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# Deformation temperatures and flow vorticities near the base of the Greater Himalayan Crystalline Sequence, Sutlej Valley and Shimla Klippe, NW India

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We report new flow vorticity and deformation temperature data from the base of the Greater Himalayan Series (GHS) exposed in the Sutlej River section of NW India. We focus on exposures in the hanging wall to the Main Central Thrust (MCT) at the western end of the Sutlej section, but also report new data from the Shimla Klippe and the eastern end of the Sutlej section that represents more foreland and hinterland exposures, respectively, of GHS hanging wall rocks.

At the western end of the Sutlej section exposures of mylonitic granite and quartzite at distances of 350-900 m above the MCT were used by Grasemann et al. (1999) in the first quantitative study of flow vorticities reported from the Himalaya. This study, which employed the Rxz strain ratio / quartz c-axis method, indicated that penetrative deformation close to the base of the GHS was associated with a general shear. However, due to uncertainty in the strain values employed, only semi-quantitative estimates of flow vorticity could be made. We have re-examined the western Sutlej exposures at 70-1150 m above the MCT using the rigid grain and oblique grain shape / quartz c-axis fabric methods of Wallis (1992, 1995). Our rigid grain data indicate flow vorticities in the Wm = 0.73–0.83 range (47-37% pure shear; 53-63% simple shear component), confirming the basic conclusion of a general shear. Our oblique grain shape / quartz c-axis fabric data indicate higher Wm values (Wm = 0.83-0.98) and hence higher simple shear components.

At the western end of the Sutlej section we have also estimated deformation temperatures for the mylonitic granite and quartzite in the hanging wall to the MCT using the quartz c-axis fabric opening angle thermometer of Kruhl (1998). Deformation temperatures of c. 535 °C are indicated at 70 m above the MCT. Fabric opening angles and inferred deformation temperatures steadily increase up structural section reaching 615 °C at 1150 m above the MCT and reflecting the well-known inversion of metamorphic isograds at the base of the GHS. The steepest inferred apparent thermal gradients are recorded adjacent to the MCT and progressively decrease up structural section following a power law relationship. The temperature estimates are in good agreement with observed quartz recrystallization microstructures.

Close to the base of the GHS preserved in the Shimla klippe, quartz fabrics and recrystallization mechanisms (subgrain rotation with minor grain boundary migration) at 60-80 m above the MCT indicate slightly lower deformation temperatures (510-540 °C) than those recorded at similar structural positions in the western Sutlej mylonites. In contrast, quartz-rich tectonites located above the mapped position of the MCT in the eastern part of the Sutlej River section, and occupying a more hinterland position than the western Sutlej exposures, record the highest deformation temperatures. Deformation temperatures of c. 610 °C are indicated by fabric opening angles at 20 m above the MCT, steadily increasing to 685 °C at 2500 m above the MCT. These significantly higher deformation temperatures are confirmed by microstructural evidence for widespread quartz grain boundary migration recrystallization and locally prism [c] slip. The tectonic implications of these flow vorticity and thermal data will be discussed.