Model perspectives on stable mineral recrystallization

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Stable mineral recrystallization is a recently identified process by which minerals exchange with ambient solution without overt mineralogical, compositional, or morphological changes. It is a phenomenon that has significant implications for the interpretation of geochemical proxies, and thus can impact mineral-based biosignatures and paleoclimatic reconstructions. Recent work suggests that significant mass fractions of minerals, such as iron oxides, exchange with ambient solutions over extremely short time scales. Similar behavior has also been observed in non-redox active minerals, such as calcite and barite, but generally to lesser extents. We note that there are clearly coherent proxy-based trends that reveal critical information about the past. The objective of this work is not to call that into question, but to understand how minerals interact with solutions and quantify the extent to which such interactions can alter bulk solid chemistry, and thus, impact proxy-based reconstructions of the past.

To date, experimental stable mineral recrystallization data have been interpreted using two endmember models: the so-called “homogeneous” and “heterogenous” models. The former assumes a solid reservoir that is always open to exchange (and instantaneously equilibrates with the fluid), while the latter supposes that recrystallized solid is unreactive. The two models can result in substantially different interpretations of recrystallization rate and extent of reaction, which will be discussed. The key points that arise from model-based explorations are that the solid to fluid mass ratio, as well as measurements of both the solid and fluid phases, are critical to take into account when interpreting exchange experiments.

Recent experimental work has suggested that neither the homogeneous nor the heterogeneous models are appropriate to explain short-term stable mineral recrystallization, and that instead a hybrid model is appropriate. This finding will be discussed in light of recent “respike experiments”, in which ^{55}Fe tracer is used to elucidate solid-fluid exchange over 60 days. A clear understanding of stable mineral recrystallization allows for more accurate interpretations of mineral-based archives, and consitutes a framework for identifying low fidelity minerals in the rock record that may be impacted by diagenesis.