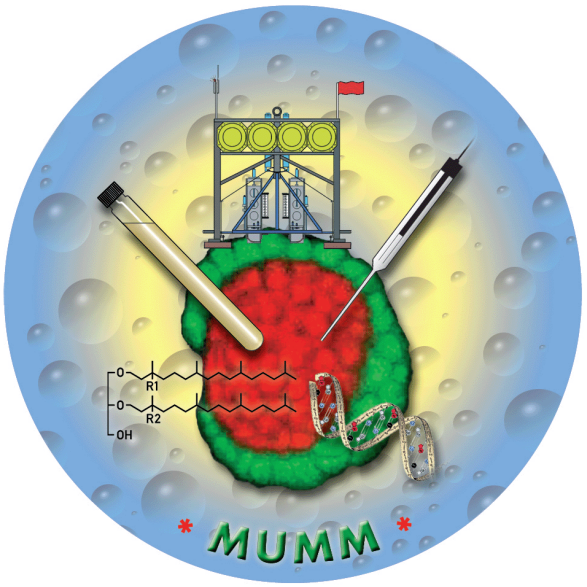
GEOTECHNOLOGIEN

MUMM

(Methan in Marinen Gashydrathaltigen Sedimenten – Umsatzraten und Mikroorganismen)

Methane in Gas Hydrate Bearing Sediments – Turnover Rates and Microorganisms



Report 01 January 2001 – 31 December 2003

BMBF Program

”Gas hydrates in the Earth´s System”

Bundesministerium für Bildung und Forschung

GEOTECHNOLOGIEN

Submitted by:

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and
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With Participation of the
K. U. M. Umwelt- und Meerestechnik GmbH, Kiel

In Cooperation with:

Project GHOSTDABS (Gas Hydrates: Occurrence, Stability, Transformation, Dynamics and Biology in the Black Sea), Institut für Biogeochemie und Meereschemie, Universität Hamburg (Coordination: W. Michaelis)

Project OMEGA (Shallow Marine Gas Hydrates: Dynamics of a Sensitive Methane Reservoir), GEOMAR (Coordination: G. Bohrmann)

Project LOTUS (Long-term observatory for the study of trigger mechanisms of the formation and destabilisation of gas hydrates), GEOMAR (Coordination: P. Linke)

AWI/IFREMER Project HMMV (Methane turnover at the Haakon Mosby Mud Volcano), Alfred-Wegener-Institut für Polar- und Meeresforschung (Coordination: M. Klages, M. Schlüter)

NSF - Life in Extreme Environments (LexEn) Project: Molecular Microbial Ecology and Biogeochemistry of Methane Hydrates and Brine Pools: Distribution and Activity of Microorganisms in Two Extreme Deep Sea Environments, University of Georgia, Georgia Tech (Coordination; S. Joye, P. Sobecky)

University Bremen „Gashydrates in Pelagic Sediments – KONGO“ (Coordination: V. Spiess)

Key Topic:
Methane turnover rates and methane-oxidizing microorganisms in gas hydrate bearing sediments

Acronym:
MUMM

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Topics of the Projects

Project I:
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Title: In situ measurements of microbial turnover rates
Topics: Marine Biogeochemistry, Carbon Cycle, Sulfur Cycle, In Situ Rate Measurements, Bacterial Turnover Rates, Deep-Sea Technology

Project II:
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Title: Microsensor measurements in gas hydrate bearing sediments
Topics: Marine Biogeochemistry, Microsensors, Optrodes, Biosensors, Methane sensor, in situ Profiling, Sulfur Cycle, Carbon Cycle, Marine Technology

Project III:
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Title: Isotope signatures of the methane and sulfur cycles
Topics: Marine Biogeochemistry, Organic Geochemistry, Carbon Isotopes, Sulfur Isotopes, Biomarker, Methane Cycle

Project IV:
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Title: Distribution and diversity of microorganisms in gas hydrate bearing sediments
Topics: Marine Microbiology, Molecular Ecology, Archaea, Sulfate Reducing Bacteria, Methanogens, Methylotrophs, Whole Cell Hybridization, Environmental Gene Libraries

Project V:
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Title: Identification of microorganisms in gas hydrate bearing and other methane-rich marine sediments
Topics: Marine Microbiology, Physiology, Archaea, Sulfate-Reducing Bacteria, Isolation, Growth and Interaction, Genetic Relationships

Project period: 01. September 2000 – 31. August 2003

I Project Description

I.1 Objectives

The objectives of the proposed project were:
1) The in situ quantification of the microbial turnover of methane in gas hydrate bearing sediments.
2) The development of a CH_4-microsensor for the in situ characterisation of the geochemical conditions for the methane oxidation and its temporal and regional variation.
3) The in situ identification of methane-consuming microorganisms from diagnostic organic molecules and their isotope signature as biomarkers.

4) The in situ distribution and molecular (rRNA-based) diversity of microorganisms involved in methane oxidation.
5) The isolation, identification and characterisation of methane-oxidizing microorganisms.

Contribution to the BMBF Programmes and Policies

The proposed project contributed directly to the programme "Gas Hydrates in the Earth´s System" of the BMBF (August 1999), by investigating the microbial diversity and function in gas hydrate bearing sediments as well as by characterising and quantifying the processes of methane turnover (Chapter 2.2 Role of methane in the global carbon cycle). Also, the proposed research contributed to the understanding of the temporal and spatial variability of carbon isotopes from methane (Chapter 2.3 Changes of the global methane balance with time: Relevance to climate). Furthermore, the proposed project included substantial advancements in marine in situ technology. The results enhance our knowledge of the ocean as ecosystem and as resource, two of the main key actions of the BMBF programme "Marine and Polar Research".

Summary of results of the project MUMM

The subsurface seabed is a gigantic bioreactor and would also be a substantial source for methane on earth, if rising gases were not efficiently utilized by microbial methanotrophic guilds. More than 90 percent of the methane rising from the subsurface ocean is oxidized anaerobically with sulfate as electron acceptor. It is a striking fact that this process of unknown functioning, carried out by very few phylogenetic groups of archaea, substantially effects atmospheric concentrations of methane (Hinrichs and Boetius 2002). The project MUMM (Methan in Marinen Gashydrathaltigen Sedimenten-UMsatzraten und Mikroorganismen) of the "Geotechnologien program " of the BMBF "Gas hydrates in the earth's system" investigated turnover rates and microorganisms based on field work and laboratory experiments. In 2001-2003, we participated in expeditions to gas hydrates and petroleum seeps in the Gulf of Mexico, to Hydrate Ridge off Oregon, to the Arctic mud volcano Haakon Mosby (Tab. 1-3). In comparison to the methane seeps, a variety of other gassy sediments were investigated, from deep subsurface cores to the Wadden sea. We were able to identify a greater diversity of methanotrophic archaea and sulfate reducing bacteria as previously anticipated. The comparison of AOM rates showed that at seep sites with very high methane fluxes (up to 200 mmol m^{-2} d^{-1} at Hydrate Ridge), methane turnover rates were two to three orders of magnitude higher compared to non-seep sites with methane fluxes <2 mmol m^{-2} d^{-1} (Treude et al. 2003). At seep sites with methane as the sole carbon source, AOM and SRR are tightly coupled and reflect the stoichiometric relationship between sulfate reduction and methane oxidation (Michaelis et al. 2002). At sites with petroleum seepage sulfate reduction (SRR) gets decoupled from AOM, which drops to less than 10% of SRR (e.g at Guaymas basin, some of the Eastern Mediterranean seeps and Gulf of Mexico) (Joye et al. in press). At sites with high AOM above dissociating hydrate and high gas fluxes sulfate is the limiting factor and may become depleted within 1-3 cm below sediment surface. If sulfate concentrations drop below 3 mM, a substantial decrease in AOM was observed (Nauhaus et al. 2002). Hence, a strong lateral heterogeneity in AOM is typical for active seeps and is caused by transient gas injection, inhomogeneous distribution of gas hydrates, precipitated carbonates and bioturbation processes (Treude et al. 2003). Research on the Black Sea microbial mats showed further evidence for the direct relation between AOM and the formation of carbonate precipitates with light carbon isotope signatures (Michaelis et al. 2002). Sections through methanotrophic microbial mats from the Black Sea which were