Mineralization rates across the sulfate-methane-transition of Holocene marine sediments are continuous and partially mediated by syntrophic acetate oxidation

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Knowledge about controls and rates of organic matter (OM) degradation in marine sediments is key to our understanding of carbon cycling in the deep biosphere. Although individual processes in the microbially mediated OM degradation chain are thought to be well constrained it remains highly uncertain how rates of OM mineralization progress through different geochemical zones. In order to study the transition from sulfate reduction– to methanogenesis–driven mineralization, we performed highly depth-resolved analysis of geochemistry and microbial activities in Holocene sediment cores (up to 8 m length) from 5 stations in the Baltic Sea. Sulfate reduction rates, as determined by $^{35}S\text{-}SO_4^{2-}$ tracer experiments, decreased along a similar depth-trend at all sampling sites. At the sulfate-methane transition the rate of sulfate reduction dropped abrubtly, with a concomitant increase of ^{14}C-DIC methanogenesis rates. As a result, overall rates of mineralization progressed continuously with OM age and reactivity throughout the sediment, irrespective of the prevailing redox zonation and associated changes in the microbial degradation pathway. This suggests that the efficiency of OM mineralization in marine sediments is not attenuated under methanogenic conditions, and confirms the often predicted primary 'donor' control on the activity of the sediment microbiome. In all depths CO_2 reduction was the predominant pathway of methanogenesis, and ^{14}C-acetate was almost exclusively converted to $^{14}C\text{-}CO_2$, even in the methane zone where potential electron acceptors other than CO_2 are depleted. Challenging previous views of the microbial degradation chain in marine sediments, we attribute this observation to the only known alternative pathway for acetate consumption under methanogenic conditions – acetate oxidation (to CO_2 plus H_2 and/or electrons) that is syntrophically coupled with hydrogenotrophic methanogenesis.