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Exhumation rates estimated from diffusion modelling of chemical zonations in garnet (Tianshan, NW China)

Esther Schwarzenbach (1), Mark Caddick (2), Timm John (1), Martina Menneken (1), and Lutz Hecht (3)

(1) Freie Universität Berlin, Institut für Geologische Wissenschaften, Fachbereich Geowissenschaften, Berlin, Germany (esther.schwarzenbach@fu-berlin.de), (2) Department of Geosciences, Virginia Tech, Blacksburg, VA, USA, (3) Museum für Naturkunde, Berlin, Germany

Chemically zoned garnet crystals are common in metamorphic rocks despite the fact that thermally-activated intra-granular diffusion relaxes initial chemical zonation. This leads to suggestions that preservation of complex zoning implies short durations of thermal and geodynamic processes. Here we use complexly zoned garnet to determine durations of the final stages of burial and rates of early stages of exhumation of subducted rocks from the Tianshan in north-western China. Blueschist-facies garnet-glaucophane-albite schists contain garnet with a distinct and sharp oscillatory Mn-zonation. Ca is also zoned, with irregular, jagged (serrated) distributions forming peaks with widths of $\sim$5 μm. Thermodynamic modelling for one of these samples suggests a P-T path that reached $\sim$20.5kbar before undergoing $\sim$2kbar of initial decompression during heating to a peak T of 520-530°C. These conditions are confirmed by Raman spectroscopy of carbonaceous material (T) and quartz inclusions in garnet (P). The thermodynamic models imply that $\sim$20 vol.% of the garnet grew during late stages of subduction, interpreted as reflecting a time while still part of a coherent slab. The remaining $\sim$80 vol.% grew during early exhumation and continued heating, presumably following decoupling and ascent along the plate interface.

A numerical model for coupled Ca, Mn, Mg and Fe diffusion in garnet was used to estimate the duration between establishment of high-resolution Mn and Ca zoning during growth and cooling below nominal closure conditions upon exhumation. All models suggest that conditions of $\sim$520˚C were maintained for <100,000 years, with most results yielding better fits to observed zoning for durations <10,000 years. The strong dependence of diffusivity on temperature extends these timescales if peak T is overestimated, but all results imply rapid cooling. For likely exhumation P-T paths, this implies that the studied sample experienced exhumation rates in the range of <10cm/year assuming temperature gradients at the plate interface of about 6.5°C/km.