Higher Himalayan Crystalline (HHC) Belt: its shear sense indicators and their implications on its tectonic evolution

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As a consequence of the Cenozoic India–Himalayan convergence, the Himalaya exhibits some of the most spectacular features like ductile, inverted metamorphism and generation of migmatite/leucogranite within the Higher Himalayan Crystalline (HHC) Belt, and its subsequent thrusting along the Main Central Thrust (MCT) over the Lesser Himalayan Sedimentary Belt (LHSB). In central parts of Uttarakhand, more than 20 km thick and homoclinal NE-dipping HHC is almost continuously exposed between Helang and Malari along the Dhauli Ganga Valley. This road dip-section traverse provides an excellent opportunity to investigate the (i) ambiguity regarding the position of the MCT in terms of the Munsiari Thrust (the MCT–I), and the Vaikrita Thrust (the MCT–II), and the South Tibetan Detachment System (STDS), (ii) intense ductile shearing of the HHC, having top-to-the-southwest and top-to-the-northeast shear indicators, (iii) structural control on melt accumulation of the Himalayan migmatites, (iv) Himalayan inverted metamorphism, and (vi) assessment of channel flow or other models.

Based on lithologies and grade of metamorphism from the lower to higher structural levels northwards, the HHC is divisible into two main groups above the Munsiari Thrust. In the lower parts, the Munsiari Group of low to medium grade contains garnet mica schist/gneiss, quartzite, amphibolite and biotite-rich phyllonite, mylonitic gneiss and augen gneiss. Overlying the Vaikrita Thrust, the Vaikrita Group is comprised of the Joshimath Formation (garnet-biotite-muscovite schist/psammitic gneiss), the Suraithota Formation (kyanite-garnet-biotite schist/psammitic gneiss and amphibolite), and the Bhapkund Formation (sillimanite/fibrolite- kyanite-garnet-biotite psammitic gneiss/schist with pervasive migmatite, concordant to discordant pegmatite veins, and small tourmaline-rich leucogranite lenses/dykes and the Malari leucogranite). The Vaikrita Group is typically characterized by inverted metamorphism, where sillimanite–K-feldspar gneiss and migmatite in the uppermost parts of the Bhapkund Formation was metamorphosed under upper amphibolite facies at about >800 °C (Spencer et al., 2012). The Bhapkund Formation constitutes the footwall of the STDS, which separates it from the very low biotite-grade to unmetamorphosed quartzite and slates/phyllite of the Martoli Formation of the basal Tethyan Sedimentary zone under peak metamorphic conditions of 450±50 °C.

Various shear sense indicators proliferate the HHC between Helang and Malari. From the asymmetry of structures like S-C and S-C' fabric, boudins, mantled porphyroclasts, folds etc., sense of ductile to brittle-ductile shearing reveals two phases of ductile shear deformation: (a) an older top-to-the-SW upwards phase throughout the HHC having an overall thrust geometry, and (b) a younger superposed top-to-the-NE downwards phase with normal fault sense from the middle to upper parts (Shreshtha et al. communicated).

In the upper parts of the HHC migmatite is ubiquitously distributed up to Malari in the upper parts of the Bhapkund Formation, having five different phases of melt accumulation (Jain et al. 2013). The oldest migmatite phase (Me1) parallels the main foliation S_m as the stromatite layers and concordant leucogranite bands. Younger melt phases Me2, Me3 and Me5 are recorded along small-scale ductile thrusts, extensional fabric and structureless patches, respectively. It is only the Me4 melting phase that is evidenced by large-scale melt migration along cross-cutting irregular veins. These were possible conduits for migration and accumulation of melt into larger leucogranite bodies like the Malari granite (19.0±0.5 Ma).

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Various tectonic models for the evolution of the Himalayan metamorphic belt can be critically assessed in this section, as these shear indicators provide invaluable constraints on various tectonic models currently in use for the evolution of the Himalayan metamorphics.

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