Thrusting, extension, and doming in the High Himalaya of Lahul-Zanskar area (NW India): structural and pressure-temperature constraints

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Along the Miyar Valley - Gianbul Valley transect in NW Lahul - SE Zanskar area, the High Himalayan Crystalline Zone crops out as a large-scale dome structure, called the Gianbul dome. Although the metamorphic field zonation is comparable on both sides of the dome, detailed petrographic, geothermobarometric and structural observations reveal a succession of four events, related to NE-directed and SW-directed contractional and extensional tectonic movements.

The first event corresponds to a crustal thickening associated with the NE-directed Shikar Beh nappe emplacement. This event is responsible for a prograde Barrovian-type metamorphism on the southern limb of the Gianbul dome in the Miyar Valley, characterized by peak conditions increasing gradually from the chlorite zone, to the SW, to the sillimanite-migmatite zone, to the NE. In the central part of the Gianbul dome, partial melting related to the M1 phase occurred at temperatures between 700 and 800oC. The main structures related to this event is the Miyar Thrust Zone, a 20 km wide ductile shear zone characterized by the presence of mylonites, in which shear sense criteria indicate a clear top-to-the-NE thrusting. A similar shear sense is confirmed by sigmoidal inclusion trails in syntectononic M1 garnet porphyroblasts.

A second event of crustal thickening is observed only in the northern part of the transect, in the footwall of the Zanskar Shear Zone in the Gianbul Valley. This phase is associated with a M2 Barrovian metamorphism, responsible for a gradual zonation increasing from the chlorite zone, to the NE, to the sillimanite-migmatite zone, to the SW. Thermobarometry results indicate peak conditions evolving from 650oC / 7 kbar for the kyanite zone to 800 oC / 12 kbar for the sillimanite-migmatite zone. Sigmoidal inclusion trails in M2 garnets porphyroblasts indicate a syntectononic growth during a SW-directed shearing, and these microfabrics are superposed by the extensional structures associated to the NE-dipping Zanskar Shear Zone. These observations implies that: (1) the M2 prograde metamorphism in the northern limb of the Gianbul dome is the consequence of a SW-directed crustal thickening, in contrast to the M1 tectono-metamorphic evolution in the southern limb of the dome; and (2) the Zanskar Shear Zone reactivates an older SW-directed thrust zone as a NE-directed ductile extensional shear zone during the exhumation of the High Himalayan Crystalline Zone. The M2 crustal thickening phase most likely reflects the underthrusting of the High Himalayan beneath the frontal part of the SW-directed Nyimaling-Tsarap nappe affecting the sedimentary series of the Tethyan Himalaya.

Two phases of extension and retrograde metamorphism are superposed on the contractional M1 and M2 tectono-metamorphic events. In the northern limb of the Gianbul dome, NE-directed extension is responsible for the shearing of the M2 isograds along the Zanskar Shear Zone, and for the sharp metamorphic contrast between the high grade High Himalayan Crystalline Zone and the overlying low grade Tethyan Himalaya. This event is related to the exhumation of the High Himalayan Crystalline Zone controlled by extension along the Zanskar Shear Zone, as well as by SW-directed thrusting of the High Himalayan nappe along the Main Central Thrust. In the footwall of the Zanskar Shear Zone, this rapid exhumation is characterized by a nearly isothermal decompression and enhanced partial

melting during the M3 retrograde metamorphism. The fourth and last major tectono-metamorphic phase affecting the studied area corresponds to the creation of the Gianbul dome. In the northern limb of the dome, this event is associated with high-angle, brittle-ductile normal faults superposed on the Zanskar Shear Zone. In the Miyar Valley to the south, this large-scale doming is associated with a SW-dipping extensional structure, the Khanjar Shear Zone. This extensional event is marked by high T-low P retrograde conditions superposed on the prograde M1 assemblages in the Miyar Valley. Although characterized by an apparently simple, symmetrical geometry and metamorphic zonation, the large-scale doming commonly observed in the High Himalayan Crystalline Zone of Zanskar appears to be the consequence of a complex, polyphase tectono-metamorphic evolution.