Deformation Temperatures and Rapid Exhumation of the Greater Himalayan Series, Sutlej Valley, NW India

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In the Sutlej Valley, NW India, late, high-amplitude NW-SE trending folding and subsequent erosion has resulted in the formation of several klippen comprised of Greater Himalayan Series (GHS) rocks bounded by the Main Central thrust (MCT). The Largi-Kulu-Rampur structural window exposes underlying Lesser Himalayan sedimentary rocks and metamorphosed Lesser Himalayan Crystalline Series rocks in the central region of the Sutlej Valley (see e.g., Vannay and others, 2004). Exposure of the MCT in several locations from more foreland to more hinterland (in the west and east, respectively) positions allowed us to examine multiple structural levels along a continuous crustal-scale structure. Rocks in the hanging wall of western exposures of the MCT attained peak temperatures at greenschist facies coonditions. Helicitic garnet porphyroblasts in rocks ≥1 km structurally above the MCT suggest deformation was ongoing during garnet growth (and therefore presumably during near-peak metamorphism), but temperatures were below that required for significant feldspar plasticity in MCT mylonites at the base of the section.

Assuming an ~25º dip on the MCT and that transport was parallel to the finite stretching lineation, the easternmost exposure of the MCT in the Sutlej Valley represents an ~3 km deeper crustal level than the more westerly MCT exposures described above. An approximately 10 km thick continuous section of the GHS is exposed between the MCT and Sangla Detachment, a part of the South Tibetan Detachment System of normal faults. Low thermodynamic variance pelitic assemblages (garnet ± staurolite + muscovite + biotite ± plagioclase + ilmenite ± rutile) are exposed <300 m structurally above the thrust suggesting metamorphism to mid-amphibolite facies. Microstructures observed in mylonitic granitoids and paragneisses adjacent to the MCT display evidence for high-temperature deformation. Large recrystallized quartz grains have lobate grain boundaries and occluded trails of aligned mica indicating exceptionally mobile grain boundaries during mylonitization and dynamic recrystallization. Thick mantles of recrystallized material surrounding large primary igneous feldspar grains in mylonitic footwall granitoids indicate that feldspar accommodated strain by crystal plastic processes. Semi-quantitative deformation temperatures obtained from the quartz c-axis fabric opening angle thermometer (~625 ºC; Kruhl, 1998, Law and others, 2004) are consistent with observed microstructure and are in excellent agreement with near-peak temperatures calculated by conventional garnet–biotite thermometry (~620 ºC) for pelitic samples in the immediate hanging wall of the MCT. In some samples, garnet X-ray compositional maps reveal euhedral Mn and oscillatory Ca zoning. Because Mn is the fastest-diffusing major divalent cation in garnet the presence of sharp zoning profiles indicates these rocks cannot have remained at near-peak temperatures for a significant period of time.

Lower calculated deformation and peak metamorphic temperatures and spatial position of western MCT exposures, versus those in the east, support the interpretation that western MCT mylonites represent shallower crustal levels. Identical results from multiple analytical techniques for temperature estimation, in addition to microstructural evidence of synkinematic porphyroblast growth, combined with chemical zoning evidence observed in garnet porphyroblasts all support the conclusion that post-peak exhumation of middle crustal GHS rocks was rapid.

References

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