Zoned garnets and the duration of metamorphic events

M.J. CADDICK* AND A.B. THOMPSON

Institute for Mineralogy and Petrology, ETH Zurich, Clausiusstrasse 25, NW, CH 8092 Zurich, Switzerland (*correspondence: mark.caddick@erdw.ethz.ch)

Several studies have experimentally determined diffusion coefficients for Ca, Mg, Fe and Mn in garnet, primarily as a function of temperature, and have described the interdependent behaviour of these elements. Equilibrium calculations have constrained *PT* conditions of major metamorphic reactions, predicting garnet growth (i.e. changing crystal mode, *M*, grain size, *d*, and composition, *X*) in common rock compositions (e.g. pelite) experiencing changing *P* and *T*. We combine these studies in forward models of crystal growth and intra-crystalline diffusion for specific heating/cooling rates. Our aim is to determine mineralogical indicators (*M*, *d*, *X*) that would distinguish records of fast (i.e. < 1 to 10 Myr), intermediate (10 to 30 Myr) and slow (30 to > 100 Myr) orogenic processes. Results indicate that distinct crystal zoning patterns are characteristic of certain ranges of temperature, time and grain size but that crystals with diameters > 2.5 cm or < 100 µm are not useful as duration indicators for geologically meaningful processes.

Large steps in garnet compositional profiles can generally be associated with specific prograde reactions, with important examples in pelite at normal crustal pressures (≤ 1.2 GPa) including plagioclase-in (reducing X^{Ca}) and chlorite or ilmenite breakdown (releasing Mn). Discrete steps in X^{Fe} and X^{Mg} require pseudounivariant equilibria, and are most likely associated with staurolite or chloritoid reactions. Partial or total homogenization of these features is time-dependent and the relative prominence of each step is a function of both heating and cooling rates. For example, retention of lower X^{Fe} than X^{Ca} and X^{Mn} in the cores of mm-scale garnet crystals that reached 700 ºC is indicative of very fast (<< 1 Myr) heating and cooling, but an X^{Fe} maxima between the crystal core and rim can be retained through > 20 Myr events. We target several key metamorphic assemblages and reactions that produce useful zoning profiles characteristic of orogenic episodes, emphasising those that are preserved only in short duration events (< 10 Myr).

Analytical HRSEM, HRTEM and FIB characterization of carbonaceous remains associated with hydrothermal deposits

S.L. CADY, R.C. HUGO, W.F. SMYTHE, M.N. PARENTEAU, J.C. GOIN, H. OAKES-MILLER, T. HODE[1], S. POGULA, J. HUSTER AND B. CAVALAZZI

Portland State University, Portland (cadys@pdx.edu)

Though a significant amount of research has been accomplished this past decade with regard to how microbial biosignatures form and become preserved in modern hot springs, we have found that a combination of micro-to-nanoscale imaging, diffraction, and spectroscopy analysis of such deposits continues to reveal new insight about biosignatures in hydrothermal deposits. Our strategy involves the iterative use of an analytical high-resolution scanning electron microscope (HRSEM), an analytical transmission electron microscope (HRTEM), and focused ion beam (FIB) analysis and sample sectioning for HRSEM & HRTEM use.

Our main focus is the characterization of carbonaceous remains with morphological biosignatures in hot spring deposits, with an emphasis on 1) permineralized microbial cells and extracellular polymeric substances (EPS) of biofilms and microbial mats, 2) biominerals produced by thermophilic and hyperthermophilic bacteria, and 3) biofabrics that retain evidence of microbial behavior or the former presence of microbial communities.

To recognize definitive evidence for life in mineral deposits, morphological features that appear similar to cells, EPS, and biofilm or mat structures will need to be located and analyzed with instruments that can reveal a suite of biosignatures associated with them. Though the combination of HRSEM, HRTEM, and FIB analysis cannot provide a comprehensive characterization of carbonaceous remains (e.g., biomarker and isotopic analysis are not possible), the techniques provide a means by which to 1) locate morphological biogenic-like features in rocks identified as potentially habitable, 2) target the distribution, spectroscopic, and diffraction characteristics of carbonaceous remains associated with the features, 3) identify biominerals and microbe-mineral interfaces, 4) distinguish biogenic and abiogenic components of such structures, and 5) document taphonomic alteration of (possible) biosignatures in rocks of different ages. Examples from our extensive collection of hot spring sinters from around the world will be presented and those aspects that reveal their biogenicity demonstrated.