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Tectono-metamorphic evolution of the Southern Pamir – Hindu Kush (Chitral, NW Pakistan): insights from phase equilibria modelling, garnet and monazite geochronology

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This study aims to better understand the role of the inherited crustal structures and thermal regime in the development of large-scale mountain belts during continental collision. Specially, it aims to unravel the geological characteristics of the southern Asian margin prior to its collision with India and the generation of the Himalaya and the associated Tibetan plateau through the examination the metasedimentary rocks from the Hindu Kush mountain range (Chitral region, North Pakistan). These rocks have previously been shown to preserve evidence of the tectonic evolution of the Himalaya–Karakoram–Tibet orogeny that predates the Himalayan subduction/collision history. Combined classical geothermobarometry, phase equilibria modelling, U-Th/Pb monazite and Lu/Hf garnet geochronology, and garnet and monazite trace element analysis helps elucidate the pressure–temperature–time evolution of three adjacent garnet + staurolite-bearing micaschists and three sillimanite + anatexite bearing micaschists.

Garnet and staurolite in the staurolite-bearing micaschists have a complex zonation that records multiple growth stages with distinct deformation phases (i.e. inclusion trails in grain cores oblique to the main foliation). Based on the chemical zonation, inferred pressure–temperature paths have been defined from thermodynamic modelling for each sample. Most paths outline an increase in pressure-temperature followed by an isothermal decrease of the pressure. While garnet cores crystallized in a staurolite-free environment, garnet rims crystallized in equilibrium with staurolite at peak conditions. Moreover, garnet in one sample shows a discontinuous chlorite-bearing overgrowth recording a last stage of crystallization after staurolite-breakdown in retrograde conditions. Garnet in sillimanite-bearing micaschists shows a near homogeneous composition, only recording the peak of metamorphism at supra-solidus conditions (consistent with observed textural evidence for partial melting). Monazites dated in the analysed samples yield a variety of Mesozoic and Cenozoic age populations. Based on the analysis of the garnet/monaziteRare Earth Elements partitioning, these different ages are tentatively linked to different garnet growth stages and deformation textures characterized in each sample.

Our findings provide important new constraints on the tectonics setting and the thermal structure of the main magmatic and metamorphic events that occurred along the southern margin of Eurasia, before and after the initial India-Asia collision. The pressure–temperature–time paths obtained for the different samples from the Chitral region indicate that the present-day Hindu Kush mountain range was an active-margin setting characterized by crustal thickening from 130 Ma to 80 Ma, perhaps reflecting slab flattening and/or the collision of the Kohistan island arc. Apparent decompression at 20–30 Ma occurred after the onset of the India-Asia collision. It is spatially and coevally associated with crustal anatexis and the generation of the Garam Chasma plutonic body. Therefore, we suggest that this last metamorphic event could witness the development of a metamorphic core complex ∼20-30 Ma after the onset of the Himalayan collision, similar to that described farther to the northeast in the South Pamir and the underlying Karakoram