Characterization of methanogenic Archaea and stable isotope fractionation during methane production in the profundal sediment of an oligotrophic lake (Lake Stechlin, Germany)

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ABSTRACT: The methanogenic archaeal community, methane production, and carbon isotopic fractionation were studied in the profundal sediments of oligotrophic Lake Stechlin. Because the water column of oligotrophic lakes is usually oxic, CH_4 is normally not produced in the sediment surface layers. Nevertheless, 16S rRNA gene sequences of both acetoclastic *Methanosaeta* spp. and hydrogenotrophic *Methanomicrobiales* were detected, and potential CH_4 production (assayed at 30° C) was much higher at the surface (0-5 cm) than in the deeper (20- 25 cm) sediment layers, albeit starting only after sulfate was reduced. Copy numbers of the bacterial 16S rRNA genes were also higher in the surface than in the deeper sediment layers, but those of archaeal 16S rRNA genes were similar. Hydrogenotrophic and acetoclastic methanogenesis contributed equally to methane production, as quantified by a comprehensive analysis of $\Delta^{13}C$ in organic carbon, acetate, CO_2, and CH_4 and by determination of the isotopic enrichment factor for conversion of CO_2 to CH_4. This value (~-78‰) indicates that the Gibbs free energy of hydrogenotrophic methanogenesis was more negative, implying the energetic conditions in situ were more favorable, than suggested by measured H_2 partial pressures. The fermentatively produced acetate-methyl was by about 10‰ lighter than the $\Delta^{13}C$ of sediment organic carbon, indicating an unusual fractionation during fermentative production of acetate. Homoacetogenesis from CO_2 probably played only a minor role because the intramolecular difference between the $\Delta^{13}C$ of the carboxyl and the methyl groups of acetate was only on the order of 20‰. A remarkable microbial community is able to produce methane from organic matter in the oxidized surface layer of oligotrophic lake sediments in which methane normally is not produced, so that the ecological relevance of this potential is presently unclear.