Fault heterogeneity within a single thrust zone: Case study from the Frontal Thrust of Himalayas

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Brittle faults are a typical feature of upper crustal deformation with a number of such faults being a dominant feature along the active orogens of the world. The nature of these faults has been widely studied for elucidating their stress accommodation mechanisms and response to the fault movement in terms of stress localizations and ultimately stress release by rupture or creep mechanisms. In recent years, there has been a paradigm shift in the interpretation of the nature of these faults (Collettini et al., 2019) and now there is coherence among the researchers about the heterogeneous nature of the fault in response to tectonic stresses. In the current study, we have focused on elucidating the nature of deformation mechanisms developed in Nahan Thrust (NT), a shallow crustal thrust fault within the Main Frontal Thrust (MFT) sheet of the Himalayan Fold Thrust belt (Bose et al., 2009). In the studied locality, NT has developed within the alternation of quartz-rich and phyllosilicate rich siltstone of Paleogene Dagshai Formation. It forms a wide brittle fault zone of ~190 m, with a damage zone of 110 m and a fault core of 40 m. The damage zone of NT shows dominantly brittle deformation with an increasing degree of brecciation toward the fault core. The fault core, however, shows several layers of chaotic breccia and foliated gouge zones with a single layer of ultracataclasite (forming black gouge). Calcite vein fragments present with the damage zone rocks and fault core show development of deformation twins, which suggests a deformation temperature of ~170 ℃ (Rowe and Rutter, 1990; Ferrill et al., 2004). The modal mineral analysis of the fault core rocks and the protolith, determined in conjunction with SEM-BSE, EPMA, and image processing by ImageJ software, suggests the formation of different zones within the fault core based on the lithology of individual layers of the rock. Grain size analysis of the fault core rocks, by ImageJ (Schneider et al., 2012) and their mineral species determined by EPMA, shows the control of inherited mineralogy in the generation of microstructures and therefore deformation mechanisms. Based on the microstructural observations, the quartz-rich layer of the protolith has dominantly deformed by fracturing and cataclasis with minimum effects of fluid alteration (if any) during the fault activity. The phyllosilicate rich layer, however, has exhibited pervasive alteration and generation of finer phyllosilicates, with deformation dominantly by pressure solution mechanisms. The phyllosilicate rich layers also act as sealing zones, localizing stress and subsequent stress buildup within the quartz-rich layers, thereby narrowing the active zone of the fault during subsequent fault activity. The ultracataclasite zone in the studied area is, therefore, a product of failure, at a mature stage of the fault activity, by possible seismic slip (Tesei et al., 2014), evidenced by the presence of submicroscopic spherical gas escape structures and clay clast aggregates (Boutareaud et al., 2008) due to shear heating.

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