Anatomy of internal shear zones from the Himalaya: Insights into progressive structural and kinematic evolution of an orogenic wedge.

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Shear zones represent localized manifestations of deformation, garnering extensive attention in geological studies. We studied the Main Central thrust (MCT) and the Pelling-Munsiari thrust (PT) zone exposures from the leading-edge of the Himalaya (1), to address how kinematic evolutionary paths of two successive internal shear zones vary along their transport direction due to varying structural positions. The rock parcel at the leading-edge exposures lies foreword of the Lesser Himalayan Duplex (LHD) (2) and, therefore, records the deformation signatures from trailing-edge locations during its progressive deformation. Hence, these rocks record the most complex and complete progressive deformation history compared to the other zones. Structural analysis along two internal shear zones, the MCT and the PT, reveals substantial variation in thicknesses, deformation mechanisms, and strain partitioning from the trailing- to the leading-edge of the Himalayan orogenic wedge (3,4).

The thickness-displacement plot signifies strain softening in all the studied shear zones, with leading-edge exposures exhibiting additional evidence of reaction softening and geometric softening (3,4). This is attributed to varying deformation conditions and mechanisms along the transport direction, aligning with decreasing overburden conditions and temperature toward the leading-edge. Irrespective of their structural position within the orogenic wedge, exposures of internal shear zones record a non-steady, decelerating strain path (3,4,5). In the leading-edge exposures, the PT with greater connectivity with the immediate footwall duplex records a higher strain (6), higher translation (2,3), and higher pure shear (3,4) component than the overlying MCT that does not have direct connectivity with the duplex (7). Hence, the internal shear zones record a consistent strain, pure shear component, and translation pattern in terms of their connectivity to the footwall structures, irrespective of their structural positions within the orogenic wedge. With a more complete deformation history, the leading-edge exposures of the MCT and the PT zones record a comparatively higher simple shear component and a higher strain than the trailing-edge (4). We explain this as a result of the dominance of the less competent mylonite domain over the more competent protomylonite domain in the leading-edge exposures. The weaker mylonite zone accommodates a higher simple shear component and higher strain in the leading-edge than in the more competent trailing-edge with a lesser proportion of mylonite domain (3,4). Strain partitioning due to internal structural geometry, a manifestation of the varying deformation conditions along major shear zones (6), also plays a critical role in their kinematic evolution.

This work demonstrates that the structural and kinematic behavior of shear zones associated with orogen-scale internal thrusts is intricately linked to their structural position and connectivity to footwall structures (3,4,7). It thus provides a valuable record of signatures of progressive orogenic wedge evolution.

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