What controls the growth and shape of the Himalayan foreland fold-and-thrust belt?

Djordje Grujic[1], John Hirschmiller[1], Deirdre Mallyon[1]

[1] Dalhousie University, Department of Earth Sciences, Halifax, Canada, dgrujic@dal.ca

We provide empirical evidence for the impact of surface processes on the structure and geometry of the present-day foreland fold-and-thrust belt (FTB) of the Himalaya. We have reconstructed and analysed ten balanced cross sections distributed along the entire length of the Himalayan arc (Hirschmiller et al., 2014). Although published opinions vary, we contend that the active Himalayan FTB is delineated by the Main Frontal thrust (frontal thrust) and Main Boundary thrust (backstop), with foreland sediments deformed in the style of fold-and-thrust belts lying between the two. Here, we focus on the Siwalik Group, which represents the deformed part of the foreland basin and consists of synorogenic middle Miocene to Pleistocene sediments that form the youngest and frontal part of the Himalayan orogen.

Within the active foreland fold-and-thrust belt of the Himalaya, extension, strain rate, and belt morphology vary systematically from west to east. Strain rates correlate well with west to east increases in convergence rates according to both long-term plate velocity data and GPS data, suggesting that Pliocene to Holocene shortening is externally imposed and related to plate convergence rates. Conversely, the eastward decrease in belt width corresponds to an eastward increase in rainfall rates and specific stream power. Although mass accretion rates have not been well constrained, we argue that they remain relatively constant along the FTB. We suggest that the morphology of the Himalayan FTB is controlled primarily by erosion, in accordance with the critical taper model. Surface material removal is mainly controlled through rainfall and runoff and can be expressed as specific stream power. Thus, we propose that climatically induced erosion is the principal control on Himalayan foreland fold-and-thrust belt morphology.

We test this hypothesis through a series of 1D numerical models. Among the parameters controlling the form of a wedge, lithology, erodibility, and rock mechanical properties are relatively homogeneous throughout the belt. Hence, within the range of observed values in the Himalaya, we investigate the sensitivity of the shape of the Himalayan fold-and-thrust belt to the sole-out depth of the basal décollement, flux of tectonically added material, and the erosional constant.

For parameter values within the range of those observed in nature, the models successfully reproduce the observed variations in width of the Himalayan fold-and-thrust belt. The experimental results suggest:

- The value of the rock erodibility constant (K) varies over one order of magnitude or less along-strike of the Himalaya.
- Orogen-parallel variations in erosion rate can dominate over variations in accretion flux in controlling critical Coulomb wedge width.

Cite as: Grujic, D., et al.,, 2014, What controls the growth and shape of the Himalayan foreland fold-and-thrust belt?, in Montomoli C., et al., eds., proceedings for the 29th Himalaya-Karakoram-Tibet Workshop, Lucca, Italy.

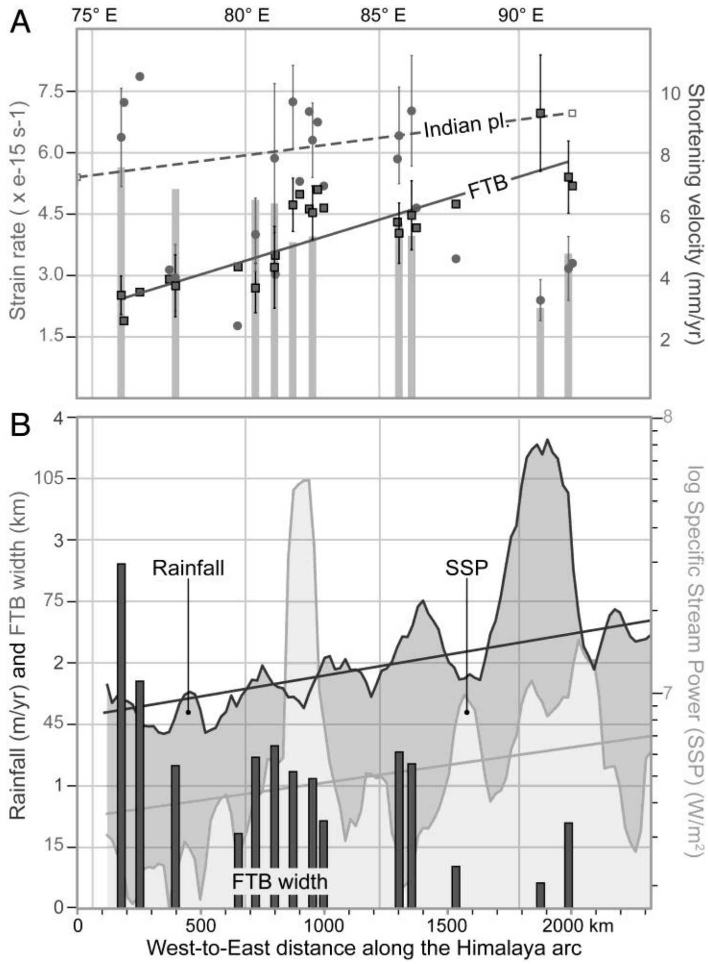

Figure 1. A) Graph of shortening velocity, strain rate, and sediment thickness of the Siwalik Group plotted against distance along the Himalayan arc. Dark and pale colours represent data from this study and published sections, respectively. Red line is the best fit of strain rate in the Himalayan FTB. The plate strain rate was calculated from the plate convergence rate of Molnar and Stock (2009), assuming the Indian plate motion is distributed over a lithosphere with a thickness of 200 km. Grey circle is the average shortening velocity and the grey line is the shortening velocity scaled to vary at the same rate as the plate convergence velocity. B) Graph plotting the width of the Himalayan fold-and thrust belt with distance along the Himalayan arc against total annual rainfall and specific steam power. From Hirschmiller et al. (2014).

References

Hirschmiller, J., Grujic, D., Bookhagen, B., Coutand, I., Huyghe, P., Mugnier, J.-L. and Ojha, T., 2014, What controls the growth of the Himalayan wedge? Pliocene to recent shortening of the Siwalik group in the Himalayan foreland belt, Geology, 42, 247–250, doi:10.1130/G35057.1.

Molnar, P., and Stock, J.M., 2009, Slowing of India's convergence with Eurasia since 20 Ma and its implications for Tibetan mantle dynamics, Tectonics, 28, TC3001, doi:10.1029/2008TC002271.