Towards a general model of isotopic fractionation for biogenic carbonates

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It is well established that the fractionation of stable-isotopes ($^{18}O/^{16}O$, $^{13}C/^{12}C$ and ^{13}C-^{18}O clumping) between biogenic carbonates and their aquatic environments is mechanistically distinct from strictly inorganic fractionation processes. Over the past decades, several theories and numerical models have emerged to explain and predict stable-isotope 'vital effects' in various biogenic carbonates such as corals, foraminifers, coccolithophores, ostracods and other taxonomic groups. A conclusion from these past works is that there are many similarities in isotopic fractionation mechanisms between different group of organisms. Despite the mechanistic overlaps, no single numerical model reproduces the stable-isotope signature of multiple groups of biological calcifiers. Hence, current numerical models of isotopic fractionation are restricted to narrow taxonomic groups, limiting model applicability and usage by the community. We attribute these limitations to three factors: (1) a lack of conceptual consistency between models, (2) a large number of unconstrained model parameters and (3) limited customization of model components.

Here we review the mechanisms that are likely to cause vital effects in biogenic carbonates and introduce a conceptual framework for the development of a general model of isotopic fractionation in biologically-secreted carbonates. The model should include a full description of the carbonate chemistry of the calcifying fluid and be adaptable to different biogenic calcifiers by (de)selecting a range of model components that simulate inorganic and metabolic processes of isotopic fractionation. We illustrate the applicability of such a general model using new and previously published isotopic data from shallow corals, foraminifers and ostracods. From this review, we highlight necessary model-development steps and identify major unknowns in model parameters that need solving by conducting new laboratory-based (bio-)carbonate growth experiments.