Reactive transport modelling the early meteoric diagenesis of a carbonate island: a critical consideration of complexity

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Reactive transport models are being used to understand carbonate diagenesis in a range of settings by investigating overarching controls on the diagenetic patterns. Most studies have focussed on the evaluation of conceptual models, and simulations of specific locations that allow comparison with observational data are rare. There is a need to understand how simplified representations of complex carbonate systems may affect the conclusions drawn from the more generic models. What is the gain for the additional effort? And what are the implications of uncertainties inherent in model parameterisation?

This work follows the development of a 2D reactive transport model of interaction between meteoric waters and young carbonates in an island setting, using TOUGHREACT. Initial simulations modeled the phreatic zone of a generic island with homogeneous rock properties. These early simulations evaluated the sensitivity of diagenesis to key controls, in both the freshwater lens and underlying fresh-salt water mixing zone. Results showed that different processes drive diagenesis in these two environments. At the top of the freshwater lens, dissolution was enhanced by increasing both the effective recharge and the biogenic CO_2 concentrations. Within the mixing zone the dissolution was more sensitive to the rate of effective recharge than to the pCO_2 of the meteoric waters. By increasing the effective recharge a deeper and thicker mixing zone develops and this increases dissolution rates.

This model was then developed to more accurately represent the well-studied meteoric system on North Andros, Bahamas. We evaluated the effects of the addition of a vadose zone along with seasonal variations in recharge on the dissolution patterns. Preliminary results suggested that both these parameters alter the effective recharge and modify the flux of CO_2 into the system. This alters both the dissolution at the top of the freshwater lens and within the mixing zone.

The impact of heterogeneities on the distribution of rock properties was included into the model. Preliminary flow simulations suggested that low permeability paleo-exposure horizons, even at some depth beneath the mixing zone, thin the lens and focus saltwater flow beneath the mixing zone, potentially enhancing mixing zone dissolution.