Bearing of topography and converging plate geometry on earthquake incidences in the Central Himalaya

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We critically examine the occurrences of great damaging earthquakes in the backdrop of topography, gravity and finite element modeling. We find positive correlation between blocks of concentrated seismicity and higher topography along Main Central Thrust (MCT) with the areas of northward-extended Gandak and Sarda depressions. Instead, the penetrating ridges (Monghyr-Saharsa, Faizabad, Delhi-Hardwar), around the gaps of seismicity and lower topography along MCT, might be prohibiting the occurrences of earthquakes (Khan et al., 2014). The less active seismic zone or the gaps possibly represent the areas of quiescence of recent episode of tectonic pulse. We further carry out gravity and finite element stress modeling of the strike-orthogonal converging Indian lithosphere and the overriding Asian land mass for the Nepal and Sikkim-Darjeeling sectors. We delineate the geometries of different intra-crustal layers and their interfaces through gravity modeling. The optimum model parameters along with rheological parameters of different layers are used for finite element modeling. Finite element modeling is done with boundary conditions of keeping the upper surface free, and rigidly fixing the section of the northern boundary below the Main Himalayan Thrust (MHT). We impart a force of amount 6×10^{12} N/m on its frontal section, which is equivalent to resistive force of the Himalayan-Tibet system, and analyze the maximum and minimum compressive stress fields evolved in the lithosphere. We testify our observations with earthquake database. We analyze 114 earthquake events (magnitude ≥ 4.0) occurring during the period 1902 to 2012 in these sectors of the Himalayan arcuate belt. The earthquake data were taken from the catalogues of Indian Society of Earthquake Technology, International Seismological Centre and US Geological Survey. A total of 13 focal mechanisms of earthquakes of magnitude $M_w \geq 4.7$ are also compiled from the Harvard Centroid Moment Tensor Catalogue and other different sources for better understanding the deformation processes.

We note an increasing flexing of the penetrating Indian lithosphere beyond the Main Boundary Thrust (MBT) becomes maxima between MCT and South Tibetan Detachment (STD) in both the areas; however, more steepening of the Moho boundary is identified in the Sikkim-Darjeeling Himalaya (Ansari et al., 2014). The more steepening Moho boundary in Sikkim-Darjeeling Himalaya is likely correlated with higher seismicity concentration in this region. Further, a significant distribution of seismicity in the upper-most part of the mantle clearly shows its higher degree of deformation. It is also apparent from the finite element modeling that the maximum compressive stress field is more confined right within the bending zone of the penetrating Indian lithosphere beneath the Greater Himalaya. Instead, the upper surface of different layers record extensional tectonics. Amplitude of estimated stresses in the present calculation might change due to uncertainties in the several parameters utilized to compute the stresses; however, the pattern would remain same, and the inferences drawn from the present study remain valid.

Focal mechanisms of earthquake events reveal that the sharp bending section of the lithosphere is associated with both strike-slip and thrust dominated movements, and shear planes of most of these events are more or less parallel with the interfaces of the different crustal layers of the converging Indian lithosphere. We find one event lying on the surface of Indian lower crust is dominated by normal faulting, and likely associated with operative extensional stress field. Another significant observation is the dominant right-lateral shear movements in the crustal part of the converging lithosphere, which is possibly controlled by either local or regional changes of plate obliquity, and presumably associated with the general dynamics and kinematics of the Himalaya (Ansari and Khan, 2014). We finally propose that

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the zone of sharp bending of the descending Indian lithosphere is the nodal area of major stress accumulation, occasionally released in form of earthquakes. Motivated thrust-dominated movements along this margin possibly support this inference. Similar type of deforming domain of higher seismic potential right within the bending portion of the converging lithosphere was also identified elsewhere (Khan and Chakraborty, 2009; Khan, 2011; Khan et al., 2012).

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