Expeditionsprogramm Nr. 66

FS POLARSTERN

ARK XIX/ 3

2003

STIFTUNG ALFRED-WEGENER-INSTITUT
FÜR POLAR- UND MEERESFORSCHUNG

BREMERHAVEN, APRIL 2003

EXPEDITIONSPROGRAMM NR. 66

FS POLARSTERN

ARK XIX/3

"VICTOR in the North"

23.05.2003 - 07.08.2003

Bremerhaven - Tromsø

Koordinator:

Eberhard Fahrbach

Fahrtleiter:

ARK XIX/3a: Jörn Thiede

ARK XIX/3b+c: Michael Klages

STIFTUNG ALFRED-WEGENER-INSTITUT
FÜR POLAR- UND MEERESFORSCHUNG

April 2003

INHALTSVERZEICHNIS/ CONTENTS

Fahrtabschnitt ARK-XIX/3 a - c / Cruise leg ARK XIX/3 a- c

Bremerhaven - Brest - Galway – Tromsø – Longyearbyen - Tromsø

INHALTSVERZEICHNIS/ CONTENTS

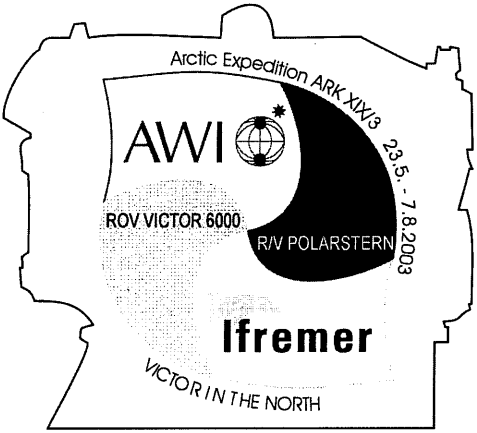
FAHRTABSCHNITT ARK-XIX/3 A - C

BREMERHAVEN - BREST - GALWAY – TROMSØ – LONGYEARBYEN - TROMSØ

(23.05. - 07.08.2003)

CRUISE LEG ARK XIX/3 A- C

"VICTOR IN THE NORTH"



Summary and Itinerary

During the third leg of RV "Polarstern" expediton ARK XIX/3 the French deep-sea ROV (Remotely Operated Vehicle) "VICTOR 6000" will be onboard. Shiptime demand was so high that the cruise leg was separetd into three sublegs in order to make "Polarstern" and "VICTOR 6000" accessible to as many European research groups as possible. Three geographical areas with different scientific objectives will be investigated: (i) the Porcupine Seabight and the Porcupine Bank southwest of Ireland with focus on deep-water corals, (ii) the Håkon Mosby Mud Volcano (HMMV) northwest of Norway at about 1250 m water depth where the greenhouse gas methane enters the hydrosphere, and (iii) the AWI long-term deep-sea station "Hausgarten" west of Svalbard at 2600 m water depth where causes and effects of physico-chemical gradients at the sediment-water interface are studied in detail with regard to biodiversity in Arctic deep-sea sediments.

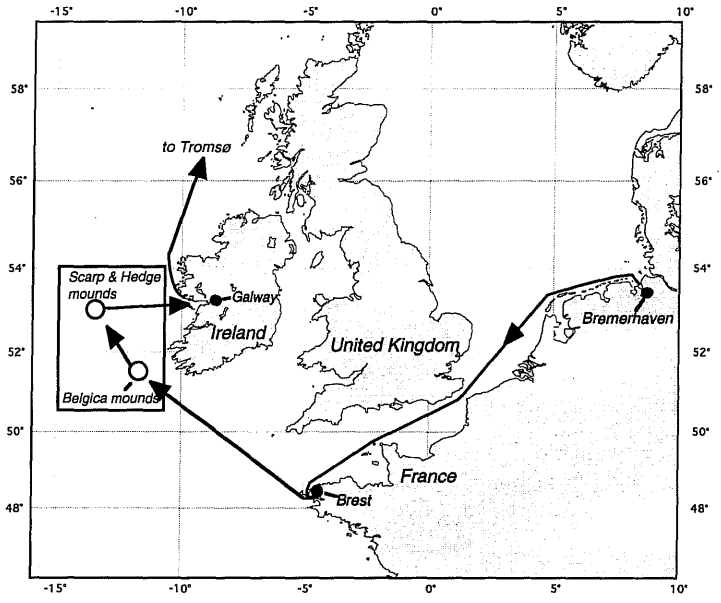


Fig. 1: Cuise track of "Polarstern" from Bremerhaven via Brest to the Porcupine Seabight during ARK XIX/3a
Fahrtverlauf der "Polarstern" von Bremerhaven über Brest in das Arbeitsgebiet Porcupine Seabight während ARK XIX/3a

After departure from Bremerhaven in the early morning of the 23rd of May "Polarstern" will steam to Brest harbour for installation of the ROV lasting from 25th of May until 1st of June. The 43rd Board meeting of the AWI will take place onboard "Polarstern" in transit to Brest. The first visit of "Polarstern" in Brest will be used to introduce high delegates of the German and French minstries for science and technology into the results and perspectives of the French-German cooperation in the field of marine and polar research.

It is planned to leave Brest in the night from 1st to 2nd of June with scientists, technicians and ROV pilots embarked before. The first site of scientific work will be southwest of Ireland. Here, research gropus coming from the EU-funded ECOMOUND, GEOMOUND and ACES initiatives, will focus on the geological evolution of giant, deep-water carbonate mounds in the Porcupine Basin and in the southeast part of the Rockall Basin. This will allow to investigate deep water mineral and biological resources along the European continental

margin. The main objectives of these initiatives are: (i) production of a systematic inventory (by gathering and analysing geophysical, seismic and geological data) and data set of recorded giant mound occurrences in the selected basins (from industrial data and surveys by the project teams), (ii) documenting morphologies, structural associations, patterns and temporal relationships which might identify the underlying geological control point on the genesis of mounds and on their sustained or episodic growth, (iii) in the light of available data, critically evaluate relevant hypotheses and test the diagnostic value of such mounds as potential indicators for hydrocarbons and for fluid expulsion events, delivering a genuine experimental validation scheme, (iv) to develop a model for fluid migration paths and processes which might have fuelled surface vents in the considered mound provinces, and elucidate their chronology, and (v) to prepare and define the terms of reference for a conclusive Ocean Drilling action.

The first area of scientific work during ARK XIX/3a will be in the Porcupine Seabight concentrating on the Belgica Mounds. The second dive area is on the NW Porcupine Bank. Two ROV dives of 24 hours each ("Hedge Mounds" and "Giant Mound cluster") and a 36 hour dive at the "Scarp Mounds" are proposed with about one day without ROV operation between each dive, time which will be used for sampling with multi and box corer.

The "Scarp Mounds" at 53° 43.7' N 13° 59' W are located on a scarp that appears to overlie a deep seated fault. This offers the possibility of locating carbonate mounds that overlie fluid escape structures therefore confirming the cold seep theory for gas escape. Alternatively, these mounds may exist on the scarp due to local hydrodynamic associated with this topographic rise. It is planned to survey this string on mounds and the intervening scarp to assess whether or not there is any evidence of cold seeps associated with the mound, whether hydrodynamics are important for mound growth at present and whether initial mound growth started at the base of the scarp (cold seep) or at the top (hydrodynamics).

The second dive at "Hedge Mounds" (located at 53° 36.3' N 14° 16.6' W) represent an alignment of up to 26 mounds on a slight topographic high between the upper heads of a canyon. This striking alignment suggests a strong control by hydrodynamics as tidal currents are forced to rise over this topographic high. This site therefore offers a unique opportunity to study hydrodynamic controls on mound growth.

The third dive at the "Giant Mound cluster" (location 53° 09.0' N 14° 46.4' W) represent a large cluster of very tall mounds with high SideScan Sonar backscatter and therefore probably support prolific coral growth both on and possibly around the mound. Also, based on seismic evidence, a relatively small mound at the start of this dive possibly overlies fluid escape and deep fault structures. It is therefore a prime site for finding possible cold seep associations.

On June the 20th disembarkation of personell will take place in Galway (Ireland) before "Polarstern" heads northward to Tromsø where the leg ARK XIX/3b will start (Fig. 2).

At June the 26th ROV pilots, scientists and technicians will embark in Tromsø to participate in the work at the Håkon Mosby Mud Volcano (HMMV). The HMMV at about 72° N 14° E was first investigated during an international cruise with RV "Logachev" in 1996, and most recently by a joint AWI / Ifremer cruise with RV "L'Atalante" and the ROV "VICTOR 6000" in September 2001. It is the only mud volcano in a polar region that has been studied in greater detail by photo and video camera observation. The HMMV is situated on the continental slope northwest of Norway at a water depth of 1250 m. It has a diameter of about 2 km, with an outer rim populated by methane-depending, chemosynthetic communities and an inner centre of about 500 m diameter where fresh muds are expelled. Between the central plain and the outer rim, a complex topography of hills and depressions can be observed, derived from the transport of young sediments. Methane is rapidly oxidized with sulfate in the anaerobic sediments at temperatures close to the freezing point (-1°C), producing a source of sulfide to the extensive mats of giant, sufide-oxidizing bacteria surrounding the central area. Despite its rapid turnover in the sediments, large amounts of methane dissolved in the rising mud-volcano fluids are seeping to the hydrosphere. It is unknown how much of the methane is removed in the aerobic bottom waters and how much escapes to the water column. The HMMV represents an ideal model system to study methane fluxes in polar seas. So far, only few selected key locations have been sampled with the ROV (centre of the HMMV crater, the south and southeast of the crater and the surrounding area). For a 3-D modeling of methane fluxes and turnover rates at the HMMV as one geological model system representative of a focussed methane source to the sea, we need to accomplish a more thorough sampling as well as geographical surveying of the different areas at HMMV, to estimate the areal coverage of the different chemosynthetic communities around the center with help of the mosaicing technology of "VICTOR 6000". Based on ROV video surveys and mosaicking technique the spatial distribution of key features at the HMMV will be identified and mass budgets about the distribution of bacterial mats be established. Sediment and water samples taken with the ROV will be used to further improve our knowledge on methane turnover and the distribution patterns of bacteria and archaea, as well as the rare methanotrophic-symbiont bearing tube worms. Natural radiotracer as Radon, Radium and Helium will be measured to elucidate the flux and the fate of methane in the bottom water column. A sampling of carbonates should be attempted, to investigate the contribution of methane turnover to carbonate formation (also an interest of GEOMOUND). Microbial degradation of methane in water column and sediments will be measured using radiolabelled tracers. Supplementary, sediment samples will be taken with both, the

multicorer and the giant box corer. Additionally, we will attempt a sampling of gas hydrates with deeper penetrating gravity coring. Water samples taken with two types of water samplers (rosette and horizontal water sampler) will be used to investigate the spatial distribution of the methane plume in the water column. *In situ* experiments with micro-profilers measuring pH, resistivity, oxygen and HS^- at the sediment-water interface will be carried out using the ROV to deploy the microprofiler at selected spots within the above mentioned key locations

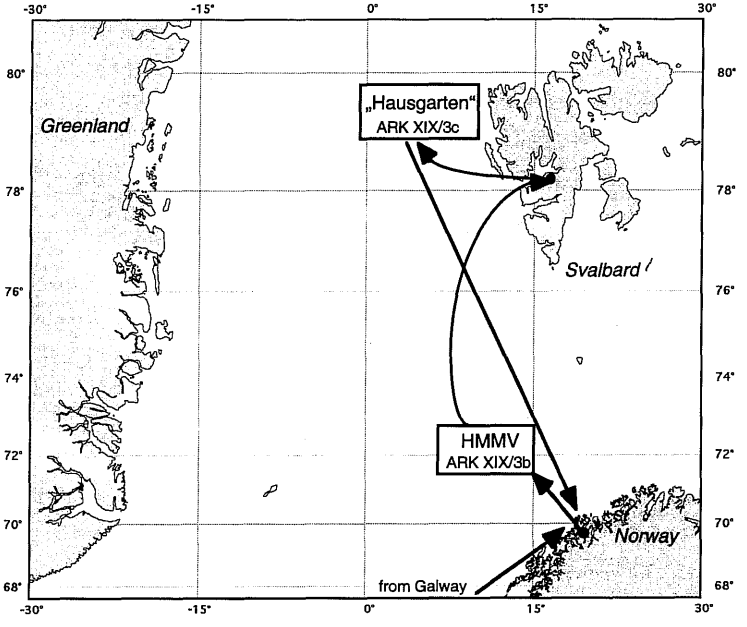


Fig. 2: Cruise track of legs ARK XIX/3b+c from Tromsø via Longyearbyen back to Tromsø.
Fahrtverlauf der Abschnitte ARK XIX/3b+c von Tromsø über Longyearbyen zurück nach Tromsø.

Because there are some indications for other mud volcanoes in the vicinity of the HMMV the cruise leg ARK XIX/3b will also be used for bathymetric mapping of the surrounding area and a survey dive with "VICTOR 6000" at a location where structural characteristics indicate the presence of a mud volcano. At July the 19th some scientists, technicians and all ROV pilots will disembark in Longyearbyen (Svalbard) while other personell will come on board for the

final leg ARK XIX/3c.

This leg is dedicated to work at the AWI long-term deep-sea station "Hausgarten" at 79 ° N and 4 ° E. First long-term experiments with special emphasis on Arctic deep-sea biodiversity and exchange prrocesses across the sediment-water interface were already launched during the "Polarstern" expedition PS ARK XV/1 in 1999 using "VICTOR 6000" and two years later again with the ROV onboard the French RV "L'Atalante". Sampling of long-term experiments started during both expeditons, e.g. sediment sampling at exclosure experiments, retrieval of artificial hard-substrates, sampling of "mimics" being deployed in 2001 and sampling at a physically disturbed area is necessary in 2003. Furthermore, new developed autonomous instruments such as microprofilers and current metres should be deployed by using the ROV at pre-selected areas at the seafloor to study processes and interactions at the sediment-water boundary layer fueling gradients in physico-chemical parameters. Sediment samples will be taken with standard instruments (MUC and box corer) to study interannual variability in sediment community structure and performance. Water sampling of the sediment – water boundary layer (the lower 2 m) is intended to validate previous measurements indicating unexpected strong gradients in oxygen, nutrient and particle content as well as in bacteria abundance.

Zusammenfassung und Fahrtverlauf

Auf dem dritten Fahrtabschnitt der "Polarstern"-Expedition ARK-XIX/3 in die Arktis wird das französische Tiefsee ROV (Remotely Operated Vehicle) "VICTOR 6000" an Bord sein. Es lagen zahlreiche Projektvorschläge zur wissenschaftlichen Nutzung der "Polarstern" und des ROV vor, so daß dieser Fahrtabschnitt in drei Unterabschnitte gegliedert werden mußte, um möglichst vielen europäischen Arbeitsgruppen den Zugriff auf die "Polarstern" und den "VICTOR 6000" zu ermöglichen. Drei geographische Regionen mit jeweils unterschiedlicher wissenschaftlicher Fragestellung werden im Rahmen der Expedition bearbeitet: (i) die Porcupine Seabight und angrenzende Porcupine Bank südwestlich von Irland zur Untersuchung der dort lebenden Tiefseekorallen, (ii) der Håkon Mosby Schlammvulkan (HMMV) nordwestlich von Norwegen in rund 1250 m Wassertiefe, der eine marine Punktquelle für das klimawirksame Treibhausgas Methan darstellt, und (iii) die Tiefsee-Langzeitstation "Hausgarten" des AWI westlich von Spitzbergen in 2600 m Wassertiefe, um Ursachen und Effekte von physikalisch-chemischen Gradienten an der Grenze zwischen Sediment und Wasser hinsichtlich ihrer Bedeutung für die Biodiversität arktischer Tiefseesedimente zu studieren.

Nach dem Auslaufen aus Bremerhaven am frühen Morgen des 23. Mai wird Kurs auf Brest genommen, um das ROV in der Woche vom 25. Mai bis zum 1. Juni zu installieren. Die 43. Sitzung des Kuratoriums des AWI wird während der Anreise nach Brest an Bord stattfinden. Der erste Besuch der "Polarstern" in Brest wird auch genutzt, um hochrangigen Vertretern der Forschungsministerien Deutschlands und Frankreichs an Bord die Ergebnisse und Perspektiven der deutsch-französischen Zusammenarbeit auf dem Gebiet der Meeres- und Polarforschung vorzustellen.

In der Nacht vom 1. auf den 2. Juni wird "Polarstern" mit den zuvor an Bord gegangenen Wissenschaftlern, Technikern und ROV-Piloten den Hafen von Brest verlassen und Kurs auf die Porcupine Seabight südwestlich von Irland nehmen. Wissenschaftler aus mehreren, von der EU geförderten Projekten wie ECOMOUND, GEOMOUND und ACES beabsichtigen dort an Tiefseekorallenriffen zu arbeiten. Die übergeordneten Schwerpunkte dieser Arbeiten, die auch vor dem Hintergrund der Erforschung mineralischer und biologischer Ressourcen entlang des europäischen Kontinentalrandes durchgeführt werden, liegen auf (i) einer systematischen Erfassung der Korallen (unter Einbeziehung vorliegender geophysikalischer, seismischer und geologischer Daten) und Komplettierung von Datensätzen die durch industrielle Vorerkundung und die Arbeit der an Bord befindlichen Wissenschaftler gewonnen wurden, (ii) Dokumentation der Morphologie, struktureller Vergesellschaftungen, von Mustern und zeitlichen Beziehungen des Korallenwuchses die helfen können, die

Kontrollmechanismen der Entstehungsgeschichte der "mounds" zu entschlüsseln, (iii) der Analyse existierender Hypothesen zur Bedeutung der "mounds" als Indikatoren für Lagerstätten von Kohlenwasserstoffen und von Fluidaustrittsereignissen, (iv) der Entwicklung eines Modells für Fluidaustritte und schließlich (v) zur Vorbereitung eines Bohrprogramms im Rahmen des Ocean Drilling Programms.

Das erste Arbeitsgebiet während des Abschnitts ARK XIX/3a wird die Porcupine Seabight sein, wobei ein Schwerpunkt auf der Untersuchung der "Belgica mounds" liegen wird. Anschließend wird in einem zweiten Gebiet im nordwestlichen Teil der Porcupine Bank an drei "mound" - Lokalitäten gearbeitet. Zwei ROV-Einsätze von jeweils etwa 24 Stunden werden an den sog. "Hedge mounds" und dem "Giant mound cluster" durchgeführt, ein weiterer Tauchgang von circa 36 Stunden an den "Scarp mounds". Die Tauchgänge mit dem ROV werden jeweils durch Stationsarbeiten wie zum Beispiel dem Einsatz von Multicorer und Kastengreifer unterbrochen. Die "Scarp mounds" bei 53° 43.7' N 13° 59' W liegen an einer Steilkante die vermutlich einer tieferliegenden Verwerfung aufliegt. Die an dieser Stelle geplanten Arbeiten an "mounds" über einer denkbaren Austrittstelle für Fluide ermöglichen damit die Überprüfung der *cold seep* - Theorie von Gasaustritt aus dem Untergrund. Alternativ könnten die "mounds" sich an dieser Stelle auch aufgrund lokaler hydrodynamischer Bedingungen aufgrund der besonderen Meeresbodentopographie ausgebildet haben.
Die "Hedge mounds" (bei 53° 36.3' N 14° 16.6' W) stellen eine Anordnung von 26 "mounds" dar, die auf einer leichten topographischen Erhöhung im Bereich der Kante eines Canyons liegen. Diese Lage läßt vermuten, daß hydrographische Verhältnisse hier eine wichtige Rolle für das "mound"-Wachstum spielen.
Im Untersuchungsgebiet ist mit dem "Giant mound cluster" bei 53° 09.0' N 14° 46.4' W eine letze ROV-Station geplant. Ausgewertete SideScan-Sonardaten dieser relativ hohen "mounds" lassen auf Korallenvorkommen auf und im Umfeld dieses clusters schliessen. Seismische Untersuchungen lassen darüber hinaus vermuten, das an einem relativ kleinen "mound" am Anfang des geplanten Tauchgangs Fluidaustritt möglich ist. Im "Giant mound cluster" ist damit am ehesten mit "cold seep" - Organismengemeinschaften zu rechnen.
Der Fahrtabschnitt ARK XIX/3a wird am 20. Juni in Galway (Irland) beendet, die meisten Wissenschaftler, Techniker und ROV-Piloten werden das Schiff verlassen bevor "Polarstern" dann am selben Tag Richtung Tromsø, dem Ausgangspunkt des Abschnitts ARK XIX/3b, aufbricht.

Am 26. Juni wird "Polarstern" den Hafen von Tromsø erreichen und die neuen Fahrtteilnehmer an Bord nehmen. Am frühen Abend wird dann Kurs auf den Håkon Mosby

Schlammvulkan (HMMV - Håkon Mosby Mud Volcano) genommen. Dieser, erst vor wenigen Jahren entdeckte untermeerische Schlammvulkan liegt am Kontinentalrand nordwestlich von Norwegen bei 72 ° N und 14 ° E in etwa 1250 m Wassertiefe. Er wurde 1996 während einer internationalen Expedition mit dem russischen FS "Logachev" beprobt. Im September 2001 wurde er im Rahmen einer gemeinsamen Expedition des AWI und des Ifremer mit dem FS "L'Atalante" und dem ROV "VICTOR 6000" dann erneut intensiv untersucht und umfangreiches Probematerial gewonnen. Der äußere Bereich des im Durchmesser ungefähr 2 km großen HMMV ist von methanabhängigen Organismengemeinschaften besiedelt, während der etwa 500 m durchmessende innere Bereich durch frisch aus dem Untergrund gepresste, wenig besiedelte Sedimente geprägt ist. Methan wird bei Umgebungstemperaturen von etwa -1 °C in den anaeroben Sedimenten über Sulfat durch Bakterien oxidiert. Das dabei entstehende Sulfid wird durch Bakterien an der Sedimentoberfläche, die ausgedehnte weiße Matten ausbilden können, weiter oxidiert. Trotz der hohen Umsatzraten in den Sedimenten gelangen große, bislang jedoch kaum abschätzbare Mengen an Methan in den Ozean. Der HMMV stellt damit ein Modellsystem für Methanaustritt aus dem Sediment in die Hydrosphäre in hohen geographischen Breiten dar. Bislang sind erst wenige Punktmessungen am HMMV durchgeführt und mit dem ROV beprobt worden (Zentrum des Schlammvulkans, der südliche und südöstliche Bereich des Kraters und der Bereich außerhalb des HMMV). Für ein 3-D Modell des Methanaustritts und der Umsatzraten am HMMV als Punktquelle für Methanfluß in den Ozean wird ein intensives Beprobungsprogramm während der Expedition durchgeführt. Unter Verwendung der sog. "mosaicking" - Technik werden mit Hilfe des "VICTOR 6000" die verschiedenen Bereiche des HMMV systematisch hinsichtlich des Bedeckungsgrades der unterschiedlichen chemosynthetischen Organismengemeinschaften vermessen. Um Methanumsatzraten und die Verteilungsmuster von Bakterien und Röhrenwürmern genauer zu bestimmen, werden Sediment- und Wasserproben mit dem ROV gesammelt. Natürliche Radionuklide (Radon, Radium und Helium) und radiomarkierte Tracer werden gemessen bzw. eingesetzt, um den Fluß, den mikrobiellen Abbau und das Schicksal von Methan in der Bodenwassergrenzschicht und in den Sedimenten zu bestimmen. Wenn möglich sollen auch Karbonatkonkretionen mit dem Greifarm des ROV aufgesammelt werden, um die Rolle des Methanabbaus für Karbonatbildung zu untersuchen (vergleichbar dem Ansatz im GEOMOUND – Projekt). Durch den Einsatz eines Schwerelots mit größerer Eindringtiefe als Multicorer oder Großkastengreifer sollen auch Gashydrate gewonnen werden. Um die räumliche Verteilung des Methans in der Wassersäule zu erfassen und zu beschreiben werden Wasserproben bodennah mit einem Horizontalwasserschöpfer und in der Wassersäule mit der Rosette genommen. An ausgewählten Schlüsselregionen des HMMV wird ein Mikroprofiler zum Einsatz kommen, der mit Hilfe des ROV gezielt abgesetzt und

aktiviert wird. Dieses Gerät mißt dann selbständig mit Mikroelektroden die Konzentration z.B. von O_2, pH und HS^- von der Sediment-Wasser-Grenzschicht bis zu mehrere Zentimetern in das Sediment.
Es wird vermutet, daß im näheren Umfeld des HMMV noch weitere Schlammvulkane vorkommen. Um diese Vermutung zu überprüfen wird während des Abschnitts ARK XIX/3b eine detaillierte bathymetrische Vermessung des Umfeldes vorgenommen. Geplant ist darüber hinaus ein Tauchgang mit dem "VICTOR 6000" an einer Lokation von der schon jetzt aufgrund seiner strukturellen Merkmale zu vermuten ist, daß es sich um einen Schlammvulkan handelt. Am 19. Juli endet der Abschnitt dann in Longyearbyen auf Spitzbergen und die Fahrtteilnehmer des Abschnitts ARK XIX/3c kommen an Bord.

Dieser letzte Abschnitt konzentriert sich auf Arbeiten an der AWI Tiefsee-Langzeitstation ("Hausgarten") bei 79 ° nördlicher Breite und 4 ° östlicher Länge. Seit 1999 werden dort Experimente durchgeführt und Langzeitdaten erhoben, um Fragen zur Biodiversität arktischer Tiefseesedimente und den Austauschprozessen an der Boden-Wasser-Grenzschicht zu beantworten. Der "VICTOR 6000" wurde bereits 1999 und 2001 an dieser Station eingesetzt, um gezielte experimentelle Arbeiten zu ermöglichen. Während des Fahrtabschnitts in 2003 sollen einige der vor vier bzw. zwei Jahren begonnenen Experimente kontrolliert, beendet und beprobt werden (z.B. werden Ausschlußexperimente (Käfige) beprobt, ausgebrachte künstliche Hartsubstrate geborgen und Sedimentproben im Umfeld von Köderexperimenten gewonnen). Im Jahr 2001 verankerte sog. "mimics" (aus Kunststoff gefertigte Strukturen, die Tiefseeschwämme in Form und Größe imitieren) sollen mit Stechrohren aufgenommen werden, um den kleinskaligen Einfluß derartiger, schwammähnlicher Strukturen auf die Organismengemeinschaft im Sediment zu untersuchen. Im selben Jahr wurde mit dem ROV in einem der Experimentierfelder des "Hausgarten" die Sedimentoberfläche physikalisch gestört. In diesem Jahr soll dieses Areal mit Sedimenstechrohren gezielt beprobt werden, um den Effekt derartiger Störungen auf die Sukzession arktischer Tiefseesedimente zu studieren und die Hypothese zu prüfen, daß Störungen mittlerer Intensität und Häufigkeit positive Effekte auf die Biodiversität haben. Darüber hinaus werden mit dem ROV an ausgewählten Standorten neuentwickelte autonome Meßinstrumente am Meeresboden abgesetzt, um räumlich hochauflösend das Strömungsregime bis etwa 1 m über dem Meeresboden zu messen. Ein anderes Instrument ermöglicht die Messung der Konzentration beispielsweise von Sauerstoff und ph-Wert im Sediment und dem darüberstehenden Wasser ebenfalls in hoher räumlicher Auflösung. Der Einfluß von punktförmigem Nahrungseintrag auf die Lebensgemeinschaften am Tiefseemeeresboden soll durch das gezielte Ausbringen von konzentrierter, im Labor gezüchteter Phytoplanktonlösung und Fischködern simuliert werden, und die beeinflußten

Areale in der Folge zu unterschiedlichen Zeitpunkten während der Expedition beprobt werden. Mit Großkastengreifer und Multicorer werden entlang eines Tiefentransekts Sedimentproben gewonnen, die als Beitrag zu einer Langzeitserie helfen sollen, mögliche Variabilität in Artenzusammensetzung und Aktivität von Organismen über die Zeit zu verfolgen und in Beziehung zu abiotischen Parametern zu setzen.

Am Morgen des 7. August endet der Fahrtabschnitt ARK XIX/3 in Tromsø.

Cruise leg ARK XIX/3a: Bremerhaven - Brest - Galway (23.05. - 20.06.2003)

Porcupine Seabight and Porcupine Bank: Overall objectives of Leg ARK XIX/3a

A. Grehan et al. (NUIG) and A. Wheeler et al. (UCC)

A series of dives will be undertaken in the Porcupine Seabight and Porcupine Bank to study various attributes of carbonate mounds that are colonised by deepwater corals. These represent unique habitats of importance both in terms of biodiversity but also as significant sinks for carbon and potential high resolution records of climate change. Understanding these unique environments is of recognised importance and has been the focus of numerous national and international research efforts including a former dive campaign of the ROV "VICTOR 6000" during an expedition with the Ifremer R/V "L'Atalante" in 2001 (CARACOLE).

The results from CARACOLE demonstrated the power of the ROV "VICTOR 6000" in unlocking the secrets of these difficult to explore environments. This leg will build on those former studies and will also explore new mound sites that offer greater insights into the functioning of deepwater colonised carbonate mounds. The objectives of this dive are set down in detail below.

Between dives there will be opportunities to accomplish additional non-ROV investigation using available winches. The scope and scale of these objectives can be expanded in the case of prolonged downtime or an unforeseen change in the cruise schedule. A limited number of boxcores will be taken form mound sites where previous cores have not been collected. This will be undertaken to quantify the biology of the mounds and assess inter-mound variation. As some mounds have already been samples previously, these particular mounds will not be resampled in order to conserve this habitat.

Boxcores will also be taken from areas where there are indication of potential hydrocarbon seepage in order to perform chemical assays on the gas content. The deployment of CTD may be undertaken to quantify water mass characteristics and study short-time scale variations

Specific objectives of dives in the Porcupine Seabight and Porcupine Bank are described in the following subchapters.

Microbathymetric maps using the ROV "VICTOR 6000" as platform for a multi-beam echososunder

J. Opderbecke et al. (Ifremer)

The aim of the project is to produce microbathymetric maps with a multi-beam echosounder (MES) onboard "VICTOR 6000" during the "Polarstern" cruise legs ARK XIX/3a+b. Microbathymetry is not available as a standard function on "VICTOR 6000", although it has been used successfully on two scientific Ifremer cruises, it is considered an experimental set-up that is operated by an engineering crew. The multi-beam echosounder will be rented for the cruise. In order to provide a large scanning sector beneath and to the sides of the multi-beam sensor, the acoustic head of the multi-beam system is installed as close as possible to the bottom level of the ROV module. Therefore, landing on the sea-bed must be avoided. For this reason the MES can not be mounted on the sampling module, so dives will be either sampling or survey dives. Raw data are stored in a proprietary binary QINSY-database, which includes all configuration parameters as well as the complete set of raw-sensor data. The database has a volume of 50MB/h for multibeam data and optional 200MB/h for sidescan data.

The database can be exported in different commercial formats, the most widely used is XTF (Extended Triton Elics Format) which contains all raw data. Any type of data can explicitely be exported as a simple ASCII file.

File transfer can be carried out by FTP or CD(700MB)/DVD(4.9GB).

The microbathymetry system is composed of rented or laboratory equipment. In order to keep the system operational in presence of component failure, most of the equipment are double or have second order replacement. Two complete MBE systems will be rented. The Doppler log will be backed up by a rental equipment. The fibre optic gyro OCTANS can be

replaced by the Seatex MRU6, signifying a degradation of the dead-reckoning navigation which is essential for mapping.
The PCs are classified in two groups, the second of which can be used to replace computers from the first one :
The indispensable set-up for bathymetry production: Navigation PC, QINSY data logging.
The complementary set-up for optimal operation: QINSY slave display, Post-processing PC, Matisse video-mosaicking PC.
The central part of the microbathymetry system is the QINSY™ PC that blends and logs multi-beam sonar data, position coordinates, depth, heading, pitch and roll angles.

The QINSY™ slave application in the piloting container displays the map in a 2D representation for the pilots and the scientist on shift.
The position is computed in the TRIADE PC: velocity (RDI DVL) data and heading (OCTANS FOG) are read from messages on "VICTOR 6000" real time network and position relative to an initial point is computed from the motion measurements. The drift of this dead-reckoning process, normally about 5m/h, is corrected in appropriate intervals by re-initialisation with a position from POSODONIA. The high-rate up-link between the sonar antenna and the sonar processor will use a specific fibre optic cable (Ifremer).

Post-processing and 3D visualisation is accomplished on the TERRAMODEL™ PC or on Ifremer's Caraïbes workstation (2nd leg only). Data are saved to two harddisk copies and on DVD+R.
A period of 4 hours should be available at the beginning of the first dive for the purposes of initial function tests and calibration of the sonar antenna.

It has to be kept in mind that the microbathymetry system is a complex experimental setup, scientists planning their dive have to take into account the eventuality of delays occurring during a dive.
Survey profiles have to be prepared by the scientist. A profile is given by a series of latitude /longitude coordinate points. These may be prepared by help of the ADELIE software, and be transferred by floppy disc, CD or FTP etc. The profile must be available to the bathymetry crew and to the "VICTOR 6000" pilot crew at least one hour before it's execution (not taking into account the time necessary to reach the start point). The permanent crew to operate the microbathymetry system is composed of three persons. They will work the same shifts as the "VICTOR 6000" crew. We suggest that one scientist assists the microbathymetry operation; this allows scientists to easily direct the survey to meet their needs and it prepares the data exploitation.

The Ifremer microbathymetry crew can post-process data (replay, data cleaning,...), if necessary, outside the survey periods. Scientists can be trained to use the tools for post-processing and visualization, and to extract data for transfer to their proper tools.

Bathymetric study - seafloor surface impact on acoustic backscatter

A. Beyer et al. (AWI)

Multibeam systems are widely used to cover large areas by bathymetric measurements in comparatively short time. For this purpose the multibeam system Hydrosweep DS2 is installed onboard RV Polarstern. In addition to the depth measurements echo amplitudes are recorded by the system. They can be converted into multibeam sidescan and angular backscatter data. The main application of sidescan is to detect small scale features which cannot clearly be recognised in the bathymetry (e. g. shallow channels or iceberg plough marks). Angular backscatter shows the same resolution as the depth measurements but supplies additional information about physical properties of the seafloor (surface- and volume roughness). Therefore, the backscatter strength and its dependence from the incidence angle of the acoustic pulse onto the seafloor is considered. Using a terrain model and taking into account the affect of the water column as well as internal signal processing of the multibeam, the recorded amplitude values are transformed into angular backscatter strength. Maps showing the areal extension of the backscatter data are used as basis to segment the seafloor into regions of different backscatter characteristics. Seafloor classification is also an appropriate approach based on this maps and further backscatter analyses. Based on the combination of surface sample information and backscatter distribution / segmentation of the seafloor, the spatial validity of surface samples can be determined.

This study intends to get ground truths for the backscatter analyses along the European continental margin southwest of Ireland (Porcupine Seabight). In this area, processed backscatter data is available. Two types of sample locations are to be focused on. One type shows that a changing morphology can cause a changing backscatter characteristic. Another type indicates changing backscatter within the same morphological surrounding. For these kind of analyses bathymetry and backscatter data have to be combined.

The aim of this study is to identify the link between seafloor properties and angular backscatter in order to use Hydrosweep bathymetric measurements for remote sensing of the seafloor. Sparsely distributed seafloor samples and related seafloor properties will be utilised to enhance interpretation of the entire area were backscatter data is available.

ROV "VICTOR 6000" will be deployed to get representative seafloor samples for ground truthing backscatter measurements in the proposed investigation area. The track line has been determined based on existing bathymetric and backscatter data. In particular, submarine channels have been selected for sampling because of significant variation of the acoustic backscatter characteristics within the channels. Video recordings and vertical imaging of the seafloor is proposed to get information about the microstructure of the seafloor along the track lines. The application of a shallow water echo sounder onboard ROV "VICTOR 6000" establishes the opportunity of recording backscatter data in addition to the Hydrosweep data for comparison and a continuous microtopographic coverage of the area. The relationship between microbathymetry and Hydrosweep backscatter is also focus of this investigation.

At additional locations, multicorer (MUC) will be deployed to analyse the properties of the upper part of the sediment layer since it mainly effects the backscatter of the acoustic pulse. A video camera attached to the MUC gives seafloor images of the sampled part of the seafloor. Thus additional information about the microstructure of the seafloor is available at locations where ROV "VICTOR 6000" is not deployed.

Further bathymetric data can be recorded at locations of different scientific interests. Thus, the number of ground truths can be enlarged using data from these stations.

At the location of the Håkon Mosby Mud Volcano at the continental margin northwest of Norway similar bathymetric investigations as described above will be realised. The area of the mud volcano and the adjacent margin will be target of bathymetric measurements deploying ROV "VICTOR 6000" and Hydrosweep. Echo amplitudes will provide backscatter data to detect changes of the seafloor sediments. Geochemical samples in this area can be used to interpret the backscatter results.

Recordings of the EK60 echo sounder above the mud volcano detect changes of the acoustical properties of the water column. This data will be analysed both qualitatively and quantitatively to determine the source of the inhomogeneities. The effect of the water column on Hydrosweep backscatter data will also be target of investigation.

Azooxanthellate corals

T. Beck, W.-C. Dullo, O. Pfannkuche (U Erlangen, GEOMAR)

Azooxanthellate coral reefs along the north-western European continental margin occur in an extremely dynamic environment alongside the boundary between the Atlantic surface water and the Mediterranean outflow water. The coral ecosystems is subjected to a strongly altering hydro-dynamical regime which greatly influences the availability of food particles.

Food availability is also subjected to seasonally fluctuating deposition of POM depending on the surface layer plankton production. Main objective is to investigate the interrelation between the coral ecosystem and the diurnal and seasonal processes in the ambient hydro-dynamical and depositional regime. These factors seem to bias the conditions of coral growth and its reproduction by geo-chemical proxies in the skeletons of the corals but are hitherto greatly unknown. Coral ecosystems are hot spots of marine biodiversity. Distribution pattern, suksession and trophic relation of the reef megafauna and interrelation between other megafauna organisms and corals are still greatly unknown.

The "Coral working group" will investigate deep-water coral ecosystems specifically with the ROV "VICTOR 6000" in continuation of the CARACOLE Cruise in 2001. The study of deep-water corals is embedded within the OMARC-Research cluster and specifically the ACES-Project. We are interested to analyse the habitat zonations and to recognize key species within the defined habitats. Another topic is to locate suitable deployment areas for a novel sea floor long-term observatory ("GeoLab") for azooxanthellate coral reefs. It is planned to deploy GeoLab in 2004 with FS METEOR (M61).

Carbonate skeleton of deep-water corals and molluscs as proxies

J. Hall-Spencer (U Plymouth), M. Bergmann (SOS)

The longest available time series on ocean currents indicates that the southward flow of water from the Greenland Sea is weakening. This has been linked to changes in regional climate which, if trends continue, could alter the flow of the North Atlantic drift within 30 years, profoundly affecting regional climates, marine ecosystems and fisheries. We are attempting to use the carbonate skeletons of deep-water corals and molluscs to find out how rapidly and how often the thermohaline circulation of the NE Atlantic has changed in the past, just as tree rings and ice cores are used to investigate climate change on land. Behaviour of the Atlantic thermohaline circulation over the coming century depends on the response of air-heat and freshwater fluxes to the increased load of greenhouse gasses.

Live, dead and sub-fossil corals and molluscs will be collected using "VICTOR 6000" and box coring. Laser ablation mass spectrometry (LA-ICPMS) will be utilised using probe microanalysis to determine variation in $\delta^{18}O$, $\delta^{14}C$, Ca, Sr and Mg concentration with time and species in an attempt to deduct age, seawater temperature and nutrient availability. Radiocarbon analysis will also be undertaken to investigate the 'age' of the water at these depths together with enrichment from anthropogenic sources. During leg XIX/3a we are

particularly hoping to be able to sample a suite of molluscs including the large bivalve *Acesta excavata* as this can be a common component of the spectacular deep-water European coral communities constructed by *Lophelia pertusa* and *Madrepora oculata* (Fig. 3).

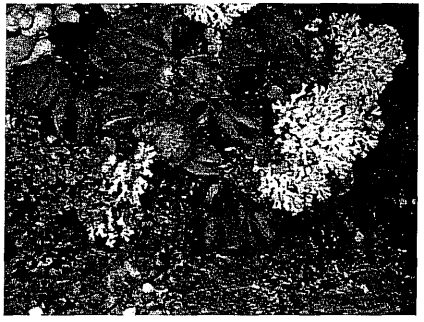


Fig. 3 Photograph of *Acesta excavata*
(courtesy of JH Fossa, IMR Norway)

By studying the mollusc assemblage and its diet we can also start to unravel the ecological complexity of the mound systems. *Acesta* is poorly known but grows attached by byssus to the coral framework and resembles the hydrothermal *Bathymodiolus* communities recently studied using "VICTOR 6000". During leg XIX/3c, we hope to sample long-lived bivalves in addition to *Yoldiella propinqua* and *Thyasira dunbari* that are known to be common at the AWI "Hausgarten" with the giant box corer for similar analyses. 'Down-time' between sampling operations will be used for video analysis of the carbonate producing communities and evidence of ghost fishing/trawling damage, together with the sorting, identification and storage of benthic samples.

Bioavailability and transport behavior of benthic boundary layer aggregates

L. Thomsen et al. (IUB)

The objectives of the studies include investigations on the bioavailability and transport behaviour of benthic boundary layer (BBL) aggregates in the vicinity of carbonate mounds and azooxanthellate coral reefs in the Porcupine Seabight and Rockall Trough with concern on geochemistry, geobiology, and biogeochemistry.

Lateral transport of particles is largely controlled by the hydrodynamics within the BBL, which is most important for the vertical exchange between sediments and water column. However detailed observations of BBL characteristics at continental margins are rare. The processes that laterally distribute and sort out the near-bed water column material are as important as is

vertical settling in determining the availability of this material as energy source to meet the benthic carbon demand. The goal of this study is to quantify and statistically evaluate particle characteristics (quality and quantity, size, settling velocity), and to obtain particle residence times in the water column under prevailing hydrodynamic conditions as a basic data set for a margin/slope sediment transport model. Multicorer samples stored under *in-situ* temperatures should be used for the determination of the critical erosion stress τ_c. Critical erosion stress will obtained onboard in an erosion chamber with calibrated, spatially homogeneous bottom stress.

Investigations on the connections between hydrographic regime and carbonate mound development

C. Borschel (U Bremen)

Recent observations indicate strong connections between the hydrographic regime and carbonate mound development. The complex morphologies of the mounds in interaction with strong bottom currents create micro current regimes, strongly affecting benthic ecology, environmental conditions and sedimentological processes on and around the carbonate mounds. To investigate these interactions seven hydrographic sensor packages (incl. a current meter and a CTD) will be deployed at key sites by the ROV on a selected carbonate mound for a one year period. These activities are part of the ESF EUROMARGINS project MOUNDFORCE.

Focus on the genesis of mounds and on the processes of mound formation and differentiation in Porcupine Seabight, SW of Ireland

A. Foubert et al. (RCMG)

Large mound structures have been discovered in the Porcupine Seabight, SW of Ireland, along the continental margin at 500 to 1100 m water depth. They were first reported by Hovland et al. (1994) from industrial seismic data. During a high-resolution seismic survey of the RCMG on board of the R/V Belgica even more mounds were discovered in other areas of the Porcupine Seabight (Henriet et al., 1998). They were studied in more detail during the TTR7 cruise on board of the R/V "Logachev" (Kenyon et al., 1998). Now three mound provinces could be distinguished, each with their own characteristics: the Hovland, Magellan and Belgica mound province (De Mol et al., 2002). The mounds appeared to be associated with the growth of cold-water deep-sea coral species such as *Lophelia pertusa* L., *Madrepora oculata* L., and *Desmophyllum* sp. (Hovland et al., 1994; Kenyon et al., 1998; De Mol et al.,

2002). After the first discoveries in 1997, several cruises followed and several types of survey equipment were used: multibeam echosounder (R/V "Polarstern" 2000), sidescan sonar (TTR7 & 8, R/V "Discovery" cruise, R/V "Pelagia" /TOBI cruise), box-, piston and gravity coring (R/V "Belgica", "Pelagia", "Logachev", "Poseidon", "Marion Dufresne"), further detailed seismic surveys. Moreover, industrial seismic data were added: Statoil 3D & TOTAL and 2D site survey. The whole research effort is framed within 3 European 5-th framework projects: Geomound, Ecomound and ACES, focusing respectively on the internal (geological), external (ecological) and biological controls of deep-water corals. Since then the knowledge about mounds and corals in the Porcupine Seabight and Rockall Trough is growing, mainly on topics such as mound morphology, spatial distribution, location. Still there are many unanswered questions left – certainly concerning the processes of mound formation and mound origins.

At the southeastern margin of Porcupine Seabight, channels incise the slope. The most prominent is the east-west orientated tributary Gollum Channel system, featuring small, but steep 'steer's head' canyons, all converging into one large canyon, flowing into the Porcupine Abyssal Plain. Several dives with the French submersible "Cyana" (Tudhope & Scoffin, 1995) mentioned that there were localised *Lophelia pertusa* coral thickets on both the flanks and the floor of the canyon.

Backed by the very large data set already acquired in the area, last year's CARACOLE cruise with "VICTOR 6000" was planned (R/V "L'Atalante"), resulting in fantastic data. Insights in fauna, in coral and coral debris distribution, in mound dynamics and sediment interaction became possible. From these experiences a new deployment (with guaranteed success) of "VICTOR 6000" is necessary to expand the research and the results. Focus is placed on the genesis of the mound formation and differentiation. Therefore two dives are planned:

- Reconnaissance video survey over several steep-flanked Belgica mounds, to compare them with the results of the CARACOLE dives in mound Therese (see Fig. 4).
- Bathymetric survey with the microbathymetry multibeam system mounted on the "VICTOR 6000", over the Moira mounds. These were first pictured on side scan sonar data and visited by "VICTOR 6000" in 2001. They might be incipient mounds and therefore crucial in the understanding of the mound origin and formation processes. They are placed within an area of strong current influence, with large fields of ripples and sandwaves. A first requirement for their detailed study is a good high-resolution bathymetric map.

One further programme is suggested as backup programme if time is available: a reconnaissance video survey over the flanks and the floors of the Gollum Channels.

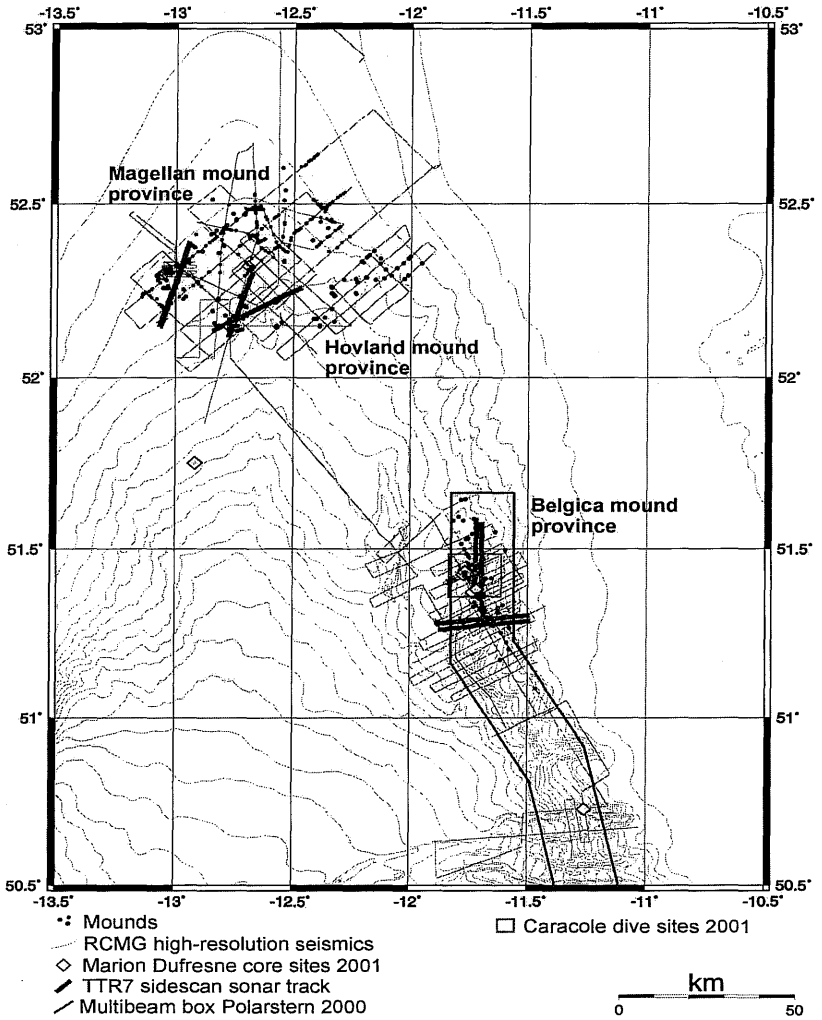


Fig. 4: Map indicating different mound locations and previous dive sites in the Porcupine Seabight. In the Belgica mound province a reconnaissance video survey over several steep-flanked mounds is planned.
Übersichtskarte verschiedener Areale in denen "mounds" während früherer Untersuchungen in der Porcupine Seabight untersucht wurden. In der "Belgica mound" - Region ist ein Tauchgang entlang mehrerer steiler "mounds" vorgesehen.

All the research work, during the first leg on board of the Polarstern, will be incorporated in the EURODOM project, which is a network initiative of the EU aiming at the involvement of students into research. Within this project real/time data transfer of video images from "VICTOR 6000" missions into student classrooms is envisaged.

"VICTOR 6000" in the North - Deep-water coral ecology and fisheries impact in the Porcupine Seabight and on the NW Porcupine Bank

A. Grehan et al. (NUIG, UCD), A. Wheeler et al. (UCC, GSI, SAMS)

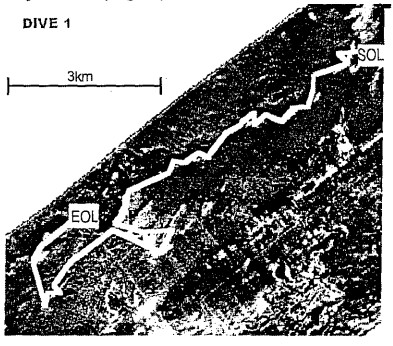
There is an urgent need to map the general distribution of *Lophelia/Madrepora* reefs on several carbonate mounds in a mound province as an essential step towards the future designation of these areas as offshore Special Areas of Conservation under the EU Habitats Directive. We will use ROV obtained video to accurately map the extent of 'living' coral resources resulting from surveys conducted in the Belgica Mound province and on the NW Porcupine Bank. Coral associated, species abundance data including fish will also be analysed and used to shed light on trophic relationships. ROV and box-core taken samples will be used to provide 'voucher' specimens for identification of species seen on video and also for stable isotope analysis to assess their trophic status (continuing work begun in ECOMOUND). Video used to identify living coral will also be assessed for evidence of fishing impacts. Preliminary analysis of Irish VMS (vessel monitoring system) data over a 10 year period suggests that fishing activity is increasing in the vicinity of the mounds. The recent dramatic expansion of the orange roughy fishery is of major concern as the modified trawling technique used is distinctly coral unfriendly. While there was little evidence of fishing impact in the areas surveyed during the CARACOLE cruise, trawl by-catch of coral has been reported elsewhere. The proposed surveys in the Belgica Mound province and on the NW Porcupine Bank will significantly extend our coverage in these potentially sensitive areas.

Collection of an integrated mapping data set for AMASON

AMASON is an EU Fifth Framework technology project which has been undertaking to improve underwater vehicle sonar and video mapping capabilities. Part of the study is devoted to the development of algorithms for improved sonar and video data fusion and object recognition using deep-water corals as a scientific target. We will collect a sample set of ROV mounted multi-beam and video data, collected at different altitudes over an area containing living and dead coral, to facilitate the improvement of algorithms currently under development by AMASON engineers.

Specific objectives of dive on the Porcupine Bank

A series of dives will be performed on the Porcupine Bank to fulfil a number of specific objectives (Fig. 5).



SOL : Start Of Line EOL: End Of Line

Fig. 5a:

Dive 1 will investigate a series of mounds that are situated along a scarp. These mounds may owe their origin to hydrocarbon seepage along faults that outcrop at the scarp. The principle objective of this dive will be to identify any evidence of gas seepage and to ascertain whether the mounds originally grow at the base of the scarp (where seepage would have occurred) or whether growth was initiated at the top of scarp where favourable hydrodynamic conditions facilitated growth and is unrelated to hydrocarbon seepage.

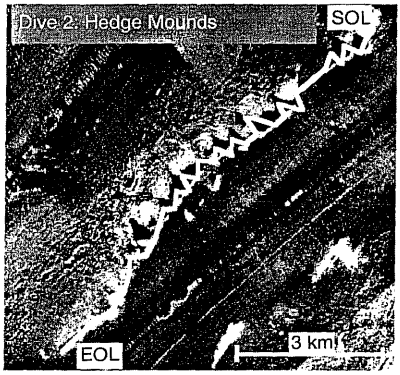


Fig. 5b:
Dive 2 will inspect a series of mound that form a spectacular alignment along a shallow ridge separating two canyon head feeder systems. The hypothesis that these mounds are strongly hydrodynamically controlled will be investigated.

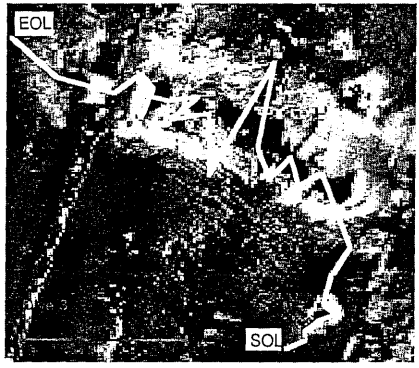


Fig. 5c:
Dive 3 will investigate one of the largest carbonate mound associations on the Porcupine Bank. This mound offers the best potential for spectacular biological associations with potential coral growth both on and off the mound. A small mound near the large mound cluster will also be investigated that overlies a fault and may be related to potential hydrocarbon seepage.

Fig. 5a-c: Proposed transect lines for ROV surveys across different mound sites at the Porcupine Bank.
Geplante Tauchfahrten mit dem ROV an drei verschiedenen "mound"-Lokalitäten in der Porcupine Bank.

It is also planned to deploy a benthic "photo lander" from "Polarstern" and use the "VICTOR 6000" to position it so that the lander cameras face areas of live coral. It is intended to relate coral and other fauna behaviour to the environmental variables recorded by the on-board instruments. The lander will be recovered some weeks later by another research vessel.

An additional dive site that may be studied depending on the results of former dives is a twin mound system that has been heavily trawled (see Figure 6). This site offer the potential to study the impact of trawling on these unique habitats.

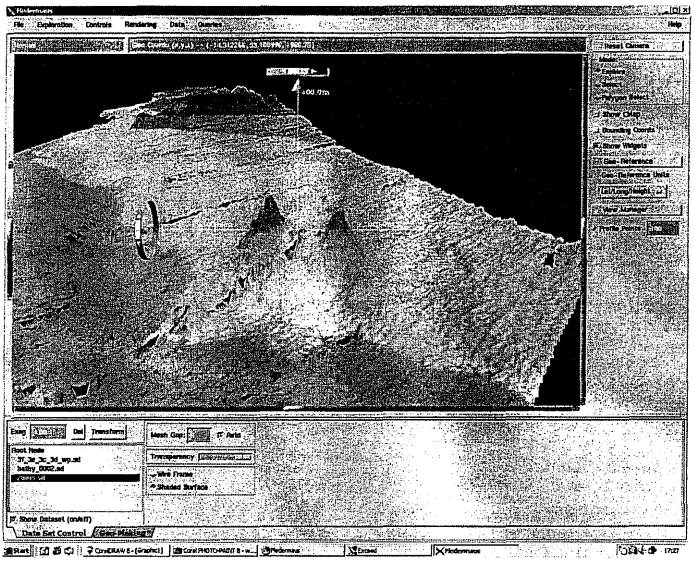


Fig. 6: Screen snapshot of the twin mound site where trawl scours indicate destruction of the habitat.
Darstellung der sog. "Zwillings-mounds" in deren Umfeld Schädigungen des Habitats, hervorgerufen durch Grundschleppnetzfischerei, bekannt sind.

Biodiversity patterns and dynamics in the deep sea

J. Gutt (AWI)

Two major topics are increasingly identified to be of high general relevance in modern marine biodiversity research. (1) The open question of whether resilience is higher in a more complex or in a simple system; (2) The controversial discussion of the two theoretical concepts, the intermediate-disturbance/stability-time hypothesis. They emphasize the role of

either a reduction of competitive displacement due to disturbance to explain a biodiversity maximum or long-term environmental stability which allows interspecific adaptation and, consequently, a coexistence of many species occupying narrow non-overlapping ecological niches.

Deep cold-water coral reefs are known to provide a three-dimensional habitat for a rich associated fauna which differ locally in quality and quantity. In a first project *Lophelia* coral reefs should be directly observed related to natural succession, fishery and other impacts. This information should provide a basis for a spatially explicit model allowing for identification of key features, structure and dynamics (driving forces) and predictions of biodiversity in specific compartments of the deep-sea fauna. Corresponding results should be compared with similar information derived from a simulation model on the disturbance of the Antarctic benthos by icebergs recently developed in cooperation with scientists from UFZ, Leipzig.

Coral concentrations should be observed in different places and covering different stages of succession by a regular grid of transects. Video strips are planned to be recorded in such a way that images can be converted to scientific reproducible data. Care should be taken to obtain representative rather than selective video observations in order to make generalisations possible. The attraction of fish and other mobile animals by the three-dimensional structure of reefs are generally well known and should be quantified.

A second approach aims at the modelling of the relationship between food availability and biodiversity. In general, knowledge about large food falls and a succession of macrofauna within days to weeks and secondary long term effects due to the presence of whale bones are relatively well known. A response of the benthos to mass occurrence of phytodetritus is also well documented. The reaction of scavengers on intermediate sized carcasses seems to differ locally in quality and quantity. A spatially explicit modelling of these biological parameters within a temporal succession should help to identify key processes and, consequently, provide deeper insight into the dynamics of deep-sea biodiversity.

Cruise leg ARK XIX/3b: Galway - Tromsø - Longyearbyen (20.06. - 19.07.2003)

A high resolution geophysical investigation of fluid transport phenomena through the seafloor at continental margins. Case of the Håkon Mosby Mud Volcano (HMMV)

J.-P. Foucher, H. Bisquay, C. Edy, L. Mear, A. Normand (Ifremer)

At continental margins, fluid and gas are emitted into the ocean via the seafloor. The forms of emissions extend from diffusive flow through the seafloor , to focussed flow through seeps and vents. Currently, the global inventory of fluid seeps at continental margins is growing rapidly, but the geological, chemical and biological processes uperating at those fluid seeps remain little known. In this regard, important research tasks are deriving methane fluxes in their relevance to climatic changes, evaluation of fluid-triggered instabilities on continental slopes, and hydrocarbon geochemical propecting in the deep offshore.

The Håkon Mosby Mud Volcano (HMMV) is a site of exceptionally large fluid escape through the seafloor in the geological context of a deep passive continental margin. The fluid activity is demonstrated by a variety of previously collected data including the occurrence of a large methane plume in the sea water above the volcano, measurements of temperature gradients in excess of 5 °C/m in the surface sediment, and observations of extensive microbial mats at the sediment-water interface. We select HMMV as a pilot study site. We propose a further investigation of fluid escape processes through HMMV by considering two main directions of work:

- to use a multibeam geophysical tool attached to ROV "VICTOR 6000" (EM2000 or similar) to obtain a detailed bathymetry and acoustic imagery record of HMMV. The survey data will be of primary importance to map the distribution of fluid escape structures at the surface of the volcano and characterize their various types. The survey data may also help to map the extent of gas hydrate occurrences.
- to conduct temperature gradient measurements in the surface sediments at two different scales: on one hand, at the large scale of the mud volcano itself, by means of transects of conventional heat flow measurements spaced 100-200 meters (or so) from each other and penetrating the sediment down to a subbottom depth of several meters (6-10 m), on the other hand, at the local scale of individual fluid escape structures, by means of a dense distribution of shallow temperature measurements operated from ROV "VICTOR 6000" and penetrating the sediment down to 60 cm or so. Temperature data will be analysed to infer the nature, diffusive through the seafloor or focussed at vents or seeps, of fluid flow processes, to infer fluid flow rates (in combination with anlyses of chemical gradients by geochemists), to determine the

gas hydrate stability domain in the sediment, to relate temperature anomalies to the temporal dynamics of the gas hydrate system.

The proposed study of HMMV is one of several studies of fluid flow processes through mud volcanoes to be conducted in the framework of a broader research programme, in particular allowing for a comparison of those processes in North-Atlantic mud volcanoes (the present proposal on HMMV) and in Mediterranean mud volcanoes (for example the ESF MEDIFLUX-NAUTINIL proposal) between AWI and Ifremer.

Methane in Gas Hydrate bearing sediments – turnover rates and microorganisms

A. Boetius, U. Witte, D. de Beer (AWI, MPI)

Mud volcanoes are very interesting habitats, both from the biological and geological perspective. The rising mud and gas represents a window between the deep geosphere and the biosphere, which consists of highly specialized chemotrophic communities. With regard to the global climate change, the study of gas seeps at continental margins is an important contribution to our understanding and quantification of the methane cycle. Also, understanding how microbes make a living from methane is important for our understanding of the evolution of the earth's atmosphere, which was rich in methane and poor in oxygen for the longest time. Hence, the geological, chemical and biological investigation of gas seeps in polar regions and other areas of the world`s ocean is a focus of research at the AWI, carried out in cooperation with several other national and international institutions.

Only recently it has been discovered that mud volcano ecosystems are similar to those found at hot vents. Mud volcanoes like the HMMV are present at tectonically inactive areas of continental margins. These ecosystems can occur independently of volcanic sulfide and heat above gas and petroleum reservoirs buried in the sea floor. Natural gas is formed in deep sediment strata and rises to the surface of the seafloor. The gas may accumulate in the sediments and form gas reservoirs such as gas hydrates (frozen methane). If these gas reservoirs reach a certain pressure, they can form geological structures called mud volcanoes. At mud volcanoes, sediment pore water, gas and mud is expelled from deep below forming mounds and crater at the sea floor. Active mud volcanoes are a seep for natural gas (methane) and are often densely populated by tube worms, clams and other symbiotic organisms – just like hot vents. Hence, chemotrophic communities, i.e. organisms which are fuelled by the chemical energy of dissolved minerals can indicate the presence of active gas seeps. Other indicators of gas seeps at continental margins are carbonate

structures and gas plumes in the water column. Only recently the mystery of the link between gas seeps and chemotrophic organisms has been solved: in gassy sediments a microbial symbiosis has been detected, which is able to consume methane by oxidizing it with sulfate. This symbiosis consists of archaea and bacteria, which can use the abundant sulfate in seawater instead of oxygen. Product of this reaction is sulfide which is used as energy source by the chemotrophic organisms (tube worms, clams, giant sulfur bacteria). Hence, in contrast to hot vents, it is not the volcanic energy but methane-consuming microbes which are sustaining large biomasses of chemotrophic animals.

The symbiotic association of methane-consuming microbes was only recently discovered and has not been obtained in culture yet. Hence, little is known about the microbiology and functioning of this association. So far, it can only be studied in its natural environment – the gassy sediments. Working with the ROV allows us to study the role of sedimentary microbes in consuming the greenhouse gas methane and in delivering energy to the chemotrophic communities on the sea floor. Understanding the interaction between geology, chemistry and biology is necessary to analyze the fluxes of methane between the different compartments, and to find out about the magnitude of methane emission from mud volcanoes. Interestingly, recent investigations showed that a lot of methane is emitted from the barren center of the mud volcano. Here, the symbiotic association of archaea and bacteria consuming methanewas lacking in the surface sediments. However, they were present in the sediments below the carpets of tube worms and – in very high abundances - beneath the mats of sulfur bacteria covering the outer rim of the mud volcano. In these areas only very little methane escaped to the water column. Obviously, the methane-consuming microorganisms form an effective barrier against the greenhouse gas methane.

Since January 2001 the BMBF-funded project MUMM (Mikrobieller Umsatz von Methan in gashydrathaltigen Sedimenten) investigates the microbial methane turnover above focussed sources of methane in the sea. Other key research areas are Hydrate Ridge (Cascadia Margin off Oregon, USA, Projects LOTUS and OMEGA, GEOMAR), the pockmarks off Congo continental slope (University Bremen) and the methane seeps of the north-western Black Sea (Project GHOSTDABS, University Hamburg). The Håkon Mosby Mud Volcano on the Barents Sea continental margin is of medium depths and coldest site investigated in this project. The investigations at HMMV in the framework of the project MUMM in cooperation between MPI, AWI, University of Bremen, and the Ifremer aim at an analysis of the main factors regulating the activity of the methanotrophic microorganisms and their contribution to biogeochemical fluxes at this mud volcano. There are three main work packages planned: 1)

geomicrobiological investigations, 2) high resolution biogeochemistry with microsensores, 3) *in situ* measurements with benthic landers.

Geomicrobiology of the HMMV

A. Boetius, V. Beier, H. Niemann, I. Müller, F. Heinrich, T. Feseker (AWI, MPI, U Bremen)

Microbially mediated anaerobic oxidation of methane (AOM) is the major biological sink of methane in marine sediments. Hence, this process is crucial in maintaining a sensitive balance of our atmosphere's greenhouse gas content. However, a fundamental understanding of the associated biology is still lacking, consequently preventing a thorough biogeochemical understanding of an integral process in the global carbon cycle. Studies employing stable isotopes, radiotracers, modeling, and microbiological techniques have now established that methane in marine sediments is oxidized biologically under anoxic conditions. Although no anaerobic methanotroph has ever been isolated, biogeochemical studies have shown that the overall process involves a transfer of electrons from methane to sulfate. Accordingly, the isotopic and genetic signatures of the dominant microbial populations in environments enriched with methane proved that this transfer is mediated by a microbial consortium that includes archaea and sulfate-reducing bacteria. The current hypothesis is that AOM is mediated by the two syntrophic partners, which rely on interspecies hydrogen transfer: methanogenic archaea mediating the oxidation of methane with water (reaction 1), and sulfate reducing bacteria scavenging the intermediate hydrogen (reaction 2):

$$CH_4 + 2\ H_2O \rightarrow CO_2 + 4\ H_2 \quad (1)$$

$$SO_4^{2-} + 4\ H_2 + H^+ \rightarrow HS^- + 4\ H_2O \quad (2)$$

The net reaction of methane oxidation can thus be formulated as:

$$CH_4 + SO_4^{2-} \rightarrow HCO_3^- + HS^- + H_2O$$

Thus, measurements of methane and sulfate turnover rates in sediments and bottom water and methane emission to the hydrosphere are extremely important for realistic calculations of methane consumption in the sea. The main questions for this investigation are:

- Where are the hot spots of methane turnover at the Håkon Mosby Mud Volcano ?
- How much methane is oxidized anaerobically in the sediments ?
- How much methane is oxidized aerobically in the bottom water ?

- What are the dominant microbial populations mediating anaerobic methane turnover ?
- Is their isotopic signature indicative of methane consumption ?
- What is the link between microbial methane turnover and the chemosynthetic communities at the HMMV ?

The major aim of this study is the investigation of microbial sulfate reduction (SRR) and anaerobic methane oxidation (AOM) in methane enriched surface sediments of the HMMV, as well as sampling the sediments for microbiological and molecular analysis. Samples will be obtained from the sediment cores which were retrieved by the ROV and by multiple corer hauls and gravity cores. In parallel to the on board rate measurements, sub-samples are taken from cores to determine the total number of bacteria, to quantify different taxonomic groups of bacteria by fluorescence *in situ* hybridisation (FISH, 16s rDNA clone libraries, DGGE) and to investigate the metabolic activity of methane consuming micro-organisms involved in sulfate reduction and methane oxidation under controlled laboratory conditions in microcosms. Furthermore, sediment sub-samples are obtained to investigate the distribution of lipid products derived from members of AOM consortia and their stable carbon isotopic composition which bears diagnostic information on the carbon source and/or metabolic carbon fixation pathway utilised by its producer. All these samples will be processed in the home laboratories of MPI and AWI. We will compare oxidation rates obtained by numerical modeling of changes in pore water concentrations of methane and sulfate to the measurements with radioactive tracer. Bottom water samples are obtained at various sites to investigate methane oxidation in the water column. Water samples are taken with two types of water samplers (rosette and horizontal water sampler) as well as from the multiple corers and ROV push cores to investigate the methane emission from the sediments into the water column. All investigations focus at the three main geobiological communities in the center of HMMV, at the Beggiatoa mats and Pogonophora fields as well as at the surrounding reference sites.

Biogeochemistry of the HMMV: High resolution studies with microsensors

D. de Beer (MPI)

The sediment of HMMV host three methane oxidizing communities: anaerobic methanotrophs (*Beggiatoa* mats), freeliving aerobic methanotrophs (Center) and symbiotic aerobic methanotrophs. (Pogonophora fields). The methane originates from a deep source and the areas covered by the different microbial communities are relatively large. The center

of the vulcano shows relatively little microbial activity, although sulfate gets reduced in some cores. There are indications that the sediment is turned over by mudslides, consisting of fine mud that recently surfaced from the mud volcano. Surrounding this center is a ring of Beggiatoa fields, covering anaerobic methane oxidizers, this sediment is soft and fine and contains high amounts of sulfide. The peak in methane oxidation capacity is at 1-3 cm under the sediment surface. Then there is an outer ring of pogonophora fields with relatively oxidized sediments.

It is planned to investigate these sediments with high spatial resolution measurements using microsensors. This will be done with *in situ* measurements, using a profiler in collaboration with the AWI goup and the MUMM benthic lander (U. Witte), and *ex situ*, i.e. on retrieved cores on board of the ship. The measurements will be done in collaboration with E. Sauter from the AWI, who will operate a specially designed profiling lander that can be manoevered by the ROV. It can thus be precisely positioned, but a limitation is that it can profile only a few cm. Deeper profiles can be obtained by ex situ studies for comparison. For microsensor-studies the center and the *Beggiatoa* mats are central to this study. To collect as much information as possible and enhance the chance of success an as large variety of sensors will be used.

In situ studies

The profiling unit will be mounted on the free-falling lander, that is further equipped with a sulfate reduction measurement and a chamber. The lander will be operated by Ursula Witte (MPI, MUMM).

The following sensors will be used: O_2, H_2S, pH, redox, Ca^{2+}, CO_3^{-2}. This will improve insight into the carbonate chemistry inside the sediments. The redox sensor responds mainly to O_2, H_2S and Fe^{2+} , thus it may also give a hint to interesting iron chemistry in the anaerobic methane oxidizing zone. Most recordings will be done to ca 15 cm depth, i.e. the standard length of a sensor. One set of redox, pH and H_2S sensors will be elongated to ca 60 cm and deep profiles will be recorded.

Ex situ studies

Ex situ measurements will be done with the same type of sensors. Of course the sediment structure will be disturbed by degassing. Most likely the methane oxidation rate will decrease due to lowering of the partial pressure. This limits to some extent the value of the ex situ

measurements, however, it allows comparative analysis between communities and reference sited and will help to observe the effects of experimental changes, e.g.

- addition of nitrate, and sulfide to the water column to study the sulfide oxidation by Beggiatoa, nitrate reduction can be measured with N_2O sensors
- the effect of certain possible intermediates of the methane oxidation (fatty acids, hydrogen, formate or to interfere in the coupling between MOB and SRB quinones or methylene blue) on redox, H_2S and pH profiles,
- the effect of metabolic inhibitors on the iron chemistry (azide, cyanide, chloroform).

Benthic lander work – *in situ* investigations of total oxygen and sulfide fluxes and sulfate reduction rates

U. Witte, D. de Beer, J. Langreder, A. Nordhausen (MPI)

During Polarstern cruise ARK XIX/3b to Håkon Mosby mud volcano, a comprehensive campain of *in situ* measurements will be carried out using the MPI modular lander system. The platform can be equipped with two benthic chambers, the sulfate reduction module ORPHEUS and/ or one of two profiling modules. Main aim of the lander work will be to quantify oxygen and sulfide dynamics along a gradient of stations from sites colonized by *Beggiatoa* and Pogonophora towards sediments not influenced by methane seepage. From each chamber incubation, a series of 7 water samples is taken at preset intervalls that will be analysed for oxygen, nutrients, sulfide and methane concentrations. The sediments retrieved will be sampled for analysis of the small benthic size classes and macrofauna. The attachment of the ORPHEUS module - designed for *in situ* measurement of sulfate reduction by injection of ^{35}S-labelled SO_4 into three parallel cores.- allows the simultaneous measurements of oxygen consumption and sulfate reduction at the same spot. In addition, the profiling module will be equipped with O_2 and H_2S microsensors to determine the respective microprofiles. Parallel to the *in situ* investigations, microprofiles will also be determined on board in "VICTOR 6000" pushcores.

Sediment and pore water geochemistry at Håkon Mosby Mud Volcano (HMMV)

E. Sauter, M. Schlüter, L. Baumann, K. Jerosch (AWI)

As revealed by pre-investigations Håkon Mosby Mud Volcano (HMMV) functions as a spot emitter for methane in the sub-arctic ocean. Fluidized muds associated with large amounts of methane are expelled at the volcano's center (eye) ascending from several thousand meters

below the see floor. At its surface HMMV's deep source manifests in different types of sedimentary environments, more or less concentrically arrayed around the eye (Fig. 7).

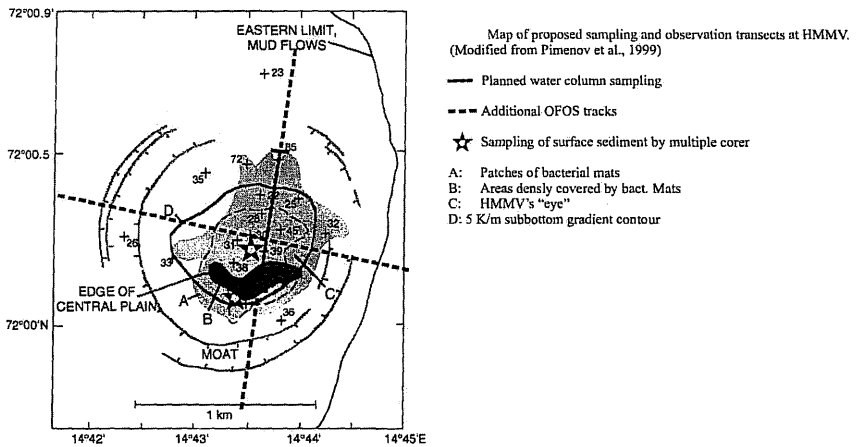
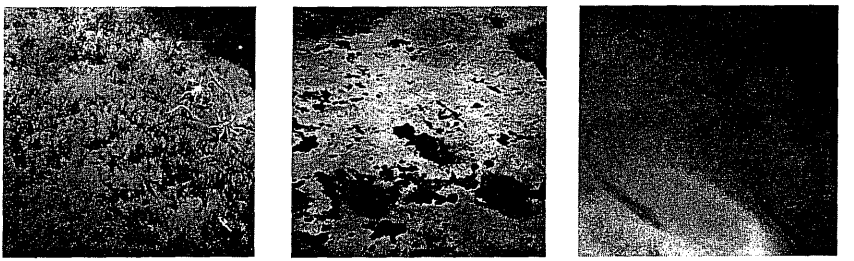


Fig. 7: Habitats at Håkon Mosby Mud Volcano.
Habitate beim Håkon Mosby Schlammvulkan.

The different types of benthic habitats reflecting the pore water geochemistry below the sediment surface, are most palpable: Large populations of small tube worms (*pogonophora*) are distributed along the volcano's outer rim (Fig. 8a) whereas the sediment next to the eye is covered by mats of sulfur bacteria (*beggiatoa spp.*, Fig. 8b). The later depend on the H_2S released as a product of sulfate reduction by methane oxidizing microbial consortia (consisting of bacteria and archea) living below the sediment surface. Finally, there is the central area of HMMV, a fine grained grayish sediment apparently completely unpopulated (Fig. 8c). In contrast to the bacterial mats area where methane is efficiently eliminated by these "bio-filters", the eye is recognized to be the zone from which large amounts of methane are released to the water column, i.e. to be the ultimate methane source in the ocean.



a) b) c)

Fig. 8: The three "key areas" to be distinguished at HMMV: (a) Pogonophora at the outer rim, (b) bacterial mats, (c) naked sediment an the mud volcano's center (Photographs from "VICTOR 6000" operation in 2001).
Die drei als "Schlüsselregionen" angesehenen Bereiche am HMMV: (a) Pogonophora am äußeren Rand, (b) Bakterienmatten, (c) nacktes Sediment im Zentrum des Schlammvulkans (Fotos durch "VICTOR 6000" Operation 2001).

Our investigations on the release of methane at HMMV and associated processes continues the efforts which started during expeditions with R/V "L'Atalante" / ROV "VICTOR 6000" and R/V "Polarstern" (ARK XVIII/1b) in 2001 and 2002, respectively. Methane release and the related pore water chemistry will be studied in more detail by means of ROV-guided sampling and *in situ* experiments. In particular, this cruise is dedicated to get a better sample coverage over the mud volcano's key areas and their transition zones and to extend the pore water investigations to deeper sediment horizons by longer cores (gravity coring). Re-visiting some of the sites investigated previously, we aim to get more information about the temporal dynamics of fluid flow, methane release and habitat development. One key question is in this context, which amounts of mud is expelled at HMMV's eye and on which time scales the sediment surface is populated by the respect organisms.

Sediment and pore water investigations are closely interlinked with the work of the other participating groups: Geochemical gradients will be related to

- microbial reaction rates derived from tracer incubation experiments.
- geothermal sub-sea floor gradients (heat fluxes)
- sedimentological parameters and elemental composition of the sediment
- discharge of dissolved gasses (methane, radon) and particles into the water column
- faunal small scale variabilities
- remote sea floor observations by video and acoustic tools
- bottom currents

For this purpose we plan to deploy coring devices (TV-MUC, gravity corer, ROV-based push cores), water samplers (CTD rosette and bottom water sampler) and an *in situ* microprofiler. Methane is analysed on board, immediately after sampling. Sulfide and pH is planned to be

measured on board as well. Pore water and sediment samples for subsequent investigations (e.g. sulfide, nutrients, C/N, porosity, chloride) will be separated and fixed in the ship's cool laboratory.

Water column investigations above Håkon Mosby Mud Volcano (HMMV)

E. Sauter, M. Schlüter, S. Muyakshin, M. Gernsheimer (AWI, IAP)

Complementing the geochemical investigations at the sedimentary environment of HMMV, the fate of methane released to the water column will be targeted on this cruise as well. During ARK XVII/1b a large plume image of about 600 m height and 500 m in diameter was discovered by the ship's fish echo sounder (Simrad EK60). The plume is suggested to be related to mud expulsion and fluid discharge from the volcano's eye. Several CTD transects will be laid across HMMV to sample the water body above and aside the mud volcano. For the near-bottom zone a special bottom water sampler (BoWaSnapper) will be deployed for high vertical resolution sampling. The the EK60 will be used to guide both devices into or beside the plume structure and to image it in respect to its spatial extension as well as in its temporal dynamics. Water samples will be analyzed immediately for methane oxygen and sulfide. According to one theory the plume consists of fine sediment particles instead of gaseous methane. To clarify that it is planned to deploy *in situ* pumps for filtering a large volume of water within and outside the plume, respectively. Beside an imagery of shape and dynamics of the plume it is hoped to collect an acoustic and geochemical dataset which allows the quantification of the expulsed sediment and the released gas, respectively.
In addition, radon-222 will be measured in the near-bottom zone of HMMV to get information on pore water discharge and intermixing times.

Håkon Mosby mud volcano - influence of methane discharge on the benthic foraminiferal community, stable isotope ratios of foraminiferal tests, and potential symbiosis of foraminifera and bacteria

J. Wollenburg et al. (AWI)

During cruise leg ARK XIX/3b multidisciplinary investigations will be continued which were started during the expedition onboard the French RV "L'Atalante" to the Håkon Mosby Mud Volcano in 2001. In the area of methane discharge the low $^{13}C/^{12}C$-ratios of methane should be reflected by the stable isotopic composition of inorganic carbon of porewater and accordingly low $\delta^{13}C$-values of calcareous tests of endobenthic foraminifera. Notwithstanding that recently low $^{13}C/^{12}C$-ratios of fossil foraminiferal tests often are ascribed to high methane

concentrations, isotope studies on living foraminifera from sites of methane extrusion are rare. At lower latitudes submarine methane sources are usually indicated by mussel fields of *Calyptogena* and *Bathymodiolus*. These animals are able to culture symbiotic bacteria in their gills. Yet, no such species were found at submarine methane sources from high northern latitudes. However, transmission-electron-microscopic (TEM) analyses of benthic foraminifera from *Beggiatoa* mats in the Santa Barbara Basin revealed bacteria-foraminifera symbioses. In the next years specific benthic foraminiferal species will be selected from methane sources for investigations on potential symbioses with bacteria. The first cruise in 2001 revealed specific foraminiferal faunas from the various compartments (pogonophora fields, bacterial mats, center) of the Håkon Mosby. Additional samples will help to map these associations and clarify interannual variations. Our findings will be compared to other methane sources and to a large data set on living benthic foraminifera of the whole Arctic Ocean.

The principal aims are:

- To determine the stable carbon and oxygen isotopic composition of the dissolved inorganic carbon in the water column and the porewater, as well as of benthic foraminiferal tests.
- To analyse the benthic foraminiferal assemblage and its vitality using Rose Bengal staining and ATP-measurements.
- Transmissionselectrone microscope investigations of benthic foraminifera to indentify specific cell adaptations and potential symbiosis with bacteria.
- Microbiological and molecular biological investigations to identify and quantifiy symbiontic bacteria.
- To determine the bacterial community of the water column.

Nematode diversity in different habitats along the continental margin: local versus regional biodiversity

A. Vanreusel et al. (U Ghent)

The aim of the research project is to get a better insight in the importance of different particular structures on the seafloor for the observed diversity patterns of Nematoda along the continental slope. We will investigate to what extent the local (alpha) and regional (gamma) biodiversity increase in relation to the large topographic structures such as mounds and in relation to the chemical gradients due to seeping? Along these macro structures, estimations will be made of the species turnover (beta diversity) of the Nematoda (the

frequency by which species appear of disappear along a gradient in the habitat). Also small scale patchiness will be examined, in order to estimate its influence into the present biodiversity.

By means of the multicorer and ROV corer, sediment samples will be collected along the mud volcano at different locations :
- On a macro scale, samples will be be collected on the top, slope and edge of the volcano in addition to some off mound samples. Meiobenthic samples will be taken at the three different micro habitats : the zone with bacterial mats, the Pogonophora fields and the center of the volcano lacking both. Samples will be vertically sliced in order to get an idea of the meiofaunal depth distribution in the sediment.
- On a micro scale, a survey of the seabed will be made by the ROV. If any particular small scale structure or gradient is observed, micro scale gradients will be sampled by ROV push corer from the underlying sediment and the sediment respectively on a distance of 5 cm, 10 cm and 15 cm apart from the structure.

From all samples, nematodes will be identified up to species level and biodiversity estimated. The following hypotheses will be tested :
1. The presence of a topographic structure or chemical gradients in the deep-sea changes the meiobenthic community structure and results in an increased regional diversity. Through community analyses by means of multivariate statistics, species turnover will be established along a gradient form the summit of the volcano, along the slope and the tail until the background sediments.
2. The presence of a small scaled biogenic structure in or on the sediment results in a change of the community structure by which the local diversity increases. Therefore the species turnover will be investigated along a short, horizontal gradient of 20 cm.

Marine Geology - quantification and characterization of terrigenous discharge in the Arctic Ocean

N. Kukina (MMBI)

The overall goals of the marine-geological research program are high-resolution studies of changes in paleoclimate, paleoceanic circulation, paleoproductivity, and sea-ice distribution in the Arctic Ocean and the adjacent continental margin during Late Quaternary times, and the long-term history of the Cenozoic Arctic Ocean and its environmental evolution from a warm polar ocean to an ice-covered polar ocean.

The research will comprise primarily investigations on the terrigenous sediment supply. The terrigenous sediment supply in the Arctic Ocean is controlled by river discharge, oceanic currents, sea-ice and iceberg transport and down-slope transport. Most of these mechanisms also influence biological processes in the water column as well as at the sea floor (i.e., surface-water productivity, particle fluxes through the water column, benthic activities at the sea floor, etc.)

The research will be concentrated on the quantification and characterization of terrigenous discharge in the Arctic Ocean and its change through Late Quaternary period. This study will allow to obtain estimates of sedimentary budgets, identifications of major transport processes, and reconstruction of oceanic currents. Of major interest is a detailed sedimentological, mineralogical and micropaleontological study of surface sediments and sediment cores.

The future investigations at the MMBI laboratory will include:

- granulometric analyses;
- mineralogical analysis (light and heavy minerals) of fractions 63-125 µm and 125-250 µm;

  morphology of quartz grain of fraction 250-500 µm;

Cruise leg ARK XIX/3c: Longyearbyen – Tromsø (19.07. – 07.08.2003)

Interdisciplinary research at a deep-sea long-term station

T. Soltwedel, K. von Juterzenka, M. Klages, J. Matthiessen, E. Sauter, I. Schewe (AWI)

Following a pre-site study using the French ROV "VICTOR 6000" in summer 1999, we established the first long-term station in polar deep-sea regions in the eastern Fram Strait west off Spitsbergen (Fig. 9). Beside a central experimental area at 2500 m water depth (AWI-"Hausgarten"), we defined 9 stations along a depth transect between 1000 - 5500 m, which will be revisited yearly to analyse seasonal and interannual variations in biological, geochemical and sedimentological parameters. During ARK XIX/3c we will increase the number of permanent stations to a total of 15 stations by introducing additional sampling sites along a latitudinal transect following the 2500 m water depth isobath (Fig. 9).

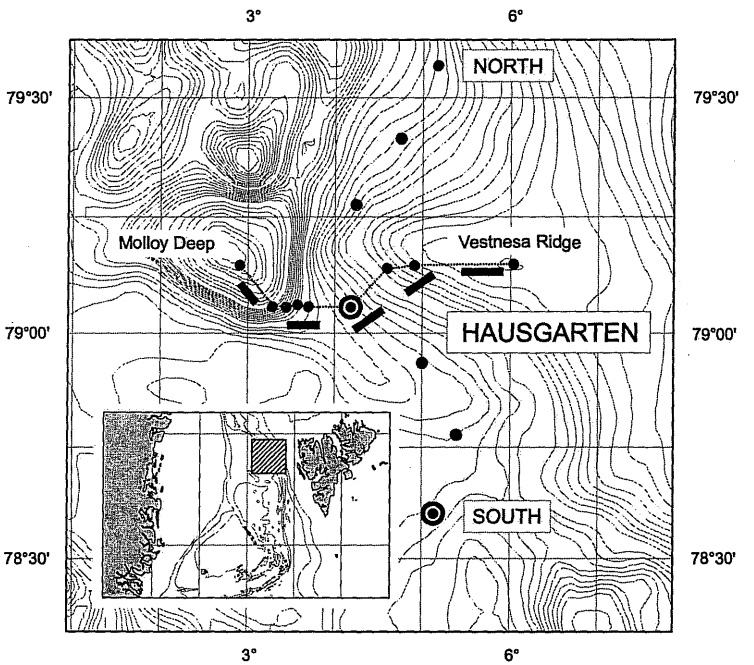


Fig. 9: Deep-sea long-term station AWI-"Hausgarten" west off Spitsbergen.
Tiefsee-Langzeitstation AWI-"Hausgarten" westlich von Spitzbergen.

To characterise the structure of the near-surface sediments and to improve the bathymetric chart of the "Hausgarten" area, we plan to record PARASOUND and HYDROSWEEP profils

along selected transects. Backscatter characteristics of the sediments will be calibrated versus the composition of the discrete bottom samples, to determine the large-scale spatial distribution of sediment types in the area.

Organic matter produced in the upper water layers or introduced from land is the main food source for deep-sea organisms. To characterise and quantify organic matter fluxes to the seafloor, we use moorings carrying sediment traps, which will be replaced during ARK XIX/3c. The exchange of solutes between the sediments and the overlaying waters as well as the bottom currents will be studied to investigate major processes at the sediment-water-interface. A free-falling device carrying respiration chambers (Fig. 10), and a micro-profiler (see Fig. 14) being positioned and activated by the ROV will be used to assess the oxygen consumption by the benthic community.

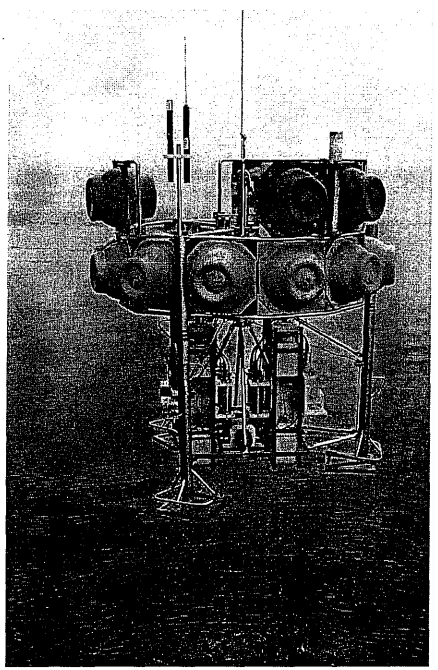


Fig. 10: Free-falling grab respirometer to assess the oxygen consumption by the sediment-inhabiting community. Freifall-Respirometer zur Ermittlung des Sauerstoffverbrauchs durch die benthische Lebensgemeinschaft.

The micro-profiler will be installed in immediate vicinity of benthic organisms or biogenic structures, to gain new insights into metabolic interactions between macrofauna organisms and their sedimentary milieu. Gradients in oxygen (and nutrients) will also be measured from bottom water samples in order to quantify interfacial solute fluxes and rates metabolism. These investigations are completed by the use of current vanes, deployed and observed by

the ROV. These vanes have proven to allow accurate short time current measurements (direction and speed) within the near-bottom water column (Fig. 11).

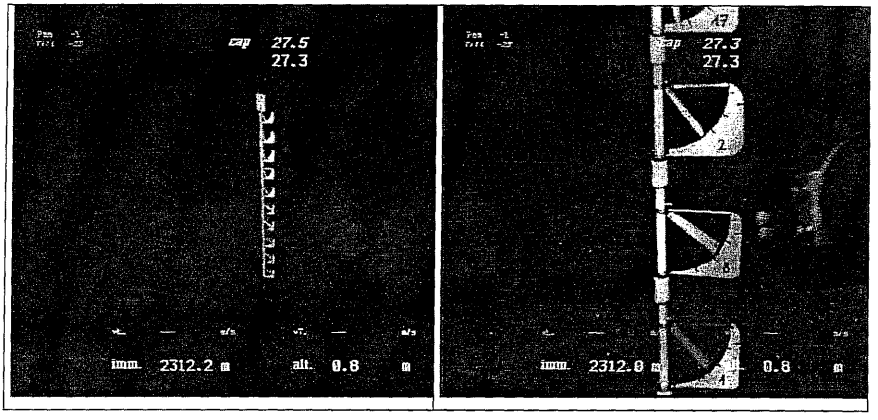


Fig. 11: Installation of an array of current flags at the seafloor.
Aufstellung von Strömungsfahnen am Meeresboden.

A video-guided multiple corer (Fig. 12) will allow to retrieve virtually undisturbed sediment samples. Vertical gradients of nutrients, C_{org} contents, C/N ratios, porosity and other geochemical parameters will be determined to characterize the geochemical milieu of the upper sediment layers. Near-surface sediments will also be sampled for sedimentological, mineralogical and micropaleontological investigations, to assess source areas for the sediments. Further investigations will try to estimate the preservation potential of organic matter in the sediments.

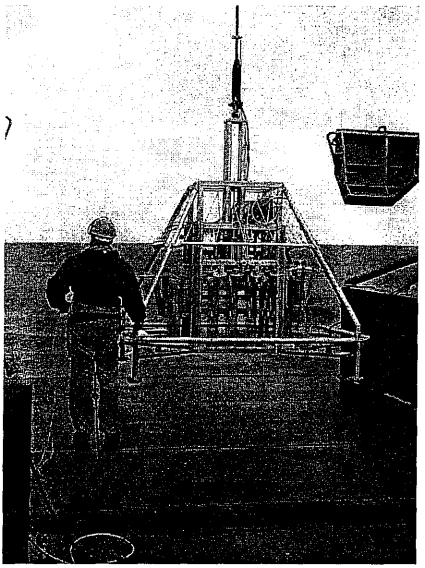


Fig. 12: Deployment of the video-guided Multiple Corer.
Einsatz des video-unterstützten Multicorers.

Biogenic sediment compounds will be analysed to estimate activities (e.g. bacterial exoenzymatic activity) and total biomass of the smallest sediment-inhabiting organisms. Results will help to describe the eco-status of the benthic system. The quantification of benthic organisms from bacteria to megafauna will be a major goal in biological investigations.

To identify factors controlling the high biodiversity in the deep sea, we started a number of biological long-term experiments at stations Hausgarten-"Central" and -"South" (Fig. 9) using the ROV "VICTOR 6000". Cages were placed on the sediment to study the development of infaunal communities not effected by disturbances (e.g. the disruption of the sediment structure, predation) introduced by larger benthic organisms. Various artificial substrates (pieces of wood, plates of stone and Perspex™) were distributed to investigate the usability of organic matter, and to study the colonisation of empty spaces in an environment short in hard-substrates to settle on. Sponge mimics were deployed to study effects of small biogenic structures (in this case sessile epibenthic organisms) on sediment-inhabiting micro-organisms.

During ARK XIX/3c, we plan to control and terminate the experiments installed in 1999 and 2001, further experiments will be started. An *in situ* flume will be installed at the seafloor to investigate benthic respiration and interfacial solute exchange under changing bottom current regimes. On the short time scale, we aim to obtain indications about the speed of adaptation in respect to geochemical gradients as well as respiration rates. Beside short time

experiments during this year's expedition, we plan for a long-term deployment to study changes in the sediment-inhabiting community under enhanced current stress. For this purpose it is planned to leave the flume at the end of the cruise at a selected site, and to re-visit it in 2005 at latest.

Large Food-Falls sunken to the deep seafloor represent an episodic and significant food supply for the benthic biocoenosis. *In situ* experiments already started during ARK XIX/1b in spring 2003 will help to understand how especially the smallest benthic organisms react to such events. In this context, we deployed so-called benthic colonisation trays, containing different types of artificial sediments (Fig. 13).

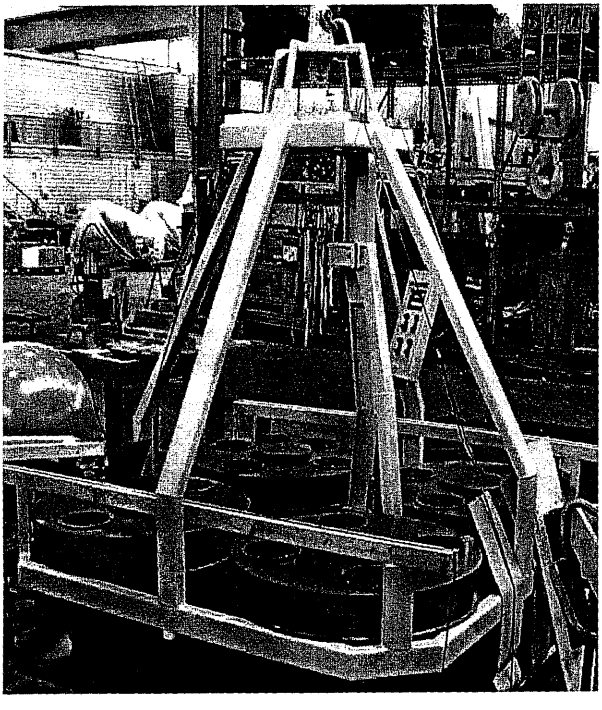


Fig. 13: Free-falling device for colonisation experiments.
Freifallgerät zur Durchführung von Besiedlungsexperimenten.

During ARK XIX/3c we will recover and sample the trays. The sediments will be analysed for organisms settled during the three months period of deployment. After sampling and reloading with fresh sediments, these trays will be replaced for a one-year deployment. In spring 2003 we also deployed a mat of artificial detritus on the deep seafloor. During

ARK XIX/3c, sediments underneath the mat will be sampled with the help of the ROV "VICTOR 6000" to investigate the benthic biocoenosis associated with this mat.

Distribution patterns and carbon demand of epibenthic megafauna

D. Piepenburg, M. Schmid (IPÖ/AWL, AWI)

The investigations on megabenthic organisms will contribute to the research programme developed for the scientific use of the Remotely Operated Vehicle (ROV) "VICTOR 6000" during cruise ARK XIX/3c of RV "Polarstern" to the AWI long-term deep-sea station ("housegarden") west of Svalbard in 2003. Their basic rationale is to complement studies on other portions of the benthic community (micro- to macrobenthos) which will be conducted by other working groups. A synopsis of the various results will allow for achieving a more comprehensive understanding of the ecosystem under study.

The term "megabenthos" has been operationally defined for the size group of benthic animals that are large enough to be visible in seabed images and/or to be caught by towed sampling gear. There is evidence that the megabenthos forms a functional group distinct from smaller macro- and meiofauna and that megabenthic animals are, in general, more important in benthic systems than their comparatively low abundances seem to imply. They often contribute considerably to total benthic biomass and carbon cycling. Furthermore, they strongly affect the structure of benthic food webs ('top-down control') and influence the micro-scale environment by, e.g., bioturbation and bioirrigation. The latter process is of particular importance in deep-sea environments. Their typical small-scale heterogeneity in both sediment structure and physico-chemical gradients is thought to be primarily created by motile megabenthic species. The biologically induced alteration of the seafloor at rather small spatial scales (metres down to millimetres) but persisting over long periods of time leads to a higher complexity in the otherwise homogeneous environment, creates a mosaic of microhabitats and, hence, causes elevated macrobenthic diversity. However, the study of such a relationship between different size portions of the benthos needs precisely targeted and well-coordinated investigations at adequately small scales, i.e. observations, sampling, and measurements conducted by means of manned submarines or ROVs. Here, we propose to carry out various megabenthos investigations that will complement other work focussing on smaller size groups of the benthic assemblages. The main goals are:

Assessment of small-scale distribution patterns of megafaunal associations in the "housegarden" area using imaging methods

Species composition, abundance and distribution patterns of megabenthic organisms occurring in the "Hausegarten" will be assessed by analysing still photographs and video footage taken during the ROV dives. This material will complement imaging data taken during 'Polarstern' cruise ARK XVIII in 2002 and, thus, enhance the spatial coverage in the inventory of habitats in the study area. In the long run, this work will contribute to an ecological mapping ('marine habitat classification') of the whole "Hausegarten" environment.

Determination of individual oxygen uptake rates of megafaunal organisms (both in situ and in the lab) and estimation of their carbon demand

Besides precise information on abundance and distribution, a sound knowledge about the individual oxygen consumption rates is critical for assessing the carbon demand of megabenthos assemblages. However, only few data on individual oxygen uptake are available for deep-sea Arctic species, mainly because many technical problems are involved in performing unbiased measurements of routine respiration rates of unstressed animals at low ambient temperatures. Therefore, live megafaunal specimens will be collected – either by means of the ROV or from box cores and trawl catches – and kept in aquaria. Respiration measurements of these specimens are difficult, but new sensitive techniques (with optodes as oxygen sensors) will be used to determine rates with sufficient precision in lab measurements conducted on board the research vessel. Furthermore, it is planned to use the capabilities of the ROV to measure the respiration of selected megabenthic specimens *in situ*.

Estimation of megabenthic carbon demand at population level by combining information on abundance and individual oxygen uptake

The carbon demand of benthic communities has been estimated in numerous studies by assessing the sediment oxygen uptake, i.e. by incubating sediment cores and following the decrease of dissolved oxygen in the ambient overlying water with time. These measurements – regardless of whether they are performed *in situ* with benthic landers or using shipboard techniques – provide a bulk parameter, i.e. the "sediment community oxygen consumption" (SCOC) or "sediment oxygen demand" (SOD), which integrates chemical oxygen uptake plus total aerobic respiration of all benthic organisms contained in the core. The cores used for sediment-water incubations are usually rather small and cover only modest sample areas (< 500 cm^2). Therefore, they only contain organisms ranging in body size from micro-, meio- to small macrobenthos but no megafauna. For these animals, total population or assemblage respiration – and, by implication, carbon demand – cannot be measured directly with an

integrating determination but has to be approximated by other approaches, such as combining abundance or biomass figures with individual respiration rates. We will use this method to estimate the oxygen and carbon demand of the epibenthic megafauna in the "housegarden" area.

Biodiversity, Molecular Phylogeny and Ecofunctional role of Amphipod Crustaceans in the Deep Sea: A Bipolar Comparison

C. DeBroyer, P. Martin (I.R.Sc.N.B.)

Peracarid crustaceans, and amphipods in particular, constitute one of the most diverse macrobenthic groups in terms of species richness, life styles, trophic types, habitats and size spectra in polar sublittoral communities. The East Arctic seas for instance, count more than 500 species of Amphipoda alone, the Barents Sea harbour 302 species and 262 species of Gammaroidea are listed from the Svalbard area only.

Investigations of the Arctic deep-sea revealed a much lower diversity with few tens of benthic, suprabenthic or benthopelagic amphipod species representing only a small fraction of the 260 species found below 2000 m deep in the World Ocean. Most of these deep-sea species belong to relatively primitive families, characterized by free-swimming males, and exhibit deposit-, suspension- or scavenging feeding habits.

The origin and determinants of the species richness of the deep-sea macrobenthos in both Polar regions are still a matter of debate. The diversity, abundance, ubiquity and low dispersal capabilities of the amphipod crustaceans make them a good model group for studying patterns and processes of biodiversity and biogeography. A bipolar analysis of the biodiversity patterns observed in this taxon can contribute to better understand some driving forces shaping the vagile macrobenthos communities in polar ecosystems.

Objectives

The study will focus on peracarid crustaceans, in particular amphipods, of the Arctic deep sea as a model group to investigate:

Patterns and processes of polar macrobenthic biodiversity

The project will contribute to characterize Arctic deep-sea amphipod biodiversity (alpha and gamma diversity, taxonomic diversity, life styles, habitats, distribution...) and to compare it with Antarctic deep-sea amphipods currently investigated under the ANDEEP project (De

Broyer et al. 2003). Taxonomic data and material will contribute to the Ant'Phipoda reference centre developed at IRScNB, Brussels. A particular attention will be given to the scavenger species which form a significant guild within the benthic trophic system and may show different degree of adaptation to necrophagy.

Molecular phylogeny and phylogeography of selected deep sea amphipod taxa

In parallel to a morphological approach, a molecular study will be carried out in order to obtain a robust molecular phylogeny of selected amphipods (with special reference to lysianassoids), on the basis of different nuclear and mitochondrial gene fragments. Such a phylogeny will be subsequently used as a tool for studying different issues related to biogeography and evolutionary biology of benthic taxa from the two Polar regions.

Depending on the availability of biological material, this phylogeny should provide us with clues as to the origin of biodiversity of this group in the Arctic, deep-sea colonization processes in the two Polar regions (the Polar submergence hypothesis), as well as possible links between the deep-sea Polar basins and the World Ocean.

Moreover, due to the temporal dimension included in models commonly used for phylogenetic reconstructions, data about tempo and mode of evolution in lysianassoids taxa are expected. They should enable us to reconstruct the evolutionary scenario of this group, to study radiations within the group and to identify possible species flocks, cryptic species, as well as convergent adaptative radiations (in particular adaptations related to trophic niches).

Trophodiversity and trophodynamics

In the framework of a general approach to understand the ecofunctional role of the Polar and deep-sea amphipod taxocoenoses, the project will try to characterize the trophodiversity and the trophodynamic role of selected Arctic deep-sea amphipods and to compare it in different benthic communities on bipolar and bathymetric scales.

The trophic approach will rely on the use of stable isotope ratios (carbon, nitrogen and sulfur) as amphipod diet tracers combined with digestive tract analyses to delineate the trophic relationships involving amphipods in the Arctic deep-sea food webs. The isotope technique will also be used to tag the possible importance of the chemosynthetic bacteria for deposit- and suspension-feeding amphipods. The results will be compared to a similar trophic study undertaken in the Antarctic.

Evaluation of debris on the sea floor

F. Galgani (Ifremer)

Evaluation of debris on the sea floor has been performed during the last decade. This work has been focused mainly on continental shelves but also in some deep sea areas. Most of the continental shelves have been investigated around European coasts and some deep sea areas were shown to accumulate debris. This is the case in the Europeans canyons. Transportation of debris by current has also been shown as , for example, in the north sea where litters are transported to northern areas without any information on the presence of debris in deep sea artic waters. We therefore intend to investigate in arctic deep sea areas where preliminary work (ROV "VICTOR 6000" observations, 1999) indicates the presence of debris. From the different methods available for quantification, imagery has been shown to be the most valuable technology for deep-sea environment as tested during "VICTOR 6000" cruise in 1998 in the bay of Biscay.

The scientific programme comprises the evaluation of surface covered by cameras of the submersible "VICTOR 6000" and the evaluation of the nature and quantity of debris.

For each dive, without any specific needs, we will evaluate the mean area on floor covered by "VICTOR 6000" during restricted times (10 min) in order to obtain a mean area covered during all routes of the submersible (extrapolation). The work will include an evaluation of debris densities, counting and identification, during all routes including origin (country of origin, sources such as fishing and marine transport) and signatures (presence of fouling). Some samples will have to be collected for further examination. No extra ROV or shiptime is needed in addition to general program.

Besides, our work will also focus on analysis of all video tapes from the 1999 cruise in order to compare densities and observations with regard to plastic or any other kind of debris in the deep sea. All data will be submitted to an existing database.

Data will help to :

- demonstrate the transportation of debris to the Arctic Ocean
- demonstrate the persistence of debris on the Arctic deep-sea floor
- determine the importance of different types of debris in the deep Arctic environment (pastics, fishing gears)
- give information on the potential impact of debris on the Arctic deep-sea ecosystem

Geochemical investigations at AWI Hausgarten

E. Sauter, L. Baumann, J. Delius (AWI)

In close interdisciplinary co-operation with the benthos biology and geology group we plan to proceed our geochemical investigations of the sedimentary and near-bottom environments at the Hausgarten area west of Svalbard.

For this purpose the main Hausgarten station at 2500 m water depth as well as the neighbor stations along the east-west depth transect from 1200 to 5500 m depth will be sampled by ROV-push cores, TV-guided multi corer, gravity core and bottom water sampler.

Vertical gradients of nutrients, C_{org} content, C/N ratio, porosity and other geochemical parameters will be determined at the sediment samples to characterize the geochemical milieu in which the organisms analyzed by the biology group live. Nutrient and oxygen gradients will also be measured at the bottom water samples in order to quantify interfacial solute fluxes and rates metabolism. These investigations are furthermore complemented by the use of current vanes that are deployed and observed by the ROV. They have proven to allow accurate short time current measurements within the near-bottom water column (see Fig. 11). The bottom-flow regime is necessary to be taken into account for an integrative comprehension of benthic ecosystems.

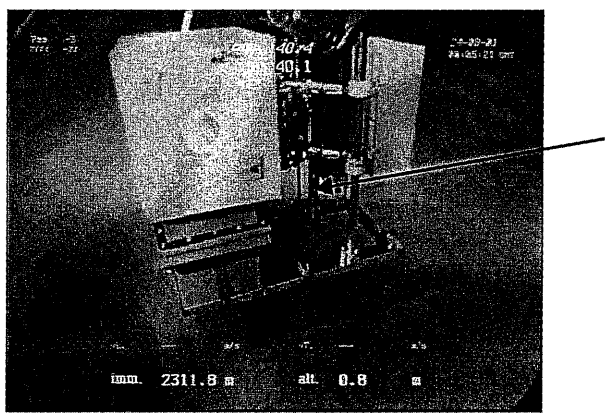


Fig. 14: The *in situ* O_2 microprofiler (MIC) being deployed at a measuring location by ROV "VICTOR 6000".

Der *in situ* O_2-Microprofile (MIC) wird vom ROV "VICTOR 6000" auf einer Messstation abgesetzt.

Special emphasis is laid on the exact measurement of oxygen micro gradients below the sediment water interface and in vicinity of organisms and biogenic structures. It is hoped that those gradients give new insights into the metabolistic interaction between macro fauna and their next environment. For this purpose a deep-sea microprofiler (Fig. 14) has been modified to fit into the shuttle lander and to be operated by the ROV at the seafloor. A switch operated by the ROV allows to keep the system down at the sea floor for several individual measurements. Due to its small dimensions the device can be placed precisely by the ROV.

Finally, it is planned to deploy an *in situ* current channel at the sea floor to investigate benthic respiration and interfacial solute exchange under changing bottom current regimes. On the short time scale it is aimed to obtain indications about the speed of adaptation in respect to geochemical gradients as well as respiration rates. Beside short time experiments during this year's expedition a long term deployment is planned to reveal how organisms behave under enhanced current stress. For this purpose it is planned to leave the channel at the end of the cruise at a well selected station and to re-visit it latest in 2005.

ANNEX

Beteiligte Institutionen/ Participating Institutions

	Acronym	Participants
Alfred Wegener Institute for Polar and Marine Research Columbusstr. 27568 Bremerhaven Germany	AWI	29
Akademie der Wissenschaften und der Literatur Geschwister-Scholl-Str. 2 55131 Mainz Germany	AWL	1
Department of Geology University College Dublin Belfield Dublin 4 Ireland	UCD	1
Department of Geology & Environment Research Institute University College Cork Cork Ireland	UCC	4
Department of Marine Sciences University of Plymouth Plymouth Devon, PL4 8AA United Kingdom	U Plymouth	1
Deutscher Wetterdienst Bernhard-Nocht Straße 20359 Hamburg Germany	DWD	5
FIELAX Gesellschaft für wissenschaftliche Datenverarbeitung mbH Schifferstr. 10 - 14 27568 Bremerhaven Germany	FIELAX	7

	Acronym	Participants
Friedrich-Schiller-Universität Jena Institut für Geowissenschaften Burgweg 11 07749 Jena Germany	U Jena	1
GENAVIR Zone Portuaire de Brégaillon B.P. 330 83507 La Seyne sur mer Cedex France	GENAVIR	28
Geological Survey of Ireland Beggars Bush Haddington Road Dublin 4 Ireland	GSI	1
GEOMAR Forschungszentrum für Marine Geowissenschaften Wischhofstr. 1-3 24148 Kiel Germany	GEOMAR	2
Institut français de recherche pour l'exploitation de la mer BP70 29280 Plouzane France	IFREMER	16
Institut Royales des Sciences Naturelles de Belgique Rue Vautier 19 9000 Bruxelles Belgium	IRSNB	3
Institute for Applied Physics Of the Russian Academy of Sciences Nishny Novgorod Russia	IAP	1
Institute for Polar Ecology of Kiel University Wischhofstr. 1-3 24148 Kiel Germany	IPÖ	1

	Acronym	Participants
Institute of Oceanology of the Polish Academy of Sciences P.B. 68 81-712 Sopot Poland	IOPAS	2
International University Bremen Campusring 1 28759 Bremen Germany	IUB	7
Martin Ryan Marine Science Institute National University of Ireland Galway Ireland	NUIG	3
Max Planck Institute for Marine Microbiology Celsiusstr. 1 28359 Bremen Germany	MPI	9
Murmansk Marine Biological Institute Vladimirskaya Str. 17 183010 Murmansk Russia	MMBI	1
OPTIMARE Coloradostr. 5 27580 Bremerhaven Germany	OPTIMARE	1
P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences 23 Krasikova 117851 Moscow, Russia	SIO	1
Renard Centre of Marine Geology Department of Geology and Soil Science University of Ghent Krijgslaan 281 S8 9000 Gent Belgium	RCMG	2

	Acronym	Participants
School of Ocean Sciences University of Wales Bangor, Askew Street Menai Bridge, LL59 5AB United Kingdom	SOS	1
Scottish Association for Marine Science Dunstaffnage Marine Laboratory Oban, Argyll, PA37 1QA United Kingdom	SAMS	1
Universität Bremen Klagenfurter Str. FB 5 Geowissenschaften 28334 Bremen Germany	U Bremen	3
Universität Erlangen Institute of Paleontology Loewenichstr. 28 91054 Erlangen Germany	U Erlangen	3
University Ghent Marine Biology Section Krijgslaan 281/S8 B-9000 Gent Belgium	U Ghent	2

Fahrtteilnehmer/-innen / *Participants* ARK XIX/3a

Baussan	Clément	Genavir
Beck	Tim	U Erlangen
Beraud	Severine	Genavir
Berov	Dimitar	IUB
Beyer	Andreas	AWI
Boda	Mathieu	Genavir
Boge	Carsten	U Erlangen (TV)
Bohlmann	Harald	Isitec
Brennan	Clare	U Cork
Buldt	Klaus	DWD
Cheilan	Patrick	Genavir
Christophe	Alain	Genavir
Coudray	Sylvain	Ifremer
Dabrowski	Peter	IUB
Devanathan	Vinod	IUB
Dorschel	Boris	U Bremen
Dullo	Wolf-Christian	GEOMAR
Fauvin	Olivier	Genavir
Foubert	Anneleen	RCMG Ghent
Gault	Jeremy	U Cork
Gektidis	Marcos	U Erlangen (TV)
Grehan	Anthony	U Galway
Guinan	Janine	U Galway
Gutt	Julian	AWI
Hall-Spencer	Jason	U Plymouth
Jouffroy	Jérome	Ifremer
Kaioun	Jean-Jacques	Genavir
Klages	Michael	AWI
Kozachenko	Max	U Cork
Krocker	Ralf	AWI
Kulaksiz	Serkan	IUB
Laurantin	Gérard	Genavir
Möller	Hans-Joachim	DWD
Monteys	Francisco X.	GSI Dublin
Opderbecke	Jan	Ifremer
Pfannkuche	Olaf	GEOMAR
Pierre	Pascal	Genavir
Pokorná	Markéta	AWI
Rathlau	Rike	AWI
Roberts	John Murray	SAMS
Saint-Laurent	Xavier	Ifremer
Sharma	Pradesh	IUB
Sumoondur	Aryani Devi	IUB
Thiede	Jörn	AWI
Thomsen	Laurenz	IUB
Tous	Jean-Yves	Genavir
Tseu	George	RCMG Ghent
Unnithan	Vikram	U Dublin

Vultaggio	Gérard	Genavir
Wheeler	Andy	U Cork
Wilson	Margaret	U Galway

Fahrtteilnehmer/-innen / *Participants* ARK XIX/3b

Armando	Magali	Genavir
Baumann	Ludmila	AWI
Beer, de	Dirk	MPI
Beier	Viola	MPI
Bergmann	Melanie	SOS
Beyer	Andreas	AWI
Bisquay	Hervé	Ifremer
Boetius	Antje	AWI
Bohlmann	Harald	Isitec
Buldt	Klaus	DWD
Dauby	Patrick	IRSNB
Duchi	Christophe	Genavir
Edy	Christian	Ifremer
Eickert	Gabriele	MPI
Fenouil	Julien	Genavir
Feseker	Tomas	AWI
Foucher	Jean-Paul	Ifremer
Gensheimer	Michael	AWI
Gini	Marc	Genavir
Heesemann	Bernd	U Bremen
Heinrich	Friederike	MPI
Hennebelle	Franck	Genavir
Jaussaud	Patrick	Genavir
Jerosch	Kerstin	AWI
Kanzog	Corinna	AWI
Kaul	Norbert	U Bremen
Klages	Michael	AWI
Kukina	Natalia	MMBI
Langreder	Jens	MPI
Leclere	Guy	Genavir
Lensch	Norbert	AWI
Mear	Laurent	Ifremer
Müller	Imke	MPI
Muyakshin	Sergey	IAP
Niemann	Helge	MPI
Nordhausen	Axel	MPI
Normand	Alain	Ifremer
Potier	Yves	Genavir
Rathlau	Rike	AWI
Richard	Serge	Genavir
Rigaud	Vincent	Ifremer
Rogenhagen	Johannes	Fielax
Rohr	Harald	Optimare
Sauter	Eberhard	AWI
Schlüter	Michael	AWI
Siméoni	Patrick	Ifremer
Sußebach	Jürgen	DWD

Tailliez	Luc	Genavir
Triger	Pierre	Genavir
Usbeck	Regina	Fielax
Vanreusel	Ann	U Ghent
Vincent	Anne-Gaelle	Ifremer
Wegner	Jan	AWI
Witte	Ursula	MPI
Wollenburg	Jutta	AWI

Fahrtteilnehmer/-innen / *Participants* ARK XIX/3c

Bauerfeind	Eduard	AWI
Baumann	Ludmila	AWI
Baussan	Clément	Genavir
Bergmann	Melanie	SOS
Birgel	Daniel	AWI
Boda	Mathieu	Genavir
Bohlmann	Harald	Isitec
Bonfiglio	André	Genavir
Broyer, de	Claude	IRSNB
Budaeva	Natalia	SIO
Chopin	Jean Pierre	Genavir
Christophe	Alain	Genavir
Delius	Judith	AWI
Dittmer	Klaus	DWD
Fauvin	Olivier	Genavir
Galgani	François	Ifremer
Hasemann	Christiane	AWI
Hoste	Eveline	U Ghent
Jankowska	Katarzyna	IOPAS
Juterzenka, von	Karen	AWI
Kaioun	Jean-Jacques	Genavir
Kanzog	Corinna	AWI
Klages	Michael	AWI
Kolar	Ingrid	AWI
Kukina	Natalia	MMBI
Kunz-Pirrung	Martina	AWI
Laurantin	Gérard	Genavir
Lecornu	Fabrice	Ifremer
Lubin	Patrice	Ifremer
Martin	Patrick	IRNSB
Matthiessen	Jens	AWI
Piepenburg	Dieter	IPÖ
Pirrung	Bernd Michael	U Jena
Potthoff	Michael	AWI
Röhrlich	Dagmar	Deutschlandfunk
Sablotny	Burkhard	AWI
Sauter	Eberhard	AWI
Schewe	Ingo	AWI
Schmid	Michael	AWI
Soltwedel	Thomas	AWI
Sonnabend	Hartmut	DWD
Tous	Jean-Yves	Genavir
Toutoux	Claude	Ifremer
Urban-Malinga	Barbara	IOPAS
Vultaggio	Gérard	Genavir
Wegner	Jan	AWI

Schiffsbesatzung / *Ship's Crew* ARK XIX/3

Domke	Udo	Master
Grundmann	Uwe	1. Offc.
Pluder	Andreas	Ch. Eng.
Spielke	Steffen	2. Offc.
Hartung	René	2. Offc.
Peine	Lutz	2. Offc.
Schneider	Martina	Doctor
Koch	Georg	R.Offc.
Delff	Wolfgang	1. Eng.
Ziemann	Olaf	2. Eng.
Zornow	Martin	3. Eng.
Muhle	Heiko	Electr.
Bretfeld	Holger	FielaxElo
Muhle	Helmut	FielaxElo
Verhoeven	Roger	FielaxElo
Roschinsky	Jörg	FielaxElo
Loidl	Reiner	Boatsw.
Reise	Lutz	Carpenter
Gil Iglesias	Luis	A.B.
Pousada Martinez	S.	A.B.
Winkler	Michael	A.B.
Hagemann	Manfred	A.B.
Schmidt	Uwe	A.B.
Bastigkeit	Kai	A.B.
Hartwig-Labahn	Andreas	A.B.
Bäcker	Andreas	A.B.
Preußner	Jörg	Storek.
Ipsen	Michael	Mot-man
Voy	Bernd	Mot-man
Elsner	Klaus	Mot-man
Hartmann	Ernst-Uwe	Mot-man
Grafe	Jens	Mot-man
Haubold	Wolfgang	Cook
Völske	Thomas	Cooksmate
Silinski	Frank	Cooksmate
Jürgens	Monika	1. Stwdess
Wöckener	Martina	Stwdss/KS
Czyborra	Bärbel	2. Stwdess
Silinski	Carmen	2. Stwdess
Gaude	Hans-Jürgen	2. Steward
Möller	Wolfgang	2. Steward
Huang	Wu-Mei	2. Steward
Yu	Kwok, Yuen	Laundryman

NOTIZEN / *NOTES*

NOTIZEN / *NOTES*