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The isotopic signature of methane oxidation in a deep south-alpine lake

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Anoxic aquatic environments are an important source of biogenic methane, which contributes significantly to the atmospheric methane budget. Anaerobic oxidation of methane (AOM), mediated by Archaea in symbiosis with sulfate-reducing bacteria, is mainly responsible for the elimination of methane in marine ecosystems. In contrast, the oxidation of methane in fresh-water environments is usually attributed to aerobic methanotrophic bacteria. In this study, modes of microbial methane oxidation in south alpine Lake Lugano were investigated using biogeochemical, lipid biomarker and stable carbon isotope techniques. The northern basin of Lake Lugano is meromictic, with a permanent anoxic hypolimnion below 125 m water depth. Here, methane concentrations were found to decrease from 50 μM in the bottom water to about 20-40 nM at the oxycline. The steepest concentration gradient was observed at a water depth of ca. 200 m, i.e. 70 m below the oxycline. Concomitant with decreasing methane concentrations, we observed an increase in the δ^{13}C-values of the residual methane, with εgf about 20‰ within the anoxic zone, suggesting strong C-isotope fractionation during microbial CH_4 oxidation. A negative shift in the δ^{13}C-values of monoenoic C16 fatty acids in association with the observed methane gradients provides evidence for the incorporation of ^{13}C-depleted, methane-derived carbon into bacterial biomass. The spatial pattern of methane and biomarker δ^{13}C-values suggests the dominance of an anaerobic mode of methane oxidation, yet, no ^{13}C-depleted archaeal biomarkers were found. In the absence of oxygen, other possible terminal electron acceptors are under investigation. However, based on flux calculations from geochemical data, sulfate appears to be an unlikely candidate. Ongoing methane concentration and δ^{13}C-measurements since 2008 indicate an increasing importance of aerobic methanotrophy in the northern basin of Lake Lugano.