MOUNTJOY CARBONATE
RESEARCH CONFERENCE III
AUGUST 14-18, 2022 | Banff Centre, AB, Canada

Dolomitization by Tidal-pressure-driven Chemical Cycling in Organic-Rich Carbonate Sediments

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Strata-bound dolomitization must occur by alteration of initial calcium carbonate sediments during the early stages of diagenesis. For this to happen at ambient surficial temperatures requires a mechanism for recrystallization of the soft sediments in conjunction with a mechanism for the nucleation and growth of ordered dolomite crystals since diffusion rates are too low at those temperatures to create ordered dolomite from disordered dolomite and disordered dolomite is unstable. To create an ordered dolomite at ambient surficial temperatures requires alternating deposition of calcium carbonate and magnesium carbonate layers, requiring chemical cycling of $CaCO_3$ and $MgCO_3$ supersaturation along with sources for the required excess Ca and Mg.

Marine surficial sediments experience pressure cycling due to the periodic rise and fall of the tide, with fluids being driven in and out of the surficial sediment in response to the tidal cycle. Where permeability of the sediments is low, there is an appreciable lag between rise and fall of the fluid pressure in the marine water column and resulting rise and fall of the sediment pore pressures. This lag results in periodic variations in the pressure experienced by the sediment matrix, resulting in low-level pressure solution effects during the tidal rise cycle. It is this pressure solution that drives much of initial recrystallization and cementation of most marine carbonates, and it creates the appropriate supersaturation required for deposition of calcium carbonate layers in ordered dolomite.

Where the carbonate sediments are intermixed with significant concentrations of organics from photosynthetic organisms, the decay of the chloroplasts releases Mg into the pore fluid. It is this extra Mg that oversaturates the system and allows the deposition of $MgCO_3$, but only when the $CaCO_3$ is not being actively precipitated. The exhalation of pore fluids (including H_2S and various organic acids) during tidal fall (when the pressure solution of the $CaCO_3$ system is inactive) causes Eh-pH changes that further facilitate deposition of $MgCO_3$ by effectively lowering the solubility.

Thus, ordered dolomite is created during diagenesis of surficial carbonate sediments by tidally-driven pressure differences between the marine water column and the sediment pore fluid. These pressure differences are significant only in fine grained sediments or in sediments capped by an impermeable layer (such as an algal mat), and decaying photosynthetic organic material within the sediment is necessary for the $MgCO_3$ supersaturation required for dolomite growth.