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# Crustal evolution at mantle depths constrained from accessory minerals in (U)HP-UHT xenoliths

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Lower crustal xenoliths from the Pamir provide a unique opportunity to study the evolution of the crust at mantle depths during the India-Asia collision. To investigate, and constrain the timing of, the petrologic processes that occurred during burial to the peak conditions (25-28 kb, 1000-1100 °C; [1]), we performed in situ chemical- and isotope analysis of accessory minerals in 10 xenoliths, ranging from Kfs-bearing eclogites to grt-ky-qtz granulites. Laser ablation multi-collector ICPMS of zircon yielded U-Pb ages and Ti concentrations. Laser ablation 'split-stream' ICPMS was applied to monazite and rutile to obtain U-Pb ages, and concentrations of REE (monazite) and trace elements (rutile).

Zircon and monazite yielded U-Pb ages of 101.9±1.8, 53.7±1.0, 39.1±0.3, 21.7±0.3, 18.2±0.5, 16.9±0.8, 15.1±0.3 (2$\sigma$) and 12.5-11.1 Ma; most samples showed several or all of these populations. The 101.9- and 53.7-Ma minerals are xenocrystic or detrital. For younger ages, the zircon and monazite datasets are complementary in that, within a single rock, the two minerals always record different ages–although zircon in one rock and monazite in another can be the same age. The 39.1-Ma zircon and monazite predominantly occur as inclusions in minerals of the primary garnet-bearing assemblage that formed during the earliest stages of burial at ∼7 kb. Spinifex-like textures recording prograde melting events occur locally in the granulites and contain 21.7-11.1 Ma zircon and monazite. Strongly aligned kyanite close to these patches indicates associated deformation.

Rutile yielded U-Pb cooling ages of 10.8±0.3 Ma; identical to the eruption age of the host magma. Zirconium-in-rutile temperatures are 850–930°C, and Zr zoning within grains indicates prograde growth. With increasing Zr content, Zr/Hf and Nb/Ta decrease, then increase; the Nb/Ta enhancement is stronger and leads to a super-chondritic ratio. Titanium-in-zircon temperatures increase steadily from ∼830°C at 39.1 Ma to ∼900°C at 11.5 Ma and increase abruptly towards 1000°C at 11.1 Ma.

Because the analytical uncertainty on the Miocene ages is small compared to the 28-Myr burial, many individual prograde reaction- and melting processes could be constrained. These processes evidently occurred in pulses, each pulse involving extensive new growth and recrystallisation of a specific accessory phase. The high-grade foliation in the partially molten samples shows that these pulses weakened the rocks temporarily, facilitating viscous flow of the lower crust.

Reference: [1] Hacker et al. (2005) J Petrol 46 (8): 1661-1687.