The influence of a diffusive boundary layer on early organic matter and calcium carbonate diagenesis

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The diffusive boundary layer (DBL) is a thin fluid layer that extends a few hundred microns to millimeters above the sediment-water interface. In the DBL, molecular diffusion is the dominant mode of solute transport and laboratory experiments of sediment calcium carbonate (CaCO₃) dissolution in seawater suggest that diffusion through the DBL is the rate-limiting step for CaCO₃ dissolution at the seafloor. Nevertheless, earlier assessments of in situ CaCO₃ dissolution at the sediment-water interface in the central equatorial Pacific indicated that DBL thickness does not impact overall dissolution rates (Berelson et al., 1994). Here, using a diagenetic model that incorporates the latest CaCO₃ dissolution kinetics, organic-matter degradation, and a DBL above the sediment-water interface, we examine reasons for this apparent inconsistency.

We show that DBL control of benthic CaCO₃ dissolution is a function of both organic matter flux to the seafloor and bottom-water saturation state with respect to CaCO₃. In shallower, supersaturated waters, thicker DBLs trap organic-matter degradation by-products in sediment porewaters and in most cases favor CaCO₃ dissolution. In deeper, undersaturated waters, thicker DBLs maintain sediment porewater near equilibrium with respect to CaCO₃ and thus facilitate CaCO₃ preservation. Regardless of the bottom-water saturation state with respect to CaCO₃, DBL thickness strongly affects the depth distribution of porewater solutes and should be taken into account when interpreting measured or reconstructed sedimentary pH profiles. More broadly, our modeling results stress that the DBL is a diffusion barrier that acts in both directions. In sediments subject to a strong organic matter delivery, thicker DBLs can inhibit oxygen penetration and promote porewater anoxia, thus affecting both sediment chemistry and biology.

Reference: