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Fracture controlled fluid transport induced microbial activities in Vestnesa Ridge

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Fracture-controlled fluid/gas migration from deep hydrocarbon reservoirs towards the seafloor can be found at Vestnesa Ridge (Arctic Ocean, west of Svalbard, at 79°N). Vestnesa is an NW-SE trending ridge with drifted sediment featuring several pockmarks of which pockmarks 'Lunde' and 'Lomvi' are the most active ones based on acoustic flares. While large-scale fractures building pathway for fluid/gas migration are commonly observed in seismic profiles, the role of small-scale fractures/micro fractures on biogeochemical forcing in near-surface sediments is not well constrained.

Herein, we report on a rare observation of a fracture in near-surface sediments (30 cm below the seafloor, cmbsf) at the Lomvi pockmark. We visualized the fracture by rotational scanning X-ray of a multicore. Furthermore, detailed porewater geochemistry and lipid biomarker investigations from three cores recovered from the Lunde and Lomvi pockmarks provide first-hand evidence of interactions between fluid/gas transport and biogeochemical processes in near-surface sediments.

The investigated sediment cores (fractured vs non-fractured) revealed different geochemical and biogeochemical characteristics reflecting different stages/modes of fluid and methane transport. At Lunde pockmarks, we found relatively low concentrations of non-depleted DIC (∼-5 to 20‰, and low contents of methanotropic lipid biomarkers indicating mostly diffusion-dominated transport of pore water solutes and methane. In contrast, in sediments featuring the shallow fracture at pockmark Lomvi, we found extremely high contents of strongly depleted DIC (-40 ‰, and high concentrations of 13C depleted lipid biomarkers diagnostic for AOM as well as high contents of both methane and sulfate. The fractured sediments thus represent advection-dominated transport where fluids and gases transport into shallow, sulfate-rich sediments is facilitated by the fracture.

The sediment environment with fractures is a transient state and dominated by advection of fluid and gas. This fuels the shallow AOM communities in a broader sediment horizon where methane and sulfate overlap. In contrast, the non-fractured environment is dominated by diffusion of fluid and gas only supporting low amounts of AOM communities.