Cryptic sulfur and methane cycling in marine sediments

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The term “cryptic sulfur cycle” was coined for the low rates of sulfate reduction detected by Holmkvist et al. (GCA, 2011) using sensitive radiotracer experiments in subsurface marine sediments. Since then, the term “cryptic” has become widely used, mostly to describe processes of re-cycling that do not leave a net imprint in the pore water chemistry. For sulfur and methane, there are two hotspots of such cryptic cycling: the partly oxidized and bioturbated surface sediment and the deep sulfate-methane transition (SMT).

In the oxidized surface sediment, where methane concentrations are very low, peak rates of methanogenesis and anaerobic methane oxidation co-occur. The methane source is diverse methylated compounds, and the diversity of methanogenic archaea is large. Also sulfate reduction peaks here, but due to bioirrigation and sulfide re-oxidation this leaves little or no imprint in the sulfate. Whereas sulfate reduction can be measured by a radiotracer method, similar direct measurements of sulfide oxidation are hampered by rapid isotope exchange between the reduced sulfur species and have only recently succeeded.

In the sulfate-methane transition zone, co-occurring processes of methane production and methane oxidation have also been detected. This drives a cryptic methane cycle, which contributes significantly to the total methane production in the seabed. Surprisingly, putatively methane oxidizing ANME-1 archaea were found to totally dominate the *mcrA*-containing archaeal community where methanogenesis was observed, both in the SMT and in the methane zone below. The genome of these ANME-1 indicates the capacity to run their catabolic machinery either forward or backward and thereby switch between being methane oxidizers or methanogens. It is now speculated that this capacity may depend upon direct interspecies electron transfer, either to a sulfate-reducing bacterium or from an electron-donating acetate oxidizer. The sulfate flux down into the SMT generally exceeds the requirement for stoichiometric oxidation of the upward methane flux. The excess sulfate is consumed by the degradation of organic matter buried down into the SMT.