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Constraining metamorphic rates through allanite and monazite petrochronology: a case study from the Miyar Valley (High Himalayan Crystalline of Zanskar, NW India)

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Dating metamorphic rocks raises specific issues because metamorphism comprises a complex sequence of structural changes and chemical reactions that can be extended over millions or tens of millions of years so that metamorphic rocks cannot in general be said to have "an age". Therefore, an accurate interpretation of radiometric age data from metamorphic rocks requires first to establish the behavior of the isotopic system used for dating relative to the pressure and temperature (P-T) conditions that a metamorphic rock experienced. As the U-Th-Pb system in LREE-accessory phases like monazite and allanite is not easily reset during subsequent temperature increase, allanite and monazite U-Th-Pb ages are collectively interpreted as reflecting crystallization ages. As a consequence, to correctly interpret allanite and monazite crystallization ages, it is essential to accurately determine the physical conditions of their crystallization.
A meticulous account of the chemical and textural evolution of monazite and allanite along a well constrained prograde pelitic sequence of the High Himalayan Crystalline of Zanskar (Miyar Valley; e.g. Robyr et al., 2002; 2006; 2014) reveals that: (1) the occurrence of the first metamorphic allanite coincides with the biotite-in isograd and (2) the formation of the first metamorphic monazite occurs at the staurolite-in isograd. The finding of both monazite and allanite as inclusion in staurolite porphyroblasts indicates that the breakdown of allanite and the formation of monazite occurred during staurolite crystallization. Thermobarometry results show that the metamorphic allanites are appeared in the 400-420 °C, while the signature of the first metamorphic monazite is found at $\sim$ 600 °C with staurolite-in isograd. Allanite and monazite U-Th-Pb ages thus constrain the timing when the rocks reached the $\sim$ 420 °C and $\sim$ 600 °C isotherms respectively. In situ LA-ICPMS dating of coexisting allanite and monazite inclusions in garnet porphyroblasts yield respective ages of 33.6 $\pm$ 0.9 Ma and 29.5 $\pm$ 0.2 Ma, constraining the time elapsed between allanite crystallization ($\sim$ 420 °C) and monazite crystallization ($\sim$ 600°C). These data indicate that the rock needed $\sim$ 4 Myr to be subducted from the 420 °C isotherm down to the 600°C isotherm, implying a heating rate of ca. 45°C/m.y.

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