Biomineralization mechanisms: A novice biomineral enthusiast's perspective

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Biomineralization: A General Model

Organic mediated growth of mineralized skeletal components by single-celled eukaryotes is a fundamental process that occurs through several steps. Extraction of the chemical constituents for biomineral growth from aqueous solution occurs as ions are pumped through specialized cation pumps to allow specific concentration gradients to develop within the cell (Bhattacharyya and Volcani, 1999). Initial growth is fostered within membrane-bound vesicles that are shaped by cytoskeletal elements into a template for mold for test construction (Leadbeater, 1987). Within the vesicle, pH and ionic composition are controlled and allowed to develop supersaturated conditions for the nucleation and aggregationof mineral material(Vrieling etal, 1999). The walls of the vesicle are composed of polysaccharides and proteins that act as nucleation points for crystal growth. The placement of these compounds along the vesicle walls and the overall form of the vesicle are coded for within the genome of biomineral secreting protists and chromists (Hildebrand etal, 1997). After precipitation of the test, the test is either exocytosed to the exterior of the cell as in coccolithophores and diatoms or remains with the cell as an internal test as exemplified by radiolarians and silicoflagellates.

References

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Effects of temperature and transport conditions on Magnesium contents in calcite

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The potential for extracting environmental conditions from chemical impurity signatures recorded in fossil calcite samples motivates much current effort in paleoclimatology. However, correlations between trace element contents and physical or chemical conditions are not simple. Often, multiple controls appear to be at work in governing uptake of a given impurity. Reliable interpretations of element-based paleoproxies will require understanding, with some certainty, the growth behaviour of calcite for the relevant conditions. Notably absent from the literature are definite conclusions regarding relationships between temperature, growth rate, and impurity partitioning for Mg in calcite. Studies disagree on the importance of growth rate and only a few bulk precipitation studies have systematically varied temperature.

Another factor not often considered is the rate-controlling mechanism, *i.e.*, whether growth rate is limited by diffusive transport of chemical components to the mineral surface or by surface reactions such as dehydration, adsorption, and formation of lattice bonds. Variations in the dominant mechanism obviously cause variations in growth rate and boundary layer thickness and may thus affect the extent and nature of impurity incorporation during growth. The distinction potentially has important ramifications for the Mg contents of natural calcite samples.

This study links direct measurement of nanoscale effects of temperature, fluid Mg concentration, and near-surface transport conditions on calcite growth rates with high-spatial-resolution analysis of Mg contents in resulting crystals. In contrast to previous experiments on Mg partitioning into calcite, here the layer-growth mechanism was observed *in situ* and step speeds precisely measured with fluid cell atomic force microscopy over a range of temperatures, degrees of supersaturation, and solution Mg concentrations. Data collected from 15° to 30°C yield an activation energy for calcite precipitation of 33 kJ/mol for solutions with $[Mg]=5x10^{-5}$ M. Electron microprobe analyses of large hillocks grown at corresponding conditions demonstrate that Mg has a strong preference for incorporation at negative (acute) step edges, rather than at positive (obtuse) edges when growth rate is limited by surface reactions. This preference is reversed when growth is instead limited by diffusion through a boundary layer at the mineral-solution interface. This result shows that transport conditions during mineral growth may be a first-order control on impurity contents and distribution.