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Growth of methane-cycling archaea in subsurface sediments fueled by burial-related geochemical changes

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Marine sediments harbor Earth's largest reservoir of methane but are considered to only be minor sources of methane to the present-day atmosphere. This is because most of the methane that is produced in marine sediments – largely by methane-producing archaea - is consumed by anaerobic methane-oxidizing archaea before reaching the seafloor. Recent evidence, however, suggests that nearshore methane emissions are more important than previously thought and potentially on the rise. This highlights the importance of understanding the rates and pathways of microbial methane production and consumption in nearshore sediments.

Here we investigate the controls of methane-cycling archaeal abundances, community composition, and biochemical pathways at four continental margin sites across the North Sea-Baltic Sea transition. Using an interdisciplinary approach that includes analyses of geochemical gradients and stable carbon-isotopic compositions, functional gene (*mcr*A) copy numbers and DNA sequences, and thermodynamic calculations, we observe strong changes in methane-cycling archaeal communities in relation to vertical gradients in sulfate concentrations. Methane-cycling archaea in bioturbated and sulfatic sediments are dominated by methyl-disproportionating and CO_2-reducing taxa (*Methanosarcinaceaea*, *Methanomicrobiaceae*), while sulfate-methane transition zones (SMTZ) mostly harbor known methane-oxidizing taxa (ANME-2a-b, ANME-2c, ANME-1a-b). By contrast, underlying methanogenic sediments are dominated by the physiologically uncharacterized ANME-1d, novel genera of putatively CO_2-reducing *Methanomicrobiaceae*, and methyl-reducing *Methanomassiliicoccales*.

Strikingly, *mcr*A copy numbers of major methane-oxidizing and methane-producing taxa increase by 2 to 4 orders of magnitude from sulfate-rich into sulfate-depleted subsurface layers, indicating significant population growth in response to burial-related geochemical changes. We propose that methane-cycling archaeal communities in continental margin sediments undergo three successional stages (sulfatic, SMTZ, methanic), wherein each shift in successional stage coincides with a growth- and mortality-driven turnover of dominant methane-cycling archaeal taxa.