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Fluid channeling and their effect on the efficiency of benthic methane filter in various seep habitats and sediments

Philip Steeb, Peter Linke, and Tina Treude
Geomar, Marine Biogeochemestry, Kiel, Germany (psteeb@geomar.de, +49 431 600 2941)

Marine sediments and sub-seafloor gas hydrates build one of the largest methane reservoirs on Earth. Most of the methane ascending in sediments is oxidized by anaerobic oxidation of methane (AOM) with sulfate as terminal electron acceptor, the so-called “benthic microbial methane filter”. The efficiency of the benthic microbial methane filter is controlled by diffusive sulfate supply from seawater and advective methane flux from deep reservoirs. High fluid fluxes reduce the penetration depth of sulfate and limit the filter to a very narrow zone close to the sediment-water interface. However natural and catastrophic fluctuations of methane fluxes (caused e.g. by gas hydrate melting, earthquakes, slope failure) can change the fluid regime and reduce the capability of this greenhouse gas sink.

A new Sediment-Flow-Through (SLOT) system was developed to incubate intact sediment cores under controlled fluid regimes. To mimic natural fluid conditions sulfate-free, methane-loaded artificial seawater medium was pumped from the bottom and sulfate-enriched seawater medium was supplied from above. Media and system were kept anoxic and seepage medium was tracked with bromide tracer. Over the entire experiment, the change of geochemical gradients inside the sediment column was monitored in monthly time intervals using porewater extraction/analyses and microsensor measurements. In addition, in- and outflow samples were analyzed for the calculation of methane turnover rates.

In the above manner, sediments from different seeps (Eckernförde Bay, Costa Rica, Chile, and the Eastern Mediterranean Sea) and types (gassy sediments, gas hydrates containing sediments, mud volcanoes, sulfur bacteria mats, pogonophoran fields, clam fields) were incubated and monitored up to one year. Moderate to high advective fluid flow rates, which have been reported from natural seeps, were chosen to challenge the benthic microbial methane filter and investigate the response to pulses of methane loaded fluids.

The efficiency of the benthic methane filter was mainly controlled by fluid paths through the sediment. Sediments with lateral heterogeneity of the sediment matrix channelized fluids and formed small-scaled differences of sulfate penetration and residence time. While more homogenous sediments adapted to new fluid conditions within 150-200 d, heterogeneous sediment matrices with preferential fluid paths resulted in six times higher methane efflux. Increased fluid flow enforced this effect and led to fluid channeling in relative homogeneous sediment matrices.