

Sulfur isotope records of microbial sulfate reduction in cold seep carbonates

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Cold seep carbonates form in shallow subsurface of marine sediments due to the microbial anaerobic oxidation of methane (AOM). As a result they are unique archives of the locus and intensity of past methane seepage. Because AOM is mainly driven by the microbial reduction of seawater sulfate, sulfur isotopes may help to reconstruct the biogeochemical conditions under which seep carbonates precipitate. For this purpose, we have investigated the multiple sulfur isotope compositions of paired carbonate associated sulfate (CAS) and pyrite in seep carbonates, taken as proxies for porewater sulfate and sulfide, respectively. Analyzed samples were collected from 5 different seepage sites in the North and Barents Seas.

The sulfur stable isotope compositions of pyrite (average $\delta^{34}\text{S} = -6.7 \pm 11.2 \text{‰ VCDT}$, $n=38$) are depleted compared to seawater sulfate whereas CAS compositions (average $\delta^{34}\text{S} = +42.2 \pm 7.3 \text{‰ VCDT}$) are enriched. Such $\delta^{34}\text{S}$ values are consistent with dissimilatory bacterial seawater sulfate reduction associated with AOM in porewater. The wide range of isotopic composition of CAS and pyrite ($\delta^{34}\text{S}$ ranging from +26.2 to +61.6 ‰ VCDT and from -23.5 to +14.8 ‰ VCDT, respectively) suggests that carbonates have formed under changing porewater geochemical conditions in the diagenetic realm. The use of a transport-reaction model to reconstruct the obtained sulfur isotope data will help to better constrain the geochemical conditions during carbonates precipitation.