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Do zircon and monazite consistently record garnet growth in high-grade rocks?

Lorraine Tual (1,2), Ellen Kooijman (1), Melanie Schmitt (1), and Matthijs Smit (2)

(1) Department of Geosciences, Swedish Museum of Natural History, Stockholm, Sweden (lorraine.tual@nrm.se), (2) Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, Vancouver, Canada

Garnet Lu-Hf ages are used to monitor the systematics of rare earth elements (REE) and age record in accessory minerals. We performed in-situ LA-(MC-)ICPMS U-(Th-)Pb dating and REE analysis on zircon and monazite in two contrasting high-grade rock samples: dry felsic granulite xenoliths from the Pamir, Tajikistan and fluid-rich, ultrahigh-pressure (UHP) migmatites from the Western Gneiss Region (WGR), Norway. In parallel, garnet from the same samples were subjected to REE analysis and dated by Lu-Hf. The datasets are compared to see whether, and to what extent, REE systematics in accessory phases can be correlated with garnet growth.

Garnet in the hydrous UHP migmatite contains abundant zircon and monazite inclusions. The Gd/Yb values and U-(Th-)Pb ages of these inclusions show significant dispersion and do not systematically correlate. Highest Gd/Yb values occur at 420-410 and c. 420 Ma for monazite and zircon, respectively. Garnet in this rock yielded a Lu-Hf garnet bulk age of c. 422 Ma. The data obtained from the dry Pamir xenoliths show a different pattern. Accessory minerals grew in distinct pulses between 50 and 11 Ma, and indicate garnet growth between 42-37 Ma [1]. The samples produced consistent Lu-Hf garnet ages of 41-38 Ma. Zircon and monazite of this age do not show highest Gd/Yb values, which instead are observed at 30 Ma or younger.

This study illustrates the reliability of accessory mineral petrochronology in certain systems, yet also shows that fluid saturation dominates the accessory phase record in high-grade rocks. In fluid-bearing migmatites, accessory mineral inclusions in garnet underwent protracted (re-)crystallization even after garnet growth was complete. Strongly variable Gd/Yb values for zircon and monazite grains that were cogenetic with garnet show that many of these grains did not equilibrate chemically with this mineral in spite of its very close proximity; the grains may have inherited their REE signature from a precursor. The upper envelope of Gd/Yb-age data does reliably track garnet growth. In dry granulites, such as the Pamir lower-crustal rocks, accessory minerals record short pulses of re-equilibration, which may or may not involve interaction with garnet; high-Gd/Yb in zircon and monazite thus may provide a minimum age for garnet growth in such rocks. Deduction of the probable age of garnet growth solely through accessory phases may require a large quantity of data to best constrain the extremes of Gd/Yb with time, even in apparently well-equilibrated and fluid-saturated samples.

[1] Kooijman et al. (2017) EPSL 465, 59–69.