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Orogen-scale along-strike continuity in quartz recrystallization microstructures adjacent to the Main Central Thrust: implications for deformation temperatures, strain rates and flow stresses

Richard Law
Virginia Tech, Geosciences, Blacksburg, United States (rdlaw@vt.edu)

Traced for ∼ 1500 km along the foreland edge of the Himalaya from NW India to Bhutan published reports indicate a remarkable along-strike continuity of quartz recrystallization microstructures in the footwall and hanging wall to the Main Central Thrust (MCT). Recrystallization in Lesser Himalayan Series (LHS) rocks in the footwall to the MCT is dominated by grain boundary bulging (BLG) microstructures, while recrystallization in Greater Himalayan Series (GHS) rocks in the hanging wall is dominated by grain boundary migration microstructures that traced structurally upwards transition in to the anatectic core of the GHS.

In foreland-positioned high-strain rocks adjacent to the MCT recrystallization is dominated by subgrain rotation (SGR) with transitional BLG-SGR and SGR-GBM microstructures being recorded at structural distances of up to a few hundred meters below and above the MCT, respectively. Correlation with available information on temperatures of metamorphism indicated by mineral phase equilibria and RSCM data suggests that recrystallization in the structural zones dominated by BLG, SGR and GBM occurred at temperatures of ∼ 350-450, 450-550 and 550- > 650 °C, respectively. It should be kept in mind, however, that these temperatures are likely to be 'close-to-peak' temperatures of metamorphism, whereas penetrative shearing and recrystallization may have continued during cooling.

The dominance of SGR along the more foreland-positioned exposures of the MCT intuitively suggests that shearing occurred under a relatively restricted range of deformation temperatures and strain rates. Plotting the 'close-to-peak' 450-500 °C temperatures of metamorphism indicated for SGR-dominated rocks located at up to a few hundred meters below/above the MCT on the quartz recrystallization map developed by Stipp et al. (2002) indicates 'ball-park' strain rates of ∼ 10-13 to 10-10 sec-1. However, only strain rates slower than 10-12 sec-1 on the MCT are likely to be compatible with know convergence rates between the Indian and Asian plates. If shearing continued during retrograde cooling while remaining in the SGR field, then the recrystallization map suggests that a significant drop in deformation temperature (> ∼75-100 °C) would result in a decrease in strain rate. In general, however, the presence of a single recrystallization microstructure traced over a large (regional scale) distance does not necessarily mean that deformation temperature (or strain rate) remains constant but could, for example, indicate that spatial variations in deformation temperature are compensated for by changes in strain rate, with grain-scale deformation remaining within a particular recrystallization regime.

Constant stress conditions plot along a straight line in the 1/T versus log strain rate space used in the quartz recrystallization mechanism map. This suggests that the observed along-strike consistency of SGR-dominated recrystallization microstructures may indicate near to constant stress boundary conditions (albeit with varying temperatures and strain rates) prevailing along what are now the more foreland-positioned exposures of the MCT. Extrapolation of the Hirth et al. (2001) flow law suggests a flow stress of ∼ 30-50 MPa based on the deformation temperatures and strain rates inferred for foreland-positioned exposures of the MCT, in agreement with flow stresses estimated from recrystallized quartz grain size data.