The development of the sulfate-methane transition zone: A case study from the Portuguese margin

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Microbial sulfate reduction is responsible the near-quantitative anaerobic oxidation of biogenic and thermogenic methane in modern marine sediments, in a process known as sulfate-driven AOM. When sulfate is consumed through AOM, the sulfate concentration pore fluid profile is often linear from the overlying seawater to the sulfate-methane-transition zone indicating all sulfate is consumed through sulfate-driven AOM. This is enigmatic because there is often labile organic carbon within the sediments above the sulfate-methane transition zone, and the oxygen isotopes in the pore fluid sulfate often suggest that there is active sulfate reduction occurring within the overlying sediments.

At Site U1385, drilled during IODP Expedition 339, high-resolution sulfate concentration measurements in the pore fluids display non-steady-state behavior with two distinct zones of sulfate consumption; organiclastic sulfate reduction in the top of the sediments and sulfate-driven AOM deeper in the sediments with a hiatus in sulfate reduction in between. The sulfur and oxygen isotopes in the pore fluid sulfate support the idea that sulfite to sulfide reduction is the limiting step in microbial sulfate reduction, and that the isotope fractionation expressed in the residual pore water sulfate pool is inversely proportional to the net sulfate reduction rate. The sulfur isotope composition of pyrite acquires one value in the uppermost sediments, which is overprinted by a second value in the deeper sediments, due either to iron release during anaerobic methane oxidation or iron diffusion from a higher zone of bacterial iron reduction. We use a time-dependent numerical model to explore when methane was introduced into the sediment such that today we capture an evolving sulfate-methane-transition zone that has yet to reach steady state. These results are useful in understanding the development of the enigmatic linear profiles often seen in sulfate-methane-transition zones in modern marine sediments.