

Temperature reconstructions of rocks deformed at shallow crustal depths: implications of calcite thermometry from MBT and NT rocks of Himachal Himalayas

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Temperature and depth of formation of fault rocks provide important insights of fault zone processes. The temperature estimation from shallow crustal rock deformation, however, is still under investigation for optimizing simplicity and accuracy of the measurements. Current temperature estimations rely primarily on calcite twin morphology (Rybacki et al. 2013 and reference therein), Raman spectroscopy of carbonaceous material (Beyssac et al. 2002), illite crystallinity analysis (Hara and Kurihara 2010, and references therein). Each of these standard methods has its advantages and limitations in estimation accuracy of temperatures and complexity of analysis. In context with lithology, in the current study we try to elucidate the temperature and depth information for calcite bearing fault rocks.

The present study focuses on fault zone rocks developed within the Himalayan frontal wedge bounded by Main Boundary thrust (MBT) and Main frontal thrust (MFT) (Yin 2006). The MFT form boundary with the active Gangetic foreland basin, hence, the dearth outcrop exposures. Therefore, in this study rocks from Nahan thrust (NT), a regionally prominent thrust within MFT sheet is considered. The calcite sample was collected from the core zone of the NT, exposed near Pinjore, Haryana, India. For rocks from MBT, the calcite samples were collected from the hangingwall and footwall rocks exposed near Gambarpul, Himachal Pradesh, India.

Calcite twin morphology from NT exhibits a primarily single set of Type-I twins (Ferrill et al., 2004). The footwall calcite sample from MBT also exhibits Type-I twins with few grains developing Type-II twins. However, the calcite sample of footwall rocks near the MBT boundary shows a predominance of Type-II twins and few Type-III twins. The calcite samples from the hangingwall have limited development of Type-II twins only, primarily due to finer grain size (Newman, 1994). Thus, calcites from NT as well as footwall of MBT yields a temperature $<170^{\circ}\text{C}$, while the calcite from the hanging wall of MBT and from footwall rocks close to the boundary of MBT yields a temperature of $>200^{\circ}\text{C}$. These temperature estimates are further confirmed with absolute values obtained from the carbonate clumped isotope thermometry (Kato et al., 2019). The calcite samples, therefore, show a significant difference in temperature values for NT ($170\pm10^{\circ}\text{C}$) and MBT ($262\pm30^{\circ}\text{C}$), implying a depth difference of $\sim 4\text{km}$ between the two thrusts, considering standard continental geothermal gradient of $25^{\circ}\text{C}/\text{km}$.

This study thus provides the applicability of carbonate clumped isotope thermometry for estimating temperatures for deformed calcite at shallow crustal levels. Further studies are required to characterize the deformation microstructures from the varied crustal depths of MBT and NT.

Keywords: Calcite twinning, Clumped isotope thermometry, MBT, NT

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