Geophysical Research Abstracts
Vol. 19, EGU2017-1213, 2017
EGU General Assembly 2017

Lithologically controlled strength variation and the Himalayan megathrust geometry: an analogue modeling approach

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A moment magnitude (Mw) 7.8 earthquake associated with a Mw 7.3 aftershock hit the Gorkha region near Kathmandu, Nepal on April 25, 2015. The rupture propagated eastward for about 140 km and caused thousands of deaths. The focal mechanism of the Gorkha earthquake shows thrust sense over the mid-crustal steeply dipping ramp on the basal décollement known as the Main Himalayan Thrust (MHT). The MHT is the largest and fastest slipping continental megathrust over which the southward tapering Himalayan thrust wedge similar to the accretionary wedges is moving. The MHT ramps up to the surface beneath the Siwalik group of rocks as the Main Frontal Thrust (MFT). Below the MFT the basal décollement is flat until it reaches the mid-crustal ramp ($\sim$20°) below the Himalayan klippen and then again it becomes flat. This geometry of the décollement is consistent with the balanced cross sections, microseismic data, magnetotelluric images, INDEPTH seismic reflection profile, present day stress distribution and fits well with the prominent topographic break (physiographic transition) in the Lesser Himalaya.

Lithologically stratified sedimentary sequences in the upper crust are mechanically heterogeneous. It has been long known that the mechanical properties of the stratigraphic succession influence the resultant structural architecture of the fold and thrust belts. The rheologically weak stratigraphic horizon generally contains the basal décollement due to its relatively low frictional strength. Hence, any vertical or lateral change in frictional property may control the effective strength and the positions of the décollement in space. In the present study, we used non-cohesive sand and mica dust layers as analogue materials for simulating the strong and weak layers respectively in the sandbox apparatus. Experimental results with relatively high basal friction (μ=0.46) show that such a weak horizon at a shallow depth perturbs the sequential thrust progression, and forces a thrust to localize in the close vicinity of the weak zone, splaying from the basal décollement. Eventually, the weak horizon starts to deform by accumulating shear strain along it, leading to a new detachment at a shallow depth. At this stage, entire shallow part of the sandpack lying over the weak layer is deformed by closely-spaced imbricate thrusts. Extrapolating the model results to the natural prototype, we propose that the unmetamorphosed coal-shale-sand stone-black shale horizons below the Siwaliks as a key mechanical attribute to the basal décollement shift and the consequent flat-ramp-flat geometry of the MHT.