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Flow and transport in permeable sediments induced by gas seepage

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The transport of methane from marine sediments into the seawater and then into the atmosphere is important in the context of its role as a greenhouse gas. The microbial, anaerobic oxidation of methane (AOM) in marine sediments is an important sink in the marine methane cycle. Particularly high rates of AOM are found in the vicinity of cold seeps at the sediment-water interface. The enhanced flux of sulfate from seawater into the sediment induced by the escaping methane is a potential explanation for these high rates of AOM. The aim of the present work is to provide a quantitative estimate of this enhanced downward flow at the benthic interface in the vicinity of a gas seep.

To this end, we use an artificial laboratory setup with a transparent, refractive-index matched sediment for the 3D spatially and temporally resolved visualization of this multiphase flow phenomenon. Flow and transport inside the sediment are measured by the experimental techniques Particle Image Velocimetry (PIV) and Planar Laser-induced Fluorescence (PLIF).

Depending mainly on sediment properties and gas flowrate, we find three regimes for the dynamics of the uprising gas: migration of clusters, flow through a single channel and flow through a channel network. The area surrounding the seep is characterized by a reverse, i.e. downward directed flow of liquid into the sediment induced by the rising gas. From the analysis of a series of experiments with different sediments and gas flow rates, we provide a quantitative description of the downward velocity as a function of the distance from the seep, the gas flow rate and the permeability of the sediment. We further provide a numerical model which is able to reproduce the spatial structure of the recirculating flow in the sediment. With this model we are able to assess the

influence of the container walls and the effect of the depth of the gas source.

In conclusion, our results show that the transport of seawater solutes (like e.g. sulfate) into marine sediments can be increased significantly as a consequence of upward-migrating gas. Compared to molecular diffusion, the induced advective transport may lead to an increase of more than one order of magnitude even for moderate gas flowrates.