Thermodynamic phase equilibria modelling of retrograde amphibole and clinozoisite in mafic eclogite from the Tso Morari massif, northwest India: Insights into the source and behavior of metamorphic fluid during exhumation

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Retrograde epidote and/or clinozoisite poikiloblasts associated with compositionally zoned amphibole—the latter typically containing a substantial sodic component—are common in exhumed (ultra)high pressure – (U)HP – mafic eclogite (e.g., Massonne, 2012 and references therein). This mineral pairing is present in many subduction-related (U)HP terranes that form during continental collision and can be used to provide valuable constraints on the geodynamic/physico-chemical conditions experienced by (U)HP eclogite during the subduction–exhumation cycle (Palin et al., 2014; Waters et al., 2014).

In this work, we present the results of detailed thermodynamic phase equilibria modelling of such amphibole–clinozoisite-bearing post-peak metamorphic mineral assemblages in (U)HP mafic eclogite from the Tso Morari massif, Ladakh Himalaya, northwest India. These data have provided new insight into the behavior and source of metamorphic fluid during exhumation and constrained the P–T conditions of hydration. Serial P–M(H_2O) pseudosections constructed in the Na_2O–CaO–K_2O–FeO–MgO–Al_2O_3–SiO_2–H_2O–TiO_2–O (NCKFMASHTO) compositional system show that a number of petrographically distinct hydration episodes most likely occurred during exhumation from peak P–T conditions (~640 °C, 27–28 kbar; St-Onge et al., 2013). Initial hydration of a peak assemblage dominated by garnet and omphacite is interpreted to have occurred as a result of the destabilization of talc following isothermal decompression to P ~23 kbar, which led to the formation of barroisite–winchite amphibole core domains. A subsequent externally-sourced episode of hydration at P ~19 kbar, with or without syn-decompressional cooling to ~560 °C, resulted in additional barroisitic–winchitic amphibole growth, followed by the formation of clinozoisite poikiloblasts. Continued buoyancy-driven exhumation to the base of the lower crust is constrained to have taken place with no additional fluid input. A final hydration event, characterized by the formation of magnesiohornblende rims on the barroisite–winchite cores, was associated with later prograde overprinting in the middle crust during the final stages of exhumation. Significantly, the vast majority of externally sourced H_2O, comprising just over half of the current bulk rock fluid content, was added during this final hydration event. In a middle crustal setting, this fluid infiltration is interpreted to have occurred due to devolatilization reactions occurring in migmatitic host orthogneiss and/or metasedimentary units, or following the crystallization of partial melt.

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