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Microbially mediated sulfur cycling in cold seep sediment

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Cold seeps are unique deep-sea ecosystems that play an important role in marine biogeochemical cycles. However, the dynamics and regulation of sulfur isotope biogeochemistry in seep sediments remain unconstrained. We investigated the geochemical characteristics of active seep sites, including the content and stable isotope composition of sulfur species and sulfate reduction rates. High methane concentrations (>1 mM) with rapid sulfate depletion were observed in ~25 cm sediment cores at active seep sites. The S-shaped downcore distribution of sulfate suggested non-steady state diagenesis induced by advective transport of venting fluids. The relatively consistent $\delta^{34}S$ values of pyrite throughout the cores indicated that the majority of pyrite formation occurred during early sedimentation in surface sediments. ^{34}S-enriched pyrite (−7.3‰) was found in surface sediment, suggesting the low sulfur isotope fractionation, calculated between 30–35‰. This observation provided field evidence for the long-standing notion from laboratory incubations that high cell-specific sulfate reduction activity with elevated methane concentration leads to small sulfur isotope fractionation. High estimates of cell-specific sulfate reduction rates, 18–69 fmol cell^{-1} day^{-1}, together with data collected from previous studies, confirmed that elevated sulfate reduction activity at seeps contributed to smaller sulfur isotope fractionation (11.5–35‰) than found typically in shelf sediments (44.5–66.5‰), leading to ^{34}S-enriched pyrite (~–10‰) (Figure 1). These results together revealed a dynamic sulfur cycling fueled by anaerobic oxidation of methane and provided insights into sulfur isotope biogeochemistry in cold seep sediments.

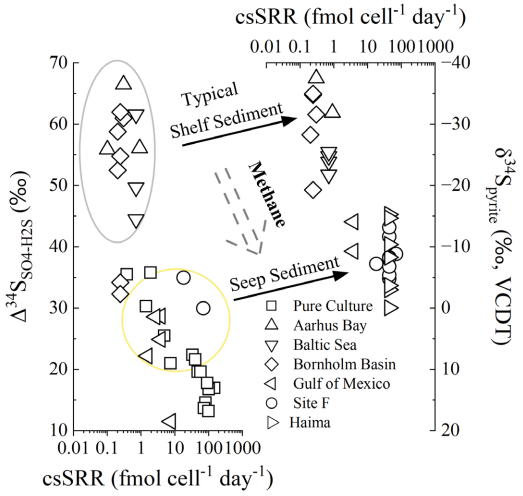


Figure 1. Relationships between cell-specific sulfate reduction rates (csSRR), the isotopic fractionation between porewater sulfate and sulfide ($\Delta^{34}S_{SO4\text{-}H2S}$) and the isotopic composition of pyrite ($\delta^{34}S_{pyrite}$) in marine surface sediment. The data were collected from pure cultures, typical shelf sediments (Aarhus Bay, Baltic Sea and Bornholm Basin) and cold seep sediments (Gulf of Mexico, Site F of South China Sea and Haima cold seep of South China Sea).