Great Himalayan Earthquakes: Recurrence Intervals and a Scaling Law

Nicole Feldl » University of Colorado, Boulder
Walter Szeliga » Dept of Geological Sciences, University of Colorado
R. Bilham » Dept of Geological Sciences, University of Colorado

A current problem in assessing seismic risk in the Himalaya is the absence of statistics suited to estimating a recurrence interval for great earthquakes. Elastic models of the collision using recently imaged subsurface interface geometries suggest that a substantial fraction of the southernmost 500 km of the Tibetan plateau participates in driving great ruptures. Theory suggests that this Tibetan reservoir of elastic strain energy is drained in proportion to Himalayan rupture length, and the consequent growth of slip and magnitude with rupture area, when compared to data from recent earthquakes, can be used to infer a renewal time for these events. The elastic models also illuminate two puzzling features of plate boundary seismicity: how great earthquakes can re-rupture regions that have already ruptured in recent smaller earthquakes, and how mega-earthquakes with ≥ 20 m slip may occur at millennia-long intervals, driven by residual strain following many centuries of smaller earthquakes (Feldl and Bilham, 2007).

We calculated both the instantaneous rupture slip and completely drained afterslip for these earthquakes—the upper and lower boundary of each curve. The scaling curves all have the same curvature but their intercept depends on the time between earthquakes. Earthquakes in the past 500 years for which Mw and length are known independently suggest a characteristic recurrence interval of ≈500 years. It appears, however, that this class of earthquakes may be atypical of the largest that occur in the Himalaya. Earthquakes with more than 20 m of slip have occurred in c.1100 AD, c.1400 and possibly as recently as 1505. These M>8.5 earthquakes release more than 20 m of slip, and may require 1000-year interseismic intervals. To efficiently to drain elastic energy in southern Tibet, an inferred essential condition in our model, they are associated with long ruptures (≥600 km).

References

Feldl, Nicole and Roger Bilham, Great Himalayan Earthquakes and the Tibetan Plateau, (2006) Nature, 444, 165-170 (9 November 2006) | doi:10.1038/nature05199.

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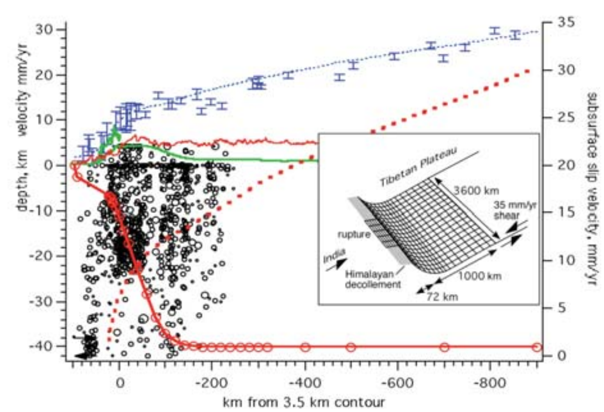

Figure 1. GPS velocity field across the Himalaya (data = blue with 1-sigma errors) have typically been fit to elastic deformation models driven by planar dislocations. These produce velocity fields that do not fit data from Tibet well. We used the geometry shown left (red from Schulte Pelkum et al., 2005) with a slip distribution (red dotted line) calculated to emulate interseismic surface velocities (predicted horizontal =blue dashed line; vertical = green line, black circles= microseismicity near Himalaya, courtesy Gaspar Monsalve). We then used boundary element methods (inset mesh) to calculate how the strain developed by this slip distribution would drive ruptures of different length in the Himalaya (curves (a.) right).