Gravitational Tectonics versus Plate Tectonics in the Himalayan Intermontane Basins: NW Himalaya

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The intermontane basins are some of the critical regions to investigate the formation, growth, and development of basins during the collisional orogenesis, and in the NW Himalaya several such basins are observed to have formed during the latest phase of the ongoing collision between India and Eurasia (Burbank and Johnson, 1982). Kashmir and the Leh basins are the two such basins that have been studied in the past (e.g., Burbank and Johnson, 1982; Sangode et al., 2011; Dar et al., 2014; Aggarwal et al., 2018; Ahamd et al., 2020, Kumar et al., 2020; Shah et al., 2021), and in the recent times several studies have mapped normal faults in these basins (references herein), which pose important questions on what really causes the formation of normal faults within a collision zone. Ahmad et al. (2021) reviewed the field evidence of normal faults in the Kashmir basin and suggested gravity tectonics as the leading cause of normal faulting, which therefore questions the previous studies that have related normal faults to the ongoing tectonic convergence between India and Eurasia (references herein). Therefore, here we extend our previous work to another similar basin, the Leh basin, and show that gravity tectonics is the cause of normal faults in the basin. We also show the major difference between the normal faults mapped within the intermontane basins, and those that are tectonically driven. We have used the previously published field data on normal faults in the Kashmir and the Leh basins, 30 m shutter radar topography to show the location of the basins, and the occurrence of faults. Geological and structural maps are overlaid on the topographic images to show the distribution of lithology, location of major Himalayan faults, and the major fluvial streams. The earthquake centroid moment tensor (CMT) data are plotted on the shutter radar topography to show the distribution of normal, reverse and strike-slip faults, which are used to map the active deformation domains in the India-Eurasia orogenic belt (Figs. 1, 2). The tectonic deformation domains are correlated with the active faults within the intermontane basins to develop a model that will answer the tectonic versus gravitational faults in the India-Eurasia orogenic belt.

Our data show that normal faults within the Kashmir and Leh basins are mostly of shallow origin (Ahmad et al., 2021; Shah et al., 2021) and are restricted to less than 1 km depth, which is inconsistent with the tectonically driven normal faulting in the orogens because typically such faults would be expected to nucleate at more than 5 km depth and would penetrate the deeper portion of the brittle crust rather than to restrict to the upper <1 km depth of the Quaternary sediments. Kashmir and Leh basins have developed during the tectonic collision between India and Eurasia, and the previous studies show that Kashmir basin is ~4 Ma old and it is filled with Plio-Pleistocene to Holocene sedimentary rocks that are ~1300 m thick. The normal faults have displaced and faulted these sediments and often not the bedrock, which further supports the interpretation that these faults are caused by the gravitational tectonics. The normal faults are routinely linked to the tectonic causes (e.g., Dar et al., 2014; Aggarwal et al., 2018), but such a correlation seems problematic, and it seems most likely that the normal faults are gravitational and are linked to the lithological variations within the sedimentary basin. Similar observations are mapped in the Leh basins where active normal faults within the basin are gravitational (Shah et al., 2021) and not tectonic. Therefore, we have shown below why tectonically driven normal faults cannot be the expected within the Kashmir, where tectonically driven reverse faults would be expected as shown by our new map that shows the active deformation domains within the Himalayan system (Figs. 2 and 3). The Leh basin could form tectonically active normal faults but those that are mapped my previous workers are mostly gravitational, which indicates that the area is perhaps tectonically quiescent, or the deformation is very slow, which makes more sense because of the discovery of the active Dras fault zone (Shah et al., 2021).

We have mapped different deformation domains in the Himalaya-Tibet orogenic system (Fig. 2), and we have mainly identified four active deformation domains, namely, Zone A, Zone B, Zone C and Zone D. These zones show the dominant type of faulting events, which are derived from the CMT data (Fig. 3). The thrust fault related earthquake events are shown as pink zones and one such zone is continuously mapped in the Himalayan front, which suggests that the zone should be dominated by occurrence of NE dipping reverse faults, which is backed by the previous works (reference herein). The Zone A is

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therefore narrow and limited to the front, while as the Zone B is broader and mainly represented by the strike-slip and normal faults, which suggests that the interior portions of the orogen are dominated by active extension that is involves normal and strike-slip faults. Dextral strike-slip fault, the Karakoram fault (Fig. 2) and the Dras fault
zone runs through the Zone B and fits the active deformation domain that we have mapped. Our data shows that the frontal portion is accommodating the India-Eurasian convergence by forming ~NW–SE trending thrust faults. The dip of these faults varies between 12° to 23°. The Zone A domain abruptly changes at the location of the Peshawar basin (Fig. 2), which is where the major Himalayan faults curl (Shah et al., 2020) and mark the position of the western Himalayan syntaxis. This region suggests a major shift in the style of active deformation, which is mostly straightforward in the east of the syntaxis where it is absorbed by the frontal thrust system but in the west of the syntaxis the active deformation is represented by a combination of reverse and strike-slip faults (Fig. 2). Similar observation is noticed in the eastern syntaxis where the active deformation is absorbed by the occurrence of thrust and strike-slip faulting. The occurrence of N–S trending normal faults seems to occur where there is a significant change in the trend and bending of the Himalayan front, and it also coincides with the curvature of the MFT, where its strike changes from ~E–W to ~NW–SE (Fig. 2). The curvature of the Himalayan front is mostly responsible for the deformation pattern that is observed in the frontal portions. Towards the north of the frontal portions, we see a very sharp termination of thrust related earthquakes. Zone A dominates about ~130 km northwards of the front. The north of the Kashmir Basin is dominated by the strike-slip and normal faults, and that changes in the west of the western Himalayan syntaxis where strike-slip and reverse faulting is dominant that is shown as Zone C (Fig. 2).

Therefore, the active deformation domains that we have mapped (Fig. 2) suggest that faults are mostly tectonic and are reflection of the ongoing plate convergence between India and Eurasia (Fig. 3). The narrow width of the Zone A supports the higher tectonic topography in the front because of the reverse fault-related folding, which is not observed in its north where the strike-slip and normal faults are causing widespread extension, which possibly facilitates the channel flow in the mantle. Th thrust and strike-slip faults are dominant in the west of the western Himalayan syntaxis that suggest transpression. The strike-slip related events observed in this region are related to the Chaman fault system. The continuous northward push and underthrusting of India under Eurasia is causing the formation of various type of faults (Fig. 2), and therefore the expected earthquake causing faults would be in accordance with the deformation domains mapped here (Fig. 2). The shallow (less than 1 km) normal faults within the Quaternary basins such as Kashmir and Leh would not
be expected from the active plate tectonic related deformation because of the style of faulting (Fig. 2). If these are tectonically driven the Kashmir basin would be expected to have a strong component of thrusting or oblique strike-slip related extension, which would form faults in a particular orientation (e.g., Ahmad et al., 2020). Likewise, the Leh basin fits a pull-apart setting related to the curvature of the Dras fault zone (Shah et al., 2021) and would be expected to have normal faults but the mapped field evidence (Shah et al., 2021) suggests gravity related soft sediment deformation, which indicates that the region is either slowly accumulating slip or the evidence for active tectonics is buried under sediments of the Indus River.

Key words: gravitational tectonics, active tectonics, Himalaya, normal faults, deformation domains

References

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