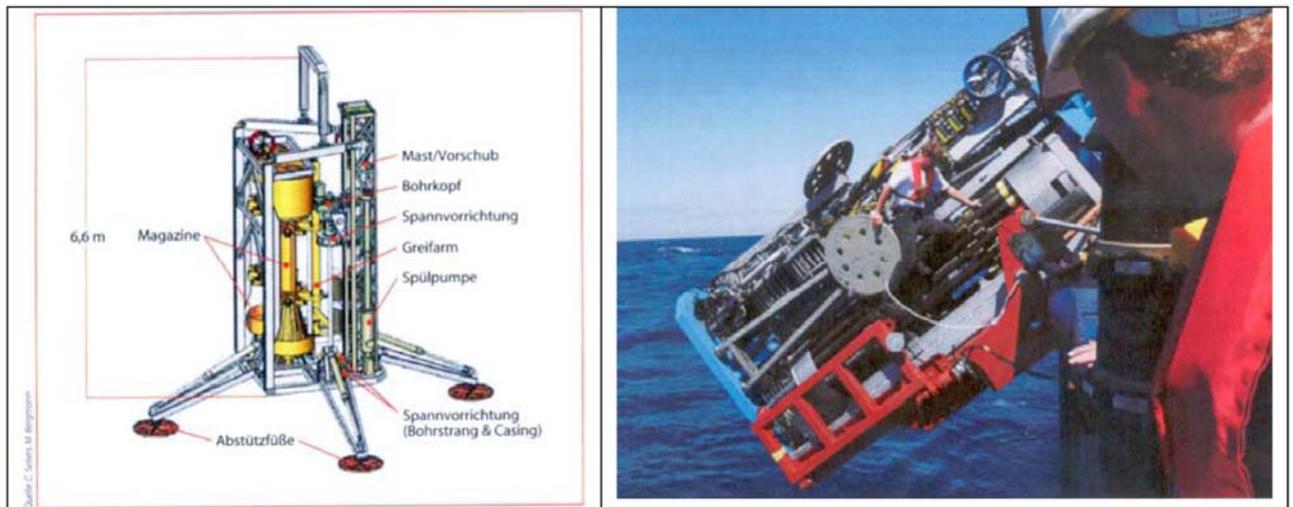


**Workshop on Marine Research Drilling
(Magellan Workshop Series)**

Exploring Escarpment Mud Mound Systems and Mud Volcanoes with new European strategies for sustainable mid-depth coring.

Murten, Switzerland, 26-29 April 2007



In Figure: the portable seafloor drill rig Meeresboden-Bohrgerät (MeBo)



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Meeting Report

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1- Summary

A fundamental and unanswered question facing Earth and Life scientists today is, *what is the relation between hydrosphere, geosphere and biosphere?*

The geological setting of Mound Systems and Mud Volcanoes provides a unique natural laboratory for studying and understanding the exciting and constructive interplay between carbonates, geofluids, biodiversity and deep biosphere and to investigate whether there is a causal link between mud volcanoes and mud mounds formation.

The Magellan Workshop sponsored by the European Science Foundation and entitled “Exploring Escarpment Mud Mound Systems and Mud Volcanoes with new European strategies for sustainable mid-depth coring” was recently held in Murten, Switzerland, 26-29 April, 2007. The workshop gathered 19 scientists and members of (1) two large IODP Proposals: 689 (Mud volcanoes as a window into the deep biosphere) and 673 (Atlantic Mound Drilling 2: Morocco Margin), (2) of two ongoing ESF EUROCORES projects (MiCROSYSTEMS and CARBONATE) and (3) of the EU-FP6 Integrated Project HERMES. These scientists, representing a wide spectrum of disciplines e.g., geophysics, sedimentology, paleoceanography, biogeochemistry and geomicrobiology joined with the aim to discuss the best strategies to study these two important geological settings.

The workshop had been designed to merge: (1) discussion on innovating technology, which addresses the new challenges of site surveying and coring in sensitive areas, of shallow exploratory drilling and of lander deployments, with (2) multidisciplinary science, boosting the synergy between respectively a palaeoceanography research community and a Deep Biosphere cluster and (3) to present and discuss the capability of Europe’s most promising and innovative tool for ocean margin exploratory drilling: the Remotely Controlled Sea-Floor Drill Rig “MeBo” (Meeresboden-Bohrgerät) developed at the University of Bremen (MARUM) to address the target objectives, in absence of highly performing drilling tools as IODP drilling platforms.

Workshop participants agreed that carbonate mounds and mud volcanoes should be addressed by drilling with MeBo to provide the preliminary framework to IODP further expeditions on (1) the Deep Biosphere, (2) the dynamics of fluids, (3) the system variability, (4) the balance between external and internal factors and (5) the role of these peculiar geologic setting as carbon sink and source.

The ideas expressed during the Murten workshop will find a broader forum at the first Conference of the Moroccan Association of Petroleum Geologists (MAPG) in Marrakech (October 2007): “Mound drilling for Science and Industry” presented by J.P. Henriot and at a dedicated session or associated meeting on Modern Mound Research, to be submitted for the October 2008 Convention of AAPG in Cape Town, South Africa.

The workshop was the ideal platform to discuss the project MeBoTech, in which all the workshop participants play a role as partners and/or associate scientists. MeBoTech was submitted after the workshop to the European Union FP7, Coordination and Support Actions programme.

2- Description of the scientific content and of discussion at the event

Rationale: An exploratory cruise of R/V Belgica in 2002 off Larache (Morocco) led to the discovery of apparently juvenile mud mounds in water depths of 500-600 m, topping a cliff: the Pen Duick Escarpment in the El Arraiche Mud Volcano Field (Van Rensbergen et al., 2005).

Mud volcanoes are the surface expression of major episodes of fluid expulsion, and hence they are a window on hydrocarbon maturation and deep-rooted flow dynamics. Presently, they are considered as one of the hot spots for the Deep Biosphere because of their potential supply of energy sources and microorganisms from great depths below the seafloor. They represent also an important source of gas hydrates. Thus, Mud Volcanoes play an important role in the global carbon cycle that still has to be investigated and understood.

Mud Mounds: in May 2005, IODP Expedition 307 “Porcupine Mound Drilling” cored the first full section of a modern, giant carbonate mound - Challenger Mound in the ‘Belgica Mound Province’, west of Ireland. The mound, 155 m high and rooted on a buried cliff, has yielded an exceptional record of Pleistocene environmental changes (Ferdelman et al. 2005). Cold-water coral intervals are recurrent throughout the mound, though in variable state of preservation. Interstitial water profiles suggest a tight coupling between carbonate diagenesis and microbial sulphate reduction (Ferdelman et al., 2005). Mud mounds may host thriving microbial consortia, which control sulphate reduction, methane oxidation and/or methanogenesis. Additionally, they potentially encode timing and amplitude of environmental changes and may provide information on the mechanisms triggering these events (e.g., climate, ice volume, productivity, etc.). Understanding modern mound systems is thus fundamental in the reconstruction of past environmental changes. Additionally, carbonate mounds in the geological record form prominent and prolific hydrocarbon reservoirs. Indeed, modern Mound Drilling, as demonstrated by IODP Exp. 307, opens new insights into both the role of primary oceanic processes and the early diagenetic controls on the shaping of the internal architecture of a mound reservoir.

The workshop was attended by 19 scientists members of

- (1) IODP Expedition 307, Porcupine Basin Carbonate Mounds
- (2) IODP 673-Pre: Atlantic Mound Drilling 2: Morocco Margin (Lead Proponents J.P. Henriot, RCMG, and W.C. Dullo, IfM-GEOMAR): mound drilling on the Pen Duick Escarpment
- (3) IODP 689-Pre: Mud Volcanoes as a Window into the Deep Biosphere (Lead Proponent D. Depreiter, RCMG): Mercator mud volcano drilling.
- (4) ESF EUROCORES project MiCROSYSTEMS (Lead Proponent J.P. Henriot)
- (5) ESF EUROCORES project CARBONATE (Lead Proponent A. Weeler)
- (6) the large-scale EU-FP6 Integrated Project HERMES.

with the goal to revise and discuss our present knowledge on Mud Mounds and Mud Volcanoes and to propose new drilling strategies to explore these two peculiar geological settings.

Discussion

The two workshop thematics, Mud Mounds and Mud Volcanoes, were discussed separately (see programme), however, common features were analysed in details and the participants agreed that very reasonably they belong to a single geologic system.

Mud Mounds: The discussion was based on the 5 presentations concerning the most recent results obtained in the framework of the above mentioned large projects and were integrated with the results of IODP Expedition 307 (J.-P. Henriot). These presentation were focused on various topics including cold-water coral ecosystems (D. Hebbeln), water mass dynamics around mounds (C. Dullo) , the significance of mud mounds (A. Foubert).

Of relevant interest was the contribution (with a short film) presented by T. Freudenthal of the capability of Europe's most promising and innovative tool for ocean margin exploratory drilling: the Remotely Controlled Sea-Floor Drill Rig "MeBo" (Meeresboden-Bohrgerät) developed at the Marum Center for Marine Environmental Sciences at the University of Bremen (MARUM) to address the target objectives, in absence of highly performing drilling tools as IODP drilling platforms.

The unique sea floor sampling capabilities of the MeBo have been proven during four expeditions between August 2005 and March 2007 at altogether 26 deployments. Down to a depth of >40 m crystalline and sedimentary rocks were sampled by rotary drilling as well as soft sediments by push coring. The possibility to switch between push coring and rotary drilling and vice versa during the same deployment makes it the dedicated tool for coring mound sites containing hardgrounds and carbonate crusts.

Relevant to the workshop was also the contribution of M. Comas (University of Granada) who presented for the first time a mound field recently discovered in the Alboran Sea and named "Mellilla Mound Field". This discovery brings important information on the coupled mud mound/mud volcanoes systems.

The discussion focused on the joint presence of these two marine structures and the workshop participants agreed that the Gulf of Cadiz mound and volcano fields and the recently discovered structures in the Alboran Sea belong to the same Mediterranean domain and can be considered a single geological system.

Mud Volcanoes: four presentations focused on this topic: the Gulf of Cadiz mud volcanoes (L. Pinheiro), the biogeochemical investigations on the microbiology of Challenger Mound in the Porcupine Basin (K. Mangelsdorf), the subsurface fluid pumping and it consequences (D. Depreiter).

As keynote speaker D. Depreiter presented an overview of the Pre-proposal 689 "Mud volcanoes as a window into the Deep Biosphere". Based on these presentations the workshop participants identified the main topic to be further developed in mound-volcanoes-related research. A special emphasis was given to the importance of studying biodiversity, Deep Biosphere and fluid flows. In particular, it was pointed out that mud volcanoes might represent one of the largest prokaryotic habitat on Earth, with high

biodiversity, and broad range of metabolism which is still unexplored and that they are the conduits to the surface for Deep Biosphere organisms as well as large reservoirs of gas hydrates.

Open questions: The workshop participants identified a broad range of fields related to mud mounds and volcanoes in which many questions are still open.

Co-occurrence of mud volcanoes and mud mounds.

In many places in the world these two geological structures have been reported together, e.g., Gulf of Cadiz, Alboran Sea. They may belong to a complex, yet not understood and unexplored geological system, driven by similar hydrodynamic conditions. There are other potential locations in which they co-occur but they have not been investigated yet (e.g., Mediterranean Ridge). An inventory of provinces where these structures occur together may be helpful to clarify this issue.

Hydrogeology of mounds.

It is necessary to measure the hydrological parameters in 3D, as they can provide an important input for modeling in multiple dimensions, measures of permeability only is not sufficient. If possible, it would be important to monitor fluid flows with permanent sensors.

Hydrodynamics of water masses around mounds and volcanoes.

Circulation patterns and water mass dynamics around these structures may provide insight to understand their development. It is necessary to monitor them e.g., by extensive collection of CTD and current measurements.

Geo-Microbiology.

The microbial populations associated to mud volcanoes must be characterized. The biodiversity of deep and surface biosphere has to be distinguished and ascertained in detail. There is a need to improve sampling tools to avoid microbial contamination, if using other coring tools (e.g. MeBo) than IODP drilling platforms. It is necessary to determine the composition of the venting fluids in order to elucidate their role as a carbon and energy source for microbial communities associated to mud volcanoes!

Mounds should be sampled from their base to study the complete system and not only part of it. An important issue concerns the provenance of the micrite fraction and the role of the Deep Biosphere in dolomite formation.

Micropalaeontology.

A more extensive study of microfossil assemblages from sediments adjacent to mud mounds, in mud mounds and from the mud breccia extruded by mud volcanoes with a quantitative approach would bring important insight in the palaeoceanographic factors triggering the development of these structures as well as the possible sources of the mud breccia itself.

System variability.

Each mound is characteristic and differs from others. Are tectonics, hydrology etc., controlling factors in mound development ? We need to investigate the balance between external and internal factors, as well as between shallow and deep environment.

Role of mud mounds in the global cycles.

Are the mud mounds carbon sinks and/or sources of CH₄ ?

Up to now the carbonate stored in carbonate mounds has not been considered in any global carbonate budget or any *global model of the distribution of the greenhouse gas carbon dioxide*. Therefore, the study of carbonate mounds and associated cold-water coral reefs was recognized as one of the first priorities of IOC/UNESCO's new Programme "Geosphere-Biosphere Coupling Processes" (GBCP).

Mound evolution in the geologic time.

An essential need is to revisit fossil mounds, model them in 3D (outcrops) and drill them according with the knowledge we have now on modern structures. However, there is a gap in our knowledge about the distribution of fossil structures that should be filled in reconsidering the definition and the terminology of the mounds themselves .

Role of mounds in oil exploration.

When a mound becomes a reservoir, what is the size limit to be exploited by the industry?

Recent research have revealed that the gas in mud mounds has a mixed biogenic – thermogenic origin, but the way this mixing occurs and the processes that produce this composition are still largely unknown.

3 - Assessment of the results and impact of the event on future direction of the field.

Science – Technology - Future.

One of the main results of the workshop is a general consensus that the scientific community needs to continue the study of Mud Mounds and Volcanoes for scientific and economic reason. To acquire further knowledge on the unexplored fields mentioned in the previous paragraph, we need to apply state-of-the-art technologies.

A first step for future cooperation is to formulate working hypotheses requiring new data, which feedback into the model. However, due to the important operational delays accumulating within IODP as a consequence of the refitting of the JOIDES Resolution (which had successfully drilled Challenger Mound in Exp. 307, in 2005) and the reduced level of programming due to financial constraints, no IODP operation on the proposed targets can reasonably be anticipated within the next few years.

Therefore, the workshop participants agree that MeBo is an excellent drilling tool for sustaining Europe's mound research in the forthcoming years, which is intermediate between gravity coring and IODP drilling and represents a new European facility.

It will provide the framework to address the target objectives, and prepare the background for future IODP expeditions.

1 - For this purpose, J.P. Henriet presented to the workshop participants The MeBoTech Project, which proposes to study the feasibility of sampling mud mounds and mud volcanoes in the Gulf of Cadiz and of deploying in a targeted way sensors at depths between 0 and 20 to 40m below the seafloor, using the remotely controlled sea-floor drill rig "MeBo" (Meeresboden-Bohrgerät).

All workshop participants, representing a multidisciplinary panel of mound research experts, endorsed this scientific and technological challenge on April 28th, 2007.

As a results the MeBoTech Project has been proposed at unanimity as a priority objective for a European Union FP7- Coordination and Support Action Programme and submitted within the call dead-line on 2 May, 2007 immediately after the Workshop. Project partners and associate scientists include some of the workshop participants under the coordination of J.P. Henriet.

2 – The possibility to equip MeBo with tools and/or specific tracers for contamination-controlled sampling of a subsurface biosphere will be explored and tested in the forthcoming cruises, in which MeBo will be mobilized. If successful, studies on the phylogentic biodiversity of subsurface microbial populations and in mud mounds also of the deep biosphere will be possible with MeBo.

3 – Building upon the on-going large programmes and projects (EUROMARGINS, EURODIVERSITY MiCROSYSTEMS, FP6 HERMES, EUROMARC CARBONATES, IODP Proposals) new direction and possibilities of research in this field will be explored e.g.:

- (a) the recently submitted MeBoTech Project for technological development

(b) the ESF EUROCORES TOPO-Europe Project

4 – A strict cooperation with the International Continental Scientific Drilling Program (ICDP) is strongly recommended to combine on- and offshore research of possible fossil mud mound analogues.

5 – In view of the great interest of oil companies in mud mounds, initial contacts have been made with the industry in the framework of the MeBoTech Project to enhance the dialogue between academy and industry on this topic:

- (a) Mud mounds and volcanoes – related research and MeBoTech will be presented by J. P. Henriet at the first Conference of the Moroccan Association of Petroleum Geologists (MAPG) in Marrakech (October 2007): “Mound drilling for Science and Industry”
- (b) A dedicated session or associated meeting on Modern Mound Research will be submitted for the October 2008 Convention of AAPG in Cape Town, South Africa.

6 – The “Melilla Mound Field” recently discovered in the Alboran Sea -Western Mediterranean will be surveyed, cored and investigated in Summer 2007, and new cores will be retrieved from the mud volcanoes in the same area.

If this preliminary investigation will reveal the potential of the “Melilla Mediterranean field” MeBo may be a promising tool for further, more detailed investigations.

7 – Additional cruises are presently planned for the forthcoming years in the Gulf of Cadiz to study mud mounds and mud volcanoes. Some of them will imply MeBo (e.g., the next cruise of the Irish RV Celtic Explorer, in the framework of the ESF-CARBONATE Project.

8 - Most of the PhD students present at the workshop will sail in these forthcoming cruises. Some of them have been invited during the workshop.

In conclusion, a large community of scientists of different disciplines including e.g., geology, biology, microbiology, technology, closely cooperated and interacted during this workshop. This synergy is already shaping an additional European added value, which amplifies the value of the single projects/proposals well beyond the workshop’s formal core size, both in operational and analytical terms.

A Meeting report short article summarizing the result of the Magellan Workshop and acknowledging the ESF, was submitted to EOS on 16 May, 2007, and is now under review.

4 – Final Programme of the meeting

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**Workshop Programme
Murten, 26-29 April 2007**

Thursday, 26 April, 2007

Arrival morning and afternoon

Informal gathering of participants and preliminary discussion

Lunch

Informal gathering of participants and preliminary discussion

Welcoming Aperó

Dinner

Preliminary discussion

Friday, 27 April 2007 - Mud Mounds

Morning Session, starting 9h00

Welcome & Review Workshop Goals: Co-Chairs D. Depreiter and Silvia Spezzaferrì

Keynote Speakers: Jean-Pierre Henriët - From Porcupine Mound Drilling to Morocco Margin Drilling - the Mound Research Forum and MEBOTECH as stepping stones

Short presentations by participants.

Cold-Water Coral Ecosystem Functioning through Time in the Deep Sea: The example of cold-water coral carbonate mounds in the northeast Atlantic (from IODP307 to EuroMARC - CARBONATE). A.J. Wheeler, T. Ferdelman, A. Freiwald, **D. Hebbeln** ,

J.P. Henriet, A. Kano, R. Swennen, T.C.E. Van Weering, T. Williams, H. De Haas, B. Dorschel.

Water mass dynamics around mounds, **C. Dullo**, A. Rüggeberg and S. Flögel

Sampling the sea floor with the remotely operated underwater drill MeBo. **T. Freudenthal**

Lunch - 12h30- 14h00

Afternoon Session starting 14h15

Short presentations by participants.

Nature and Significance of the Carbonate Mound Record: The Mound Challenger Code. **A. Foubert**

Discovery of Carbonate Mounds in the Alboran Sea: The Melilla Mound Field
M. Comas and L.M. Pinheiro

Brainstorming sessions

Poster - all day display and 5 minutes presentation

Evaluating the hydrodynamic conditions during cold-water coral carbonate mound development (Challenger Mound, Porcupine Seabight): initial results from particle size analysis at IODP Exp307 site U1317." **M. Thierens**

Dinner and Discussion

Saturday, 28 April, 2007 - Mud Volcanoes

Morning Session starting 9h00

Co-Chairs J.P. Henriet and J. McKenzie

Keynote Speaker: **Davy Depreiter**: Mud volcanoes as a window into the Deep Biosphere

Short presentations by participants.

Mud volcanism, gas hydrates and hydrocarbon-rich fluid escape structures in the Gibraltar arc system. **L.M. Pinheiro** and M. Comas

Biogeochemical investigation of deep subsurface sediments from the Belgica Mound province in the Porcupine Basin. **K. Mangelsdorf**, Zink, K.G., di Primio, R., Gragg, B., Ferdelman, T., Horsfield, B., and the Expedition 307 Scientific PARTY.

Poster - all day display and 5 minutes presentation

IODP Expedition 307: A high resolution record of contourite deposition and palaeoclimatic forcing on the eastern Porcupine Seabight (Irish continental margin).
R. O'Donnell, M Thierens, B Dorschel, A Wheeler

General discussion

Lunch - 12h30- 14h00

Short presentations by participants.

External driven subsurface fluid pumping and consequences. **D., Depreiter**, Naudts, L., Foubert, A. and J.P. Henriot

Participants discuss and prepare reports and outline proposals/propositions for further actions/projects

Working group present reports

Dinner

Continued proposition writing and completion of reports

Sunday, 29 April, 2007

Breakfast & farewell discussion – departure