

Carbon and Sulfur Cycling in Shallowly Buried Sediment of the Japan Sea/East Sea

DICKENS, Gerald^{1*}; KINSLEY, Christopher W.²; DUNLEA, Ann G.³; ANDERSON, William A.⁴; DA COSTA GURGEL, Marcio H.⁵; LEE, Kyung eun⁶; MURRAY, Richard W.³; TADA, Ryuji⁷; ALVAREZ ZAREKIAN, Carlos⁸; EXPEDITION 346, Scientific party⁸

¹Rice University, ²Massachusetts Institute of Technology, ³Boston University, ⁴Florida International University, ⁵Universidade de Sao Paulo, ⁶Korea Maritime University, ⁷University of Tokyo, ⁸Texas A&M University

Continental slopes cover about 10% of Earth's surface and represent the primary repository for sediment and organic carbon accumulation on long-time scales. For decades, the geochemical community has introduced and discussed various models for how ocean carbon and sulfur chemistry changes over time. Remarkably, in most of these models, the seafloor on continental slopes is either absent or passive. In the latter case, the prevailing view is as follows. During burial, organic carbon passes through a gauntlet of microbially mediated reaction in shallow sediment, especially including organoclastic sulfate reduction and methanogenesis. Although these reactions generate dissolved species (HCO₃⁻, HS⁻, CH₄), burial fluxes exceed those of upward advection or diffusion. The end process, therefore, is accumulation of remnant solid organic carbon, authigenic carbonate, and authigenic Fe-sulfides. As suggested in several recent papers, this view may be incorrect. Instead, on the slope, a good fraction of solid organic carbon bypasses organoclastic sulfate reduction to produce dissolved inorganic carbon, dissolved organic carbon, and methane at depth. Large portions of these species return toward the seafloor because upward dissolved fluxes exceed burial. However, upward migrating methane reacts with dissolved SO₄²⁻ to produce HCO₃⁻ and HS⁻ via AOM in shallow sediment. The end process is still accumulation of remnant solid organic carbon, authigenic carbonate, and authigenic Fe-sulfides, but the fluxes are linked through the formation, storage and consumption of methane.

It is entirely possible that variations in methane cycling within slope sediments drive significant long-term and short-term changes in ocean carbon and sulfur concentrations. To entertain this idea, however, the broad Earth Science community needs quantified fluxes of solid and dissolved components from appropriate settings. One current problem is that very few locations on continental slopes that have detailed pore water profiles extending 200 m below the seafloor with companion sedimentary records.

IODP Expedition 346 drilled multiple holes at seven sites across the Japan Sea/East Sea. The primary objective behind this cruise was late Neogene and Quaternary paleoceanography: more specifically, to reconstruct changes in surface and deep ocean water properties, riverine outflow, and dust input over the last 5-10 million years, which might be linked to the evolution and temporal differences in the Asian monsoon system. One interesting outcome of this goal was that the sites span a wide range of slope environments with considerable variation in organic carbon accumulation. Another was exquisite sediment recovery, with spliced cores between holes giving complete records from the seafloor to several hundred meters.

Expedition 346 provided a golden opportunity to chase the dynamic geochemical cycling of carbon and sulfur on continental margins. Using a combination of rhizon sampling and whole round squeezing, about 680 pore water samples were collected at the seven sites and analyzed for a broad array of dissolved species. The shipboard pore water geochemistry profiles generated on Expedition 346 are truly remarkable in terms of species examined, their detail across zones of chemical reaction, and the ability to directly couple them to the sedimentary record. Here, on behalf of the Expedition 346 scientists, we discuss the generation of the pore water profiles and their significance to carbon and sulfur cycling on continental slopes. For example, at Site U1427, there is no question as to the dominant process and where species are being produced and consumed in shallow sediment. Upward migrating CH₄ is reacting with SO₄²⁻ via AOM to produce HCO₃⁻ and HS⁻, the first product leaking to the seafloor, the latter product being consumed into sulfide minerals.

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