Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.15469

Quantification of the sources of sedimentary organic carbon at methane seeps: A case study from the South China Sea

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Large amounts of methane are stored along continental margins in the form of methane hydrate. Methane hydrate is sensitive to environmental change, releasing substantial quantities of methane upon its destabilization. In the marine subsurface, microorganisms consume most of the methane in the sulfate-methane transition zone and convert a certain, yet poorly defined amount of methane into organic matter. However, the controls on the formation and consumption of sedimentary organic matter at marine seeps remain poorly constrained, impeding accurate quantification of carbon burial at seeps and its role in the marine carbon cycle. To gain new insight into the effect of seeps on carbon burial, sediments from two seep sites of the South China Sea (Site F, Haiyang 4) and a nearby reference site (Jiulong canyon) were analyzed for total organic carbon contents (TOC), $\delta^{13}C_{TOC}$ and $\Delta^{14}C$ values, total inorganic carbon contents (TIC) and $\delta^{13}C_{TIC}$ values, as well as organic nitrogen (N) contents. Depth distributions reveal that the TOC at seeps (Site F, 0.55% ± 0.08%, Haiyang 4, 0.67% ± 0.11%) is higher than in sediments not affected by seepage (Jiulong canyon, 0.50% ± 0.10%). At the two seep sites, the sediments are characterized by more negative $\delta^{13}C_{TOC}$ and $\Delta^{14}C$ values and a lower TOC/N ratio, indicating a contribution of the microbial fixation of ^{13}C-depleted methane to the local pool of sedimentary organic matter. Using a $\Delta^{14}C$ mass balance approach, we show that carbon derived from fossil methane accounts for at least 10 to 20% of the organic carbon preserved in the sediments. By comparing seeps, hydrate-bearing sediments, modern coastal sediments, and Archaean rocks, it becomes apparent that the carbon stable isotope composition of organic carbon in seep sediments is mainly controlled by the rate of methane oxidation and marine primary productivity. High ^{13}C-depletion of sedimentary organic matter is reflecting high methane oxidation rates and relatively lower marine primary productivity. Given its abundance along continental margins, we suggest that methane seepage represents a prominent source of “old” carbon in marine environments.