Along-strike continuity in quartz recrystallization microstructures adjacent to the MCT: deformation temperatures, strain rates and implications for flow stresses

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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 (GBM I and II using terminology of Stipp et al. 2002a,b) that traced structurally upwards transition in to the anatectic core of the GHS.

In the 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. (2002b) would indicate 'ball-park' strain rates of ~ 10^{-13} to 10^{-10} sec^{-1} (Fig. 1a). 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 (Fig. 1a).

Constant stress conditions plot along a straight line in the 1/T versus log strain rate space used in the quartz recrystallization mechanism map (Fig. 1b). This opens up the possibility that the observed along strike consistency of observed 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 (Fig. 1a).

If such processes do operate along the MCT then, for a given foreland-hinterland position a constant recrystallized grain size would be predicted traced along strike as, at least under experimental conditions, grain size correlates with flow stress, but is independent of temperature, strain rate and water content (Stipp et al., 2006). Recrystallized quartz grain sizes of 35-65 microns (SGR-dominated microstructures) are recorded at 70-75 m above the MCT in the western part of the Sutlej River Valley in NW India, indicating flow stresses of 28-18 MPa using the Stipp and Tullis (2003) piezometer (Law et al., 2013).

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However, flow stresses based on quartz recrystallized grain sizes have not yet been quantified for other MCT transects along the Himalaya.

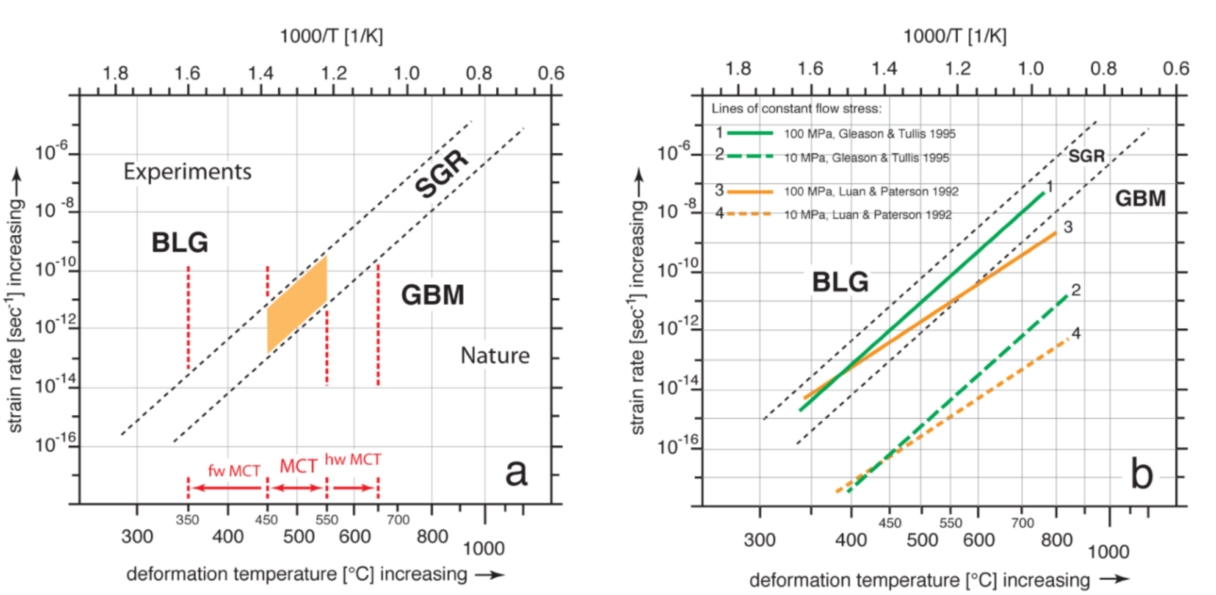

Figure 1. a) Quartz recrystallization mechanism map (Law in press, adapted from Stipp et al., 2002b) for the Main Central Thrust (MCT) with temperature ranges of close-to-peak metamorphism indicted by petrology-based thermometry. Footwall (fw) and hanging wall (hw) to MCT dominated by BLG and GBM recrystallization, respectively; recrystallization adjacent to MCT (< ~ 100-300 m above or below fault) dominated by SGR; orange field indicates predicted range of strain rates for SGR-dominated shearing on the MCT, if shearing occurred at close-to-peak temperatures of metamorphism. b) Recrystallization mechanism map displaying lines of constant flow stress from quartz flow laws of Luan and Paterson (1992) and Gleason and Tullis (1995).

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