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Fast Recycling Rate of Alkalinity at the Seafloor and the Role of Respiration-Driven Carbonate Dissolution in the Alkalinity Cycle

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In today's ocean, ecosystems at the surface produce solid $CaCO_3$ far in excess of the flux needed for burial in sediments to balance the alkalinity inputs from rivers. This overproduction implies that the control of $CaCO_3$ preservation at the seafloor, and therefore the largest output term in the alkalinity balance of the ocean, is set by the rate of carbonate dissolution, not precipitation. We built a new seafloor lander to collect filtered porewater from the upper 20-30 centimeters of sediment, so that no depressurization artifacts alter the pH, alkalinity, DIC, and $\delta^{13}C$ of DIC from their in-situ values. In a depth transect of stations at the Cocos Ridge (5°N, 87°W), we document sharp gradients in alkalinity and DIC that require $CaCO_3$ dissolution with CO_2 produced from organic matter degradation. This respiration-driven dissolution can dramatically shorten the response time for 'carbonate compensation' to adjust deep-ocean $[CO_3^{2-}]$ when either the atmospheric CO_2 or alkalinity cycle is perturbed from a steady-state.

Using a new model of the upper portion of newly forming marine sediments, RADIv1 and RADIv2, we explore how these new data from the Cocos Ridge can alter our understanding of the shape of the lysocline more generally. We also use the model to quantify the rates of alkalinity recycling at the seafloor under a range of bottom-water and sediment-flux conditions. In particular, we investigate the combined influence of nonlinear dissolution kinetics and transport across a diffusive boundary layer at the sediment-water interface, providing new insights into lysocline dynamics. The new model emphasizes the coupling of the carbon and alkalinity cycles at the seafloor as we develop a quantitative picture of the burial rates of organic carbon and $CaCO_3$, providing a mechanistic basis for representing benthic $CaCO_3$ dissolution in larger-scale carbon-cycle models.