Organic matter cycling and nutrient dynamics in permeable sediments

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Sediments of high permeability are characterized by fast exchange of solutes across the sediment-water interface (SWI), by their ability to filter out particles from the water column, and by subsequent high organic matter turnover rates. My work explores the entrapment and decomposition of particulate organic matter in reef permeable sediments and the subsequent nutrient dynamics and, specifically, the axiom that nutrients produced during organic matter decomposition may enhance pelagic primary productivity. I investigated these processes by designing a novel experimental laboratory microcosm that allows incubation of 1-m deep permeable sediment columns under controlled, oscillatory (wave-like) physical forcing. Non-destructive sampling of microcosm sedimentary pore water enables biogeochemical mass balance calculations and the estimation of decomposition rates and fluxes across the SWI. Oscillatory physical forcing during experimentation generated enhanced solute transport rates (orders of magnitude greater than diffusion), which were roughly proportional to sediment column permeability. Comparison with field observations at the Kilo Nalu Observatory in Honolulu, Hawai`i, revealed that the enhanced transport rates induced by the experimental conditions were lower than those observed in the field, and this was also reflected in the enhanced build-up of pore water nutrients relative to concentrations in field sediments. Particulate organic matter and nutrient enrichment experiments, conducted with the microcosm, demonstrated the rapid uptake of both particles and solutes by the permeable sediment column under physical forcing, the rapid decomposition of the removed particles, and the lack of regenerated nutrient build-up. These results suggested a large capacity by reef permeable sediments to burn organic matter rapidly and to retain regenerated nutrients. Another set of nutrient enrichment experiments with surface sediment plug chambers demonstrated the rapid uptake and retention of nutrients by surface permeable sediments. Stable-isotope-labeled nitrate enrichment experiments verified nitrate assimilation by reef sediment microbiota, but also gave evidence for significant nitrogen loss though benthic denitrification. The experimental conditions suggested that this denitrification must be taking place in microniches formed by the rough surface of the biogenic carbonate reef sediment grains. Ultimately, processes on the microscale may control shelf-scale biogeochemical cycling of the main bioelements.