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Weakening of the anaerobic oxidation of methane (AOM) biofilter: the combined role of methane gas transport and methanotrophic biomass dynamics.

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Ocean warming may destabilise methane hydrate, releasing methane into deep sediments, the overlying water column, and ultimately, the atmosphere, potentially driving positive feedback on global warming[1]. Yet, on the timescales over which hydrate-sourced methane release is hypothesized to occur, efficient methane sinks have the potential to slow, reduce or even prevent such release [1,2]. The microbially mediated anaerobic oxidation of methane (AOM) has been recognized as a major sink converting most of the benthic upward-flowing methane into inorganic and organic carbon pools, thus efficiently reducing seafloor methane emissions[5]. However, the AOM efficiency can be highly variable and is strongly controlled by the balance between multiphase methane transport and microbial consumption dynamics[5,6]. The interplay of environmental factors that would lead to a significant reduction of the AOM efficiency remains insufficiently delineated. This results in low-confidence predictions of seafloor methane emissions, particularly those enhanced by hydrate destabilisation[7].

Here we investigate the combined impact of gaseous methane transport and methanotrophic biomass dynamics on weakening of the AOM efficiency. We use a novel 1D multiphase reaction-transport model to examine the transient evolution of the AOM biofilter efficiency and seafloor methane emissions in response to an increase in deep methane flux on a centennial scale. Gaseous methane cannot be utilized directly by the methanotrophic community and enhances methane transport via bubble migration/irrigation and pore fluid over-pressure-triggered fracture generation. Thereby, it generally bypasses the AOM biofilter and exacerbates seafloor release. Slow methanotrophic biomass growth can further weaken the AOM efficiency in response to changes in deep methane fluxes. Such changes trigger an upward shift of the AOM, requiring the build-up of a new, efficient methanotrophic community within the shallower AOM zone. During this lag time, even a fraction of the available dissolved methane may escape the seafloor.

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