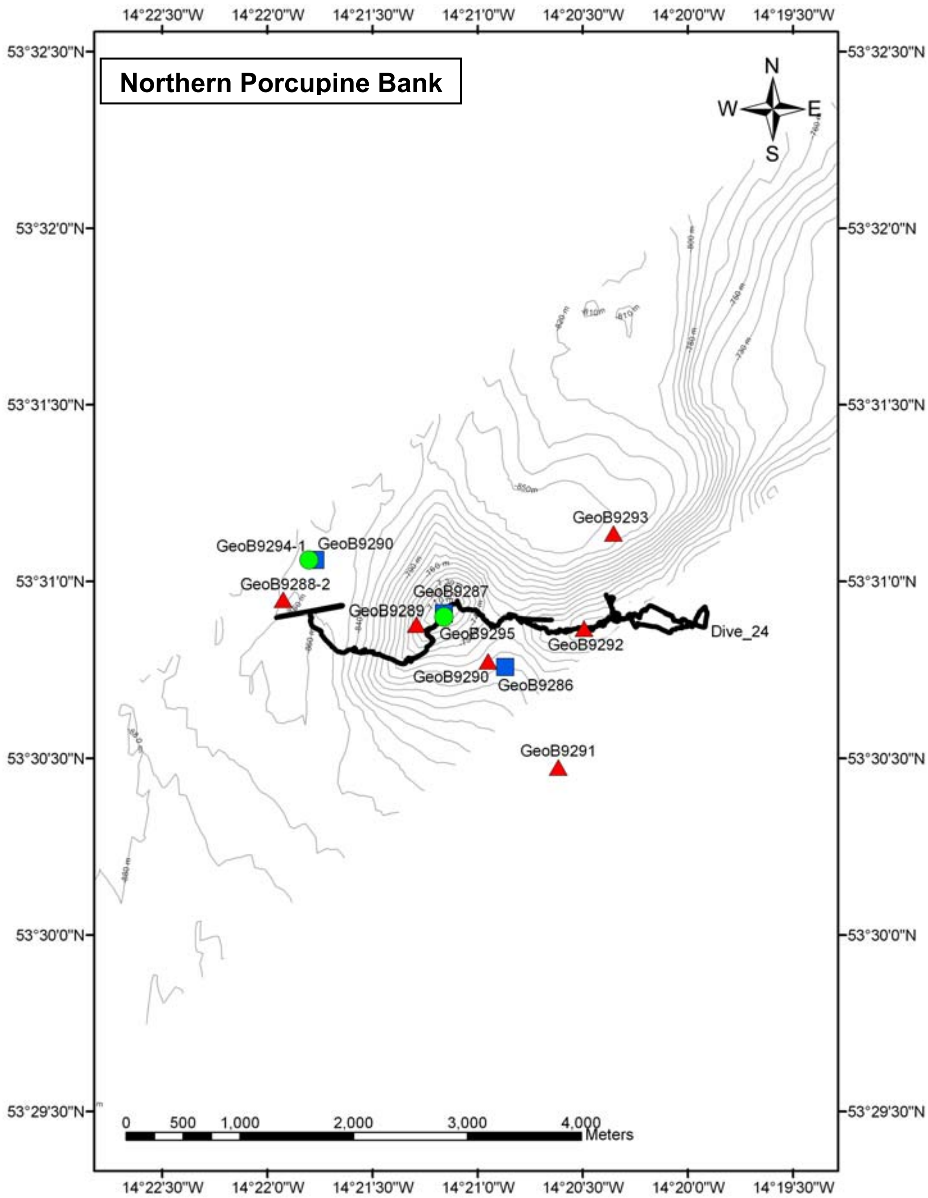

Fig. 3.20 Map of bathymetry, QUEST dives (bold line) and sampling stations along the Northern Porcupine Bank. Circles: gravity corer; squares: box corer; triangles: CTD.

3.6.4.2 Hydrography along the Northern Porcupine Bank

(A. Rüggeberg, L. Dodds)

Along the northern Porcupine Bank, six CTD casts were taken to analyse the water mass distribution in NS-transects across Connaught Mound and a submarine ridge further east. A typical CTD profile is illustrated in Fig. 3.21, presenting a water mass signature similar to a combination of previous analysed sites (Porcupine Seabight and West Rockall Bank). The surface water was slightly colder and less saline, as found within the Seabight, further to the southeast. The water mass underlying the Surface water (SW) showed a continuous decrease in temperature and salinity down to 9°C and 35.25 psu, indicating the contribution of both ENAW down to ~570 m and NACW between 600 and 780 m water depth (Fig. 3.21). The slight increase in salinity below 800 m may indicate a minor contribution of MOW or another high saline water mass similar to the West Rockall Bank site, although the general circulation of intermediate water masses is described to flow northwest passing the Rockall Bank further west (Bower et al., 2002).

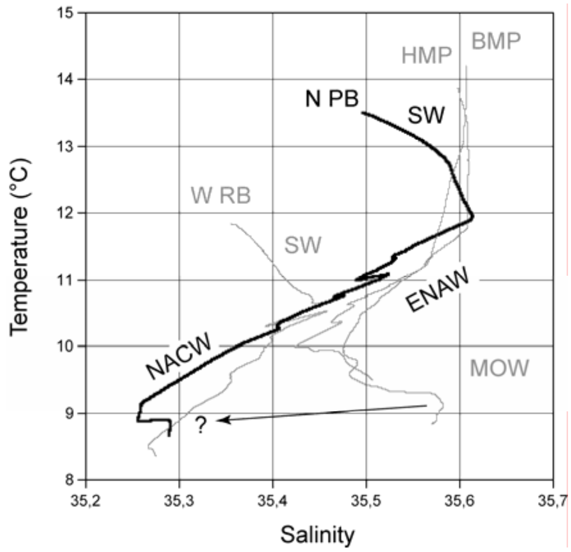

Fig. 3.21 TS-plot of a typical CTD profile of the Northern Porcupine Bank (NPB, GeoB 9288-2). SW: Surface Water; ENAW: Eastern North Atlantic Water; NACW: North Atlantic Central Water.

3.6.4.3 ROV Video Observations

(B. Dorschel, T. Beck, A. Foubert, J. Gault, A. Grehan, V. Ratmeyer, G. Ruhland)

At the Northern Porcupine Bank a feature that consisted of a small mound (Connaught Mound) extending into a scarp towards the north-east was investigated. The mound extends ~3 km in north-south direction and 1.7 km in east-west direction and rises 180 m above the surrounding seafloor (summit at 680 m water depth). The scarp continues east of the mound in a ~2.6 km long curve towards the north. At the scarp the water depth increases rapidly from 680 to 900 m.

Dive GeoB 9267 started west of the mound continued to the top, went east of the scarp crest, changed direction to north-west, crossed the scarp crest and descended the steep western slope (Fig. 3.20) and lasted for 11:30h. During that dive large coral colonies were found in the summit area of the mound and at the scarp crest. These settled on exposed hardgrounds which were common at the small mound as well as at the scarps crest and on the scarp itself. The hardgrounds were structured in decimetre to meter size banks, some showing internal structures as for example coral frameworks. The hardgrounds were sampled on a profile down the scarp using the ROV manipulators.

Comparable to the Franken Mound, the structure on the northern Porcupine Bank appeared to be a relict structure rather than a growing mound. The high abundance of hardgrounds indicate erosive current regimes at the location at present. Indications for active sedimentation had not been found in the mound and scarp area.

3.6.4.4 Surface Samples

(S. Noé, T. Beck, A. Foubert, A. Grehan)

On the northern slope of Porcupine Bank, a small coral-topped carbonate mound (Connaught Mound) extending into a scarp towards the northeast is exposed in the bathymetric interval of 870 m (western slope) and 800 m (eastern slope) with a summit at 700 m water depth. Hence the structure reaches an elevation of about 150 m over the seafloor to the west. The mound was sampled by three box corer deployments: one from the summit (GeoB 9287-1), one from the south-east (GeoB 9286-1) and one from the northwest (GeoB 9288-1) of the mound (Fig. 3.22).

Facies distribution

The summit is colonized by live *Lophelia pertusa* and associated invertebrate fauna. Underneath the living reef surface dead *Lophelia* framework is clogged by poorly sorted calcareous sands. The sampled sediment column of 12 cm thickness does not show any distinct reduction horizon due to strong bioturbation; a colour change from brownish to more olive-grey is visible, however. Underlying hardgrounds forming the substratum for the corals to settle on may have caused the low penetration of the box corer.

Poorly sorted sands with some dropstones characterized the site located at the upper slope southeast of the mound. An unusual abundance of living brachiopods and siliceous sponge spicules observed in the oxic sediment horizon demands to add a new facies type to the cool-water carbonate classification which is herewith described as BRACHIOHYALOSPONGE facies. Sediment recovery of 35 cm thickness reveals 3 horizons: the brownish oxic zone reaching down to 14 cm is rich in brachiopods and siliceous sponge spicules and shows a fining- and darkening-downward trend. Beneath a distinct reduction horizon, an olive-grey muddy silt grades into a dark-grey silty mud rich in organic matter.

The sample from the northwestern base of the mound slope revealed a dropstone pavement on top of well-sorted sands, colonized by stylasterids (*Pliobothrus symmetricus*) and abundant living ophiuroids. This off-mound facies resembles the sediments in the surroundings of Franken Mound. Sediment column of 12 cm thickness reveals a coarsening-upward succession from muddy silt to medium sand, lacking any distinct colour change indicative for changes in the redox state.

Biological features

The coral habitat fauna on Connaught Mound, sampled with box core GeoB 9287, showed to be somehow intermediate between the previous study sites. The coral framework was exclusively built up of *Lophelia*. Sands clogged the dead parts of the framework. Sessile organisms including stylasterids, sea anemones and hydrozoans, were commonly growing on dead coral fragments. The vagile fauna was represented by several ophiuroids, a stalked crinoid (presumably the same species that was found on one of the settlement plates mounted on the current meters from Galway Mound), two specimens of *Porania pulvillus* (Asteroidea) and the brachyuran *Bathynectes maravigna*. Also present were some gastropods, polychaetes and a large number of very juvenile specimens of the crab *Rochinia carpenteria*. The juvenile *Rochinia* were of about the same size than the ones found on Propeller Mound. Very characteristic features were numerous amphipod (Ampeliscidae) tubes attached in the thecae of dead *Lophelia*. Such amphipod tubes have not been reported from any other station of the whole M 61 cruise. The large living *Lophelia* colony collected at site GeoB 9287-1 was settled by numerous actinians sitting very close to the thecae of living polyps. Most probably it is the same species as on Franken Mound. In coincidence with Franken Mound, this actinian is here co-occurring with a yellow encrusting sponge growing on living parts of *Lophelia*.

Conclusions

Carbonate mound facies from the Northern Porcupine Bank sloping towards the Rockall Trough more closely resembles the sedimentary pattern exposed on Franken Mound at West Rockall Bank than that within the Porcupine Seabight. This may be controlled by oceanographic properties of the intermediate water masses and current patterns prevailing at depths of carbonate mound growth.

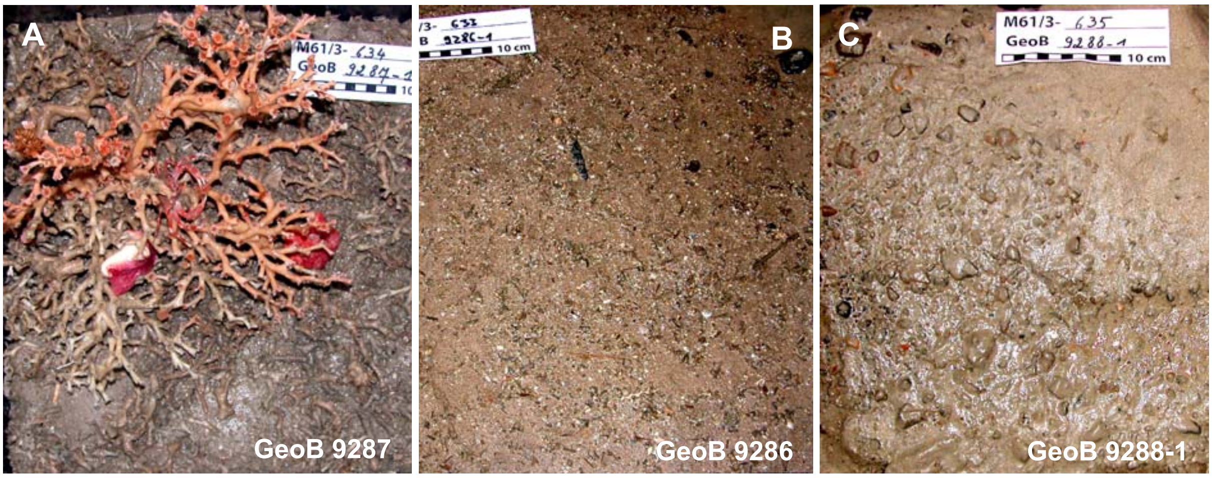

Fig. 3.22 Box core surfaces collected from (A) the summit, (B) southeastern off-mound and (C) northwestern off-mound areas of Connaught Mound.

3.6.4.5 Sediment Cores

(C. Hayn, A. Jurkiw, J. Kaiser, M. Lutz, F. Schewe, C. Wienberg)

At the northern part of the Porcupine Bank two gravity cores were retrieved; one from the top of Connaught Mound (GeoB 9294-1) and one from an off-mound setting (GeoB 9295), however, with the off-mound core yielding no sediment recovery (Tab. 3.3). The core from the top of the Connaught Mound is like the other top mound cores from Galway Mound and Franken Mound. It is primarily made up of silty to fine sandy mud which contains bioclasts dominated by fragments of *Lophelia pertusa*.

3.7 Metereological Station (DWD)

(G. Kahl)

When R/V METEOR left Cork, Ireland, on June 4th, 2004, a high of 1028 hPa was situated south of Ireland and a gale center of around 990 hPa over the southern rim of the Irminger Sea. There were just 15 hours of sailing after passing Cobh to reach the "Galway Mound" in Porcupine Seabight's Belgica Mound Province. The vessel was accompanied by light southerly winds. These favourable conditions extended into June 6th. Until then, a low had moved from the area of Newfoundland to 50 North 33 West, intensifying to 995 hPa thereby. A flat low south of the area had been incorporated in the flow around the gale center. Hence, southeasterly winds of 5 Bft were reported on June 7th, veering southwest and abating 4 Bft soon while the flat low passed the ship. On June 8th, R/V METEOR moved to the "Propeller Mound". Southeasterly strong winds of 6 Bft for a few hours while a frontal trough was passing did not inhibit sampling. The winds then veered to southwesterly 5 Bft.

R/V METEOR went on to the Rockall Bank, arriving there on June 10th. Southerly strong winds of 6 Bft while on the way brought no problems. The third working area welcomed the research vessel with light and variable conditions, being due to the fact that the gale center mentioned earlier had moved to Rockall Bank, too. The low then moved on to Scotland and further eastward. During June 11th, the vessel experienced northwesterlies of 5 Bft, abating 4 Bft and backing southwest.

The next day began with light westerly winds, backing southerly increasing 5 Bft in the evening. Meanwhile, another high 1032 hPa had established itself south and southwest of Ireland and on the other hand a gale center had gone up the west coast of Greenland, thereby inducing another one on the southeastern coast of Greenland, intensity being 990 hPa on June 13th. A frontal trough extending from the gale center was swinging towards Rockall Bank, and on the other hand the high was forecast to put on some more strength, 1036 hPa appearing on the forecast maps. In consequence, R/V METEOR reported southwesterly near gales of 7 Bft with gales 8 Bft in the forecast. As such conditions would have made further dives of the "QUEST" impossible, it was decided to move to a position on Porcupine Bank where better weather conditions were expected. When the ship arrived at the new position on June 15th, southwesterlies were down to 4 to 5 Bft.

On the frontal trough waves were developing and one of these managed to intensify into a gale center of its own. Central pressure was 1010 hPa on June 15th at 57 North 28 West. From there, the gale center moved to Scotland by June 17th and later further on to Northern Germany, steadily deepening. On the other hand, the high south of Ireland finally weakened.

These developments were of waning interest because time was running out, and when there were strong westerlies of 6 Bft on June 16th, sampling had to stop in favour of the course being set to Ponta Delgada on Sao Miguel in the archipelago of the Azores. The voyage there began by crossing of what was left of the high which had been such a dominating feature of the synoptic chart for quite a few days. Forecasts then saw a gale center moving southeast from the Newfoundland area, swinging east north of the Azores so that the ship may have to report strong southeasterly winds veering southwest and then just before calling port strong to gale force westerlies.

3.8 Station List M61-3

Tab. 3.5 Station List M61-3.

Station No.		Device	Cast	Area	Date	Time	Coordinates		Depth	Observations and subsamples
GeoB	METEOR		No.		(dd/mm/yy)	(UTC)	Lat. °N	Long. °W	(m)	
9200	547	CTD	1	BMP; S of Galway Mound	05/06/2004	05:30	51°56.75'	11°45.11'	890	12 bottles; see rosette protocol
9201	548	CTD	2	BMP; Top of Galway Mound	05/06/2004	06:34	51°27.10'	11°45.06'	810	13 bottles; see rosette protocol
9202-1	549-1	Mooring	1	BMP; Galway Mound	05/06/2004	08:25	51°27.14'	11°45.17'	828	
9202-2	549-2	HN	1	BMP; Galway Mound	05/06/2004	08:30	51°27.14'	11°45.11'	846	
9203	550	ROV+GAPS (dive 16)	1	BMP; Galway Mound	05/06/2004	09:48	51°26.70'	11°45.03'	892	3 sensors recovered
9204	551	GKG	1	BMP; S of Galway Mound	05/06/2004	21:44	51°26.94'	11°45.16'	8379	15 cm recovery; Madrepora, Lophelia, Aphrocallistes, little sediment
9205	552	GKG	2	BMP; Top of Galway Mound	05/06/2004	22:49	51°27.04'	11°45.12'	810	16 cm recovery; living and dead coral framework
9206	553	GKG	3	BMP; NE of Galway Mound	05/06/2004	23:47	51°27.31'	11°45.12'	857	box tilted, no section; living corals, little sediment, only surface sediment samples
9207	554	CTD	3	BMP; N of Galway Mound	06/06/2004	00:54	51°27.61'	11°45.31'	920	9 bottles; see rosette protocol
9208	555	CTD	4	BMP; W of Galway Mound	06/06/2004	01:56	51°27.13'	11°45.44'	932	see rosette protocol
9209-1	556-1	GKG	4	BMP; W of Galway Mound, off-mound	06/06/2004	02:51	51°26.92'	11°45.84'	983	not released
9209-2	556-2	GKG	5	BMP; W of Galway Mound, off-mound	06/06/2004	03:40	51°26.89'	11°45.81'	982	27 cm recovery; many corals and sponges, little sediment
9210-1	557-1	GKG	6	BMP; Top of Galway Mound	06/06/2004	04:49	51°27.11'	11°45.20'	810	not released; 1 coral on gear
9210-2	557-2	GKG	7	BMP; W of Galway Mound	06/06/2004	05:34	51°27.08'	11°45.25'	833	not released; coral rubble on box
9210-3	557-3	GKG	8	BMP; W of Galway Mound	06/06/2004	06:11	51°27.09'	11°45.24'	828	released but no recovery
9211-1	558-1	HN	2	BMP; Galway Mound	06/06/2004	06:45	51°27.10'	11°45.20'	804	start: 06:45, end: 19:10
9211-2	558-2	ROV (dive 17)	2	BMP; Galway Mound	06/06/2004	09:38	51°27.10'	11°45.20'	795	ROV technical problems, dive cancelled
9212	559	SL	1	BMP; Top of Galway Mound	06/06/2004	16:09	51°27.13'	11°44.99'	847	6 m tube; 193 cm recovery; 2 segments
9213	560	SL	2	BMP; Top of Galway Mound	06/06/2004	17:07	51°27.09'	11°45.16'	793	6 m tube; 515 cm recovery; 6 segments
9214	561	SL	3	BMP; Galway Mound	06/06/2004	18:15	51°27.06'	11°45.28'	857	6 m tube; 489 cm recovery; 5 segments
9215	562	CTD	5	BMP; E of Galway Mound	06/06/2004	19:38	51°27.20'	11°44.44'	923	4 bottles; bottles 5-6 did not release
9216-1	563-1	GKG	9	BMP; E of Galway Mound	06/06/2004	20:29	51°27.09'	11°44.81'	890	30 cm recovery; living and coral framework, little sediment

Tab. 3.5 (*continued*) Station List M61-3.

Station No.		Device	Cast	Area	Date	Time	Coordinates		Depth	Observations and subsamples
GeoB	METEOR		No.		(dd/mm/yy)	(UTC)	Lat. °N	Long. °W	(m)	
9216-2	563-2	GKG	10	BMP; E of Galway Mound	06/06/2004	21:36	51°27.14'	11°44.79'	903	not released
9217	564	GKG	11	BMP; Galway Mound	06/06/2004	22:37	51°27.35'	11°44.77'	925	released but no recovery
9218	565	GKG	12	BMP; N of Galway Mound	06/06/2004	23:39	51°27.47'	11°45.33'	889	20 cm recovery; coral framework, mostly dead
9219	566	GKG	13	BMP; E of Galway Mound	07/06/2004	01:44	51°27.05'	11°45.40'	920	18 cm recovery; living coral frame work
9220-1	567-1	GKG	14	BMP; Galway Mound, off-mound	07/06/2004	02:46	51°26.69'	11°45.04'	891	8 cm recovery; sand with some coral rubble
9220-2	567-2	GKG	15	BMP; Galway Mound, off-mound	07/06/2004	03:47	51°26.68'	11°45.04'	892	6 cm recovery; sand with some coral rubble
9221	568	PS	1	BMP; Galway Mound	07/06/2004	04:57	51°26.90'	11°48.50'	1040	Parasound transect start
					07/06/2004	07:21	51°27.60'	11°46.60'	997	Parasound transect end
9222-1	569-1	SL	4	BMP; Galway Mound	07/06/2004	08:11	51°27.48'	11°45.39'	900	6 m tube; 376 cm recovery; 4 segments
9222-2	569-2	HN	3	BMP; Galway Mound	07/06/2004	08:04	51°27.50'	11°45.30'	898	
9223	570	SL	5	BMP; Galway Mound	07/06/2004	09:30	51°26.90'	11°45.10'	839	6 m tube, 465 cm recovery; 5 segments
9224	571	Mooring	2	BMP; Galway Mound	07/06/2004	11:05	51°27.20'	11°45.10'	852	Deployment from June 6, 2004, recovered
9225	572	SL	6	BMP; Galway Mound	07/06/2004	12:06	51°26.76'	11°48.55'	1072	12 m tube m; 376 cm recovery; 4 segments
9226-1	573-1	SL	7	BMP; Galway Mound	07/06/2004	13:57	51°27.75'	11°43.03'	887	12 m tube; 251 cm recovery; 3 segments
9226-2	573-2	GAPS	1	BMP; Galway Mound	07/06/2004	15:10				GAPS USBL test
9227	574	GKG	16	BMP; E of Poseidon Mound	07/06/2004	19:09	51°27.40'	11°41.70'	731	41 cm recovery; dropstone pavement on fine sediment
9228	575	GKG	17	BMP; NE of Poseidon Mound	07/06/2004	20:08	51°27.70'	11°41.59'	752	10 cm recovery; coral rubble on little sediment
9229	576	GKG	18	BMP; SSE of Poseidon Mound	07/06/2004	21:10	51°26.61'	11°41.77'	772	36 cm recovery; dropstone pavement on fine sediment
9230	577	GKG	19	BMP; Poseidon Mound	07/06/2004	22:24	51°27.09'	11°44.80'	899	12 cm recovery; coral/sponge framework, little sediment
9231	578	CTD	6	BMP; Top of Galway Mound	07/06/2004	23:45	51°27.03'	11°45.82'	978	see rosette protocol
9232	579	CTD	7	BMP; E of Galway Mound	08/06/2004	00:45	51°26.98'	11°45.10'	837	see rosette protocol
9233	580	CTD	8	BMP; W of Galway Mound	08/06/2004	01:42	51°27.13'	11°44.57'	929	see rosette protocol
9234	581	CTD	9	BMP; W of Galway Mound	08/06/2004	02:45	51°26.98'	11°45.93'	987	2 bottles; see rosette protocol
9235	582	CTD	10	BMP; Top of Galway Mound	08/06/2004	03:45	51°27.10'	11°45.22'	820	2 bottles; see rosette protocol
9236	583	CTD	11	BMP; E of Galway Mound	08/06/2004	04:42	51°27.22'	11°44.39'	922	2 bottles; see rosette protocol
9237	584	CTD	12	BMP; W of Galway Mound	08/06/2004	05:45	51°27.08'	11°45.78'	972	2 bottles; see rosette protocol
9238	585	CTD	13	BMP; Top of Galway Mound	08/06/2004	06:43	51°27.08'	11°45.16'	805	2 bottles; see rosette protocol
9239-1	586-1	ROV	3	BMP; Top of Galway Mound	08/06/2004	07:25	51°27.10'	11°45.20'	781	Dive 18, 4 sensors recovered; 1 net sample

Tab. 3.5 (*continued*) Station List M61-3.

Station No.		Device	Cast	Area	Date	Time	Coordinates		Depth	Observations and subsamples
GeoB	METEOR		No.		(dd/mm/yy)	(UTC)	Lat. °N	Long. °W	(m)	
9239-2	586-2	HN	4	BMP; Top of Galway Mound	08/06/2004	14:18	51°26.90'	11°45.00'		start: 14:18, end: 21:03
9240	587	ROV	4	BMP; S of Poseidon Mound	08/06/2004	17:50	51°24.30'	11°41.20'	700	Dive 19, samples of hardgrounds
9241	588	CTD	14	HMP; N of Propeller Mound	09/06/2004	03:12	52°09.34'	11°45.94'	805	2 bottles; see rosette protocol
9242	589	CTD	15	HMP; Top of Propeller Mound	09/06/2004	04:02	52°08.89'	12°46.27'	728	2 bottles; see rosette protocol
9243	590	CTD	16	HMP; S of Propeller Mound	09/06/2004	05:01	52°08.24'	12°46.41'	732	2 bottles; see rosette protocol
9244	591	GKG	20	HMP;S of Propeller Mound	09/06/2004	06:01	52°08.61'	12°46.34'	758	not released
9245	592	GKG	21	HMP; SE-flank Propeller Mound	09/06/2004	06:59	52°08.84'	12°47.14'	769	40 cm recovery; fine-grained sediment
9246-1	593-1	GKG	22	HMP; Top of Propeller Mound	09/06/2004	07:54	52°08.17'	12°46.20'	756	tipped over
9246-2	593-2	GKG	23	HMP; Top of Propeller Mound	09/06/2004	08:38	52°09.00'	12°46.22'	746	not released
9246-3	593-3	GKG	24	HMP; Top of Propeller Mound	09/06/2004	09:17	52°08.99'	12°46.20'	750	24 cm recovery; fine-grained sediment with coral rubble
9246-4	593-4	HN	5	HMP; Propeller Mound	09/06/2004	09:08	52°09.00'	12°46.20'		start: 09:08, end: 19:36
9247	594	PS	2	HMP; Propeller Mound	09/06/2004	10:02	52°08.60'	12°46.80'	804	Parasound transect start
					09/06/2004	10:24	52°09.60'	12°45.30'	873	Parasound transect end
9248	595	HS	1	WRB; Bremen Mount	10/06/2004	14:13	57°05.20'	16°35.50'	933	Hydrosweep transect start
					10/06/2004	16:43	57°05.80'	16°36.60'	940	Hydrosweep transect end
9249	596	ROV	5	WRB; Bremen Mount	10/06/2004	18:42	57°06.40'	16°35.30'	803	Dive 20, stopped, no visibility
9250	597	CTD	17	WRB; N of Franken Mound	11/06/2004	04:47	56°31.25'	17°18.94'	729	2 bottles; see rosette protocol
9251	598	CTD	18	WRB; N-flank Franken Mound	11/06.2004	05:36	56°30.43'	17°18.56'	661	6 bottles; see rosette protocol
9252	599	CTD	19	WRB; Top Franken Mound	11/06/2004	06:24	56°30.00'	17°18.29'	655	18 bottles; see rosette protocol
9253	600	CTD	20	WRB; S-flank Franken Mound	11/06/2004	07:27	56°29.38'	17°18.45'	657	6 bottles; see rosette protocol
9254-1	601-1	CTD	21	WRB; S of Franken Mound	11/06/2004	08:24	56°28.80'	17°18.45'	690	2 bottles; see rosette protocol
9254-2	601-2	HN	6	WRB; Franken Mound	11/06/2004	09:06	56°28.80'	17°00.80'	681	
9255-1	602-1	ROV	6	WRB; Franken Mound	11/06/2004	09:46	56°30.16'	17°18.16'	607	Dive 21, mapping, sampling coral and carbonate crusts
9255-2	602-2	HN	7	WRB; Franken Mound	11/06/2004	10:00	56°30.22'	17°18.30'	641	start: 10:00, end: 10:30; at 10 m water depth
9255-3	602-3	HN	8	WRB; Franken Mound	11/06/2004	18:25	56°29.87'	17°18.66'		start: 18:25, end: 18:50; at 10 m water depth
9256	603	GKG	25	WRB; Top of Franken Mound	11/06/2004	20:07	56°30.20'	17°18.37'	629	28 cm recovery; coral framework, mostly dead
9257	604	GKG	26	WRB; E of Franken Mound	11/06/2004	20:58	56°30.13'	17°17.77'	678	33 cm recovery; fine-grained sediment with dropstones
9258	605	GKG	27	WRB; Franken Mound	11/06/2004	21:55	56°30.07'	17°18.07'	674	22 cm recovery; fine-grained sediment with coral rubble

Tab. 3.5 (*continued*) Station List M61-3.

Station No.		Device	Cast	Area	Date	Time	Coordinates		Depth	Observations and subsamples
GeoB	METEOR		No.		(dd/mm/yy)	(UTC)	Lat. °N	Long. °W	(m)	
9258	605	GKG	27	WRB; Franken Mound	11/06/2004	21:55	56°30.07'	17°18.07'	674	22 cm recovery; fine-grained sediment with coral rubble
9259-1	606-1	GKG	28	WRB; W of Franken Mound	11/06/2004	22:41	56°30.04'	17°18.30'	678	released but no recovery
9259-2	606-2	GKG	29	WRB; W of Franken Mound	11/06/2004	23:16	56°30.04'	17°18.31'	656	not released
9260	607	GKG	30	WRB; W of Franken Mound	11/06/2004	23:59	56°29.98'	17°18.63'	683	28 cm recovery; fine-grained sediment with dropstones
9261	608	CTD	22	WRB; W of Franken Mound	12/06/2004	02:12	56°29.54'	17°22.32'	757	2 bottles; see rosette protocol
9262	609	CTD	23	WRB; Franken Mound, W	12/06/2004	03:11	56°29.85'	17°20.35'	734	2 bottles; see rosette protocol
9263	610	CTD	24	WRB; Franken Mound, W	12/06/2004	04:04	56°29.91'	17°19.30'	709	6 bottles; see rosette protocol
9264	611	CTD	25	WRB; E of Franken Mound	12/06/2004	05:01	56°30.19'	17°17.53'	689	6 bottles; see rosette protocol
9265	612	CTD	26	WRB; E of Franken Mound	12/06/2004	05:55	56°30.26'	17°16.01'	671	2 bottles; see rosette protocol
9266	613	CTD	27	WRB; E of Franken Mound	12/06/2004	06:45	56°30.36'	17°14.48'	658	2 bottles; see rosette protocol
9267	614	ROV	7	WRB; Franken Mound	12/06/2004	08:25	56°30.30'	17°17.30'	685	Dive 22, mapping and sampling
9268	615	GKG	31	WRB; N of Franken Mound	12/06/2004	19:35	56°30.44'	17°18.62'	656	18 cm recovery; coral frameowrk, mostly dead
9269	616	GKG	32	WRB; NW of Franken Mound	12/06/2004	20:32	56°30.28'	17°17.63'	686	35 cm recovery; fine-grained sediment with dropstones
9270	617	GKG	33	WRB; SW of Franken Mound	12/06/2004	21:26	56°29.84'	17°18.30'	668	15 cm recovery; coral framework, mostly dead
9271	618	GKG	34	WRB; SE of Franken Mound, off-mound	12/06/2004	22:16	56°29.58'	17°18.16'	664	33 cm recovery; rippled sands with dropstones
9272	619	GKG	35	WRB; S of Franken Mound, off-mound	12/06/2004	23:03	56°29.42'	17°18.25'	651	25 cm recovery; rippled sands with dropstones
9273	620	CTD	28	WRB; W of Franken Mound	13/06/2004	01:01	56°29.93'	17°19.31'	709	no data
9274	621	CTD	29	WRB; Top Franken Mound	13/06/2004	01:58	56°30.02'	17°18.10'	652	no samples
9275	622	CTD	30	WRB; E of Franken Mound	13/06/2004	02:44	56°30.12'	17°17.25'	690	no samples
9276	623	CTD	31	WRB; W of Franken Mound	13/06/2004	03:40	56°29.90'	17°19.46'	709	no samples
9277	624	CTD	32	WRB; Top Franken Mound	13/06/2004	04:32	56°29.91'	17°18.20'		no samples
9278	625	CTD	33	WRB; E of Franken Mound	13/06/2004	05:27	56°30.17'	17°17.43'	690	no samples
9279	626	CTD	34	WRB; W of Franken Mound	13/06/2004	06:23	56°29.90'	17°19.35'	708	no samples
9280	627	CTD	35	WRB; Top Franken Mound	13/06/2004	07:10	56°29.91'	17°18.13'	641	no samples
9281-1	628-1	ROV	8	WRB; West Rockall Bank	13/06/2004	08:45	56°29.90'	17°18.20'	651	Dive 23, mapping and sampling
9281-2	628-2	HN	9	WRB; West Rockall Bank	13/06/2004	11:50	56°30.20'	17°18.40'	633	start: 11:50, end: 15:24
9282	629	SL	8	WRB; Top Franken Mound	13/06/2004	16:03	56°30.20'	17°18.31'	643	6 m tube; 169 cm recovery; 2 segments
9283	630	SL	9	WRB; Franken Mound	13/06/2004	16:45	56°29.98'	17°18.65'	684	6 m tube; 489 cm recovery; 5 segments

Tab. 3.5 (*continued*) Station List M61-3.

Station No.		Device	Cast	Area	Date	Time	Coordinates		Depth	Observations and subsamples
GeoB	METEOR		No.		(dd/mm/yy)	(UTC)	Lat. °N	Long. °W	(m)	
9284	631	PS	3	NPB; Northern Porcupine Bank	14/06/2004	16:15	53°37.60'	14°27.50'	1260	Parasound transect start
					15/06/2004	07:15	53°32.20'	14°18.50'	671	Parasound transect end
9285-1	632-1	ROV		NPB; Connaught Mound	15/06/2004	08:00	53°30.99'	14°22.00'	876	Dive 24, mapping and sampling
9285-2	632-2	HN	10	NPB; Connaught Mound	15/06/2004	14:00	53°30.91'	14°19.91'	739	
9286	633	GKG	36	NPB; SE of Connaught Mound	15/06/2004	19:44	53°30.76'	14°20.87'	799	35 cm recovery; fine-grained sediment with dropstones
9287	634	GKG	37	NPB; Top of Connaught Mound	15/06/2004	20:46	53°30.91'	14°21.16'	696	12 cm recovery; living and dead coral framework
9288-1	635-1	GKG	38	NPB; NW of Connaught Mound	15/06/2004	21:41	53°31.06'	14°21.77'	870	12 cm recovery; dropstone pavement on fine sediment
9288-2	635-2	CTD	36	NPB; NW of Connaught Mound	15/06/2004	23:36	53°30.94'	14°21.92'	873	see rosette protocol
9289	636	CTD	37	NPB; Top of Connaught Mound	16/06/2004	00:31	53°30.88'	14°21.29'	727	see rosette protocol
9290	637	CTD	38	NPB; SE of Connaught Mound	16/06/2004	01:30	53°30.77'	14°20.95'	790	no data
9291	638	CTD	39	NPB; E of Connaught Mound	16/06/2004	02:50	53°30.47'	14°20.61'	827	see rosette protocol
9292	639	CTD	40	NPB; Top of Connaught Mound	16/06/2004	03:43	53°30.86'	14°20.49'	703	no data
9293	640	CTD	41	NPB; N of Connaught Mound	16/06/2004	04:41	53°31.13'	14°20.35'	856	see rosette protocol
9294-1	641-1	SL	10	NPB; Connaught Mound, off-mound	16/06/2004	05:39	53°31.06'	14°21.80'	871	no recovery
9294-2	641-2	HN	11	NPB; Connaught Mound, off-mound	16/06/2004	05:27	53°31.05'	14°21.77'		
9295	642	SL	11	NPB; Top of Connaught Mound	16/06/2004	06:36	53°30.90'	14°21.10'	723	6 m tube; 475 cm recovery; 5 segments

Abbreviations						
Device	CTD	Conductivity Temperature Depth Profiler with Water Sampler Rosette		Area	BMP	Belgica Mound Province
	GKG	Giant Box Corer			HMP	Hovland Mound Province
	SL	Gravity Corer			WRB	West Rockall Bank
	HN	Plankton Hand Net			NPB	Northern Porcupine Bank
	ROV	QUEST 4000m Remotely Operated Vehicle				
	GAPS	USBL Acoustic Positioning System				
	PS	Parasound Sediment Echosounder				
	HS	Hydrosweep Bathymetric Multibeam Sonar				

3.9 Acknowledgements

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