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Solute transport into a saturated granular medium by the effect of gas rising

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The transport of different gases from marine sediments into the seawater and then into the atmosphere plays a vital role on global cycling. Methane, for instance, is a long-living gas which receives considerable attention due to its role as a greenhouse gas in the atmosphere. Large amounts of methane are formed by microbial production in marine sediments (Kotelnikova [1]). The release of methane into the atmosphere (by rising as bubbles from the sea bed to the water surface) may be limited by microbial anaerobic oxidation of methane (AOM) to CO2 in anoxic sediments (Boetius et al. [2]). Since AOM requires oxidants from the water body overlying sediment, the understanding of the solutes transport from the overlying water body into the sediment is essential for modeling of the fate of biogenic methane. Obviously, the counter-current flows across the water-sediment interface would have much larger impact on solute transport than pure diffusion. Of important counter-current flows can be considered as the consequence of uprising gas seepage from a liquid-porous interface and possible induced secondary flows.

Recently [3], a preliminarily study has been conducted on this subject for a single constant gas flow rate injected into a homogeneous saturated porous medium consisting of mono-sized ($d = 2.5mm$) glass beads. As a result three major effects were observed induced by the rising gas; a conical structure of trapped gas, fluctuations of liquid velocities in the porous matrix pores, and existence of a reverse downward directed flow of liquid into the porous matrix. It was concluded that the presence of such a downward flow in marine sediments could have crucial implications for the understanding and modeling of nutrient cycles and microbial life at the seafloor in the vicinity of methane seeps.

In this investigation, we visualized and quantified the solute penetration in the same system. We then provide correlations between the solute penetration speed and the uprising gas flow rate, and model the physical processes involved.

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