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A multi-geochronometer approach to investigate rates and timescales of high-pressure granulite exhumation in NW Bhutan

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The rates and timescales of deep-crustal processes can be tracked by linking geochemical signatures in metamorphic minerals to geochronological data. The relative ages of different mineral phases in a rock, grown via different metamorphic reactions, can be used to link absolute age to metamorphic stage. Detailed investigations can be enhanced by using a multi-geochronometer approach, such as the one used by this study on selection of metapelites and metabasites from a high-pressure granulite facies terrain, in north-west Bhutan. These rocks provide a rare glimpse into the evolution of the east-Himalayan deep crust, and are significant to understanding deep-crustal exhumation in orogenic settings.

U-Pb dating of monazite and zircon and Lu-Hf and Sm-Nd dating of garnet shed light on the timing and timescales of metamorphism and exhumation of a high-pressure granulite facies terrain in NW Bhutan. Previous geochronological data suggested that eclogite and granulite facies events were experienced around 14-15 Ma, followed by rapid exhumation. In contrast, similar rocks in the Dinggye region further westwards appeared to have reached their metamorphic peak much earlier around 38-34 Ma (Wang et al. 2017, Kellett et al. 2014). In a new set of samples, LA-ICP-MS analyses targeting growth zones in monazite and zircon yield distinctive U-Pb age populations spanning 20 Myrs, from 34 Ma to 14 Ma. These ages relate to episodes of accessory phase crystallisation linked to anatectic melt crystallisation.

The trace element compositions of different monazite and zircon growth zones were compared to the trace element compositions of coevally growing phases. The results show that the element uptake in accessory phases was progressively influenced by the respective dissolution and crystallisation of garnet (HREEs, Y) and feldspar (Eu) during exhumation.

The new data call for a reinterpretation of the 15-14 Ma ages, found in many of the NW Bhutan samples, as late melt crystallisation as opposed to ecologite-facies metamorphism. The prolonged period of accessory phase crystallisation suggests there are more similarities than previously thought between the east-Himalayan high-pressure terrains. A preliminary interpretation of these findings is that the exhumation of high-pressure granulites in Bhutan was facilitated by crustal weakening as a result of extensive crustal anataxis.

The dataset shows that, when applied to the right rocks, and coupled with trace element data, the multi-geochronometer approach is a powerful tool for interrogating the evolution of the orogenic deep crust.

References

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