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More than three thousand years of microbial methane consumption at cold seeps offshore Svalbard

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Microbial consumption retains a significant fraction of methane in marine sediments. Under anoxic conditions, the anaerobic oxidation of methane (AOM) is mediated by archaea with sulfate as the terminal electron acceptor, whereas the aerobic oxidation of methane (MOx) is mediated by bacteria. MOx is typically less important in marine systems because oxygen availability in sediments is very low and methane is consumed in deeper sediments through AOM. At cold seeps, however, the methane flux can be high enough to bypass the AOM filter so that methane and oxygen overlap in surface sediments. The role of MOx thus becomes more significant at highly active cold seeps. To further test this hypothesis, and the applicability of MOx-signatures as a tracer for paleo seep activity, we investigated lipid biomarkers of methanotrophic communities in modern sediments and compared them to fossilised lipids in more than 3000 years old authigenic carbonate accretions. Sediments and carbonates were recovered in the direct vicinity of bubble release sites at cold seeps offshore Svalbard, systems that have been active for at least 3000 years (Berndt et al., 2014). Samples were recovered with the submersible JAGO during an expedition with R/V M.S. Merian (MSM 21/4) in 2012. The composition of lipid biomarkers and their associated stable carbon isotope signatures provide evidence for distinctly different methanotrophic communities in modern sediments and the old carbonates. In deeper sediments, where AOM rate measurements were maximal ($\sim$500 nmol ml^{-1} d^{-1} at $\sim$5 cm sediment depth), the dominance of the ^{13}C-depleted archaeal biomarker archaeol and the absence of *sn2*-hydroxyarchaeol and crocetane point to an AOM community dominated by ANME1-archaea. At the surface of the sediment core, we found ^{13}C-depleted 4α-methylsteroids and diploptene, lipid biomarkers originating from MOx communities. The biomarker profiles are consistent with our visual observations. During sampling, methane bubbles emanated from the sea floor. This provides evidence that a fraction of methane bypassed the AOM filter in deeper sediments and implies MOx at the sediment surface. In the carbonates, we also detected ^{13}C-depleted lipids typical for AOM communities (eg. archaeol) but in contrast to the modern sediments, the carbonates also contained crocetane. This consequently suggests a contribution of ANME2-archaea to the AOM community that had been present in the sediments $\sim$3000 years ago and which were then encased and preserved in the carbonate matrix. Similar to sediments, we also found 4α-methylsteroids and diploptene in the carbonate matrix. Just as for the sediments, our results suggests a close proximity of AOM and MOx communities and thus a strong methane flux at the time of carbonate precipitation.

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