Lu/Hf closure temperature estimate from alpine eclogite garnets

Skora, S., Baumgartner, L.P., *Mahlen, N.J., **Lapen, T.J., & *Johnson, C.M.

Institute for Mineralogy and Geochemistry, University of Lausanne, 1015 Lausanne, Switzerland
*Department of Geology and Geophysics, University of Wisconsin, Madison, WI 53706, USA
**Department of Geosciences, University of Houston, Texas, TX 77204, USA

Lu/Hf geochronology on garnets often yields older ages when compared to garnet Sm/Nd ages. Scherer et al. (2000) concluded that the Lu/Hf system may close at higher temperatures than the Sm/Nd system, yielding older Lu/Hf ages for slowly cooled, granulite facies rocks. In contrast, Lapen et al. (2003) linked the Lu/Hf and Sm/Nd age differences for an alpine UHP eclogite sample (Lago di Cignana, Italy) to prograde metamorphic REE zoning. They assumed that Lu will be strongly fractionated towards the garnet core due to high HREE partitioning into garnets. A lower Sm fractionation factor in term would result in relatively flat profiles for this element. Since not much is known about REE+Hf volume diffusion in garnets, the two hypotheses are difficult to evaluate.

We measured HREE zoning in alpine eclogite garnets within the Zermatt-Saas Fee ophiolite (ZSFO, Western Swiss Alps), which all reveal sharp, exponentially decreasing central peaks. These peaks can be used to place a limit on the rate of volume diffusion since the maximum distance a diffusion front could have traveled is, a priory, given by the distance from the center to the point x where the HREE concentration is half of the core concentration. Real core concentrations need to be extrapolated due to the extreme sharpness of these peaks that have been measured with La-ICP-MS (30 μm spot size). Base for this extrapolation is a transient numerical model, where the HREE uptake is controlled by diffusion rates in the matrix surrounding the porphyroblast. Application of this model fits well the observed exponential decrease in Lu (and other HREE) in the core region with a fitted partition coefficient for $Lu^{garnet\text{-}matrix}$ of around 1000. Resulting maximum Lu volume diffusion estimates are in the order of $5*10^{-25}$ m^2/s. Closure temperature (T_c) estimates for the initially very rapid cooled ZSFO (~50°C/m.y., Amato et al. 1999) result into minimum T_c's ranging from 720-755°C (for assumed activation energies of 250-300 kJ/mol), using the Dodson (1973) equation. Additional calculations with the extended formalism of Ganguly and Tirone (1998) for arbitrarily small amounts of diffusion indicate virtually no resetting for these samples from the ZSFO where T_{max} is supposed to be around 600°C. We further conclude that this minimum closure temperature estimate based on Lu volume diffusion applies as well for the Sm/Nd system, following the general observations that $D(Hf)<D(Nd)\leq D(Sm)\leq D(Lu)$. Hence, published Lu/Hf and Sm/Nd ages in alpine eclogites must be interpreted in terms of metamorphism because peak temperatures are below the closure temperature for Lu/Hf and Sm/Nd.

REFERENCES

Amato, J.M., Johnson, C.M., Baumgartner, L.P., & Beard, B.L. (1999): Rapid exhumation of the Zermatt-Saas ophiolite deduced from high-precision Sm-Nd and Rb-Sr geochronology. Earth and Planetary Science Letters 171: 425-438.
Dodson, M.H. (1973): Closure temperature in cooling geochronological and petrological systems. Contributions to Mineralogy and Petrology 40: 259-274.
Ganguly, J. & Tirone, M. (1999): Diffusion closure temperature and age of a mineral with arbitrary extent of diffusion: theoretical formulation and applications. Earth and Planetary Science Letters 170: 131-140.
Lapen, T.J., Johnson, C.M., Baumgartner, L.P., Mahlen, N.J., Beard, B.L., & Amato, J.M. (2003): Burial rates during prograde metamorphism of an ultra-high-pressure terrane: an example from Lago di Cignana, western Alps, Italy. Earth and Planetary Science Letters 215: 57-72.
Scherer, E.E., Cameron, K.L., & Blichert-Toft, J. (2000) Lu-Hf garnet geochronology: Closure temperature relative to the Sm-Nd system and the effects of trace minerals. Geochimica Cosmochimica Acta 64: 3413-3432.