Seasonal Variations of Seismicity and Geodetic Strain in the Himalaya Induced by Surface Hydrology

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The Himalaya is characterized by an intense seismic activity ranging from frequent small magnitude earthquakes to infrequent destructive earthquakes, which have devastated the region repeatedly in the past. Nepal occupies one-third arc length of the Himalaya. This seismic activity is related to ongoing crustal shortening across the range driven by the India-Asia collision. The Department of Mines and Geology of Nepal has been monitoring local earthquakes since 1994 from a nationwide seismic network (Pandey et al, 1995; 1999). This network has been complemented with permanent GPS stations to monitor geodetic deformation. The seismic network has revealed very intense microseismicity along the front of the Higher Himalaya. Most of the activity is due to thrust events induced by north–south compression approximately perpendicular the Himalaya consistent with the geodetic strain measured form the GPS stations. The secular velocities derived from geodetic measurements across the Nepal Himalaya show that the Main Himalayan Thrust (MHT) is locked from beneath the high range to the piedmont, where it surfaces, and that it roots to the north into a subhorizontal shear zone that is creeping at about 2 cm/yr (Bilham et al., 1997; Bettinelli et al., 2006). Most of the seismicity clusters near the updip edge of the creeping zone, in a region where, according to the modeling of the geodetic data, Coulomb stress builds up at a rate higher than about 6 kPa/yr (Cattin and Avouac, 2000; Bollinger et al., 2004). This midcrustal seismicity was also observed to coincide with a zone of high electrical conductivity interpreted to reflect an interconnected fluid phase that probably comes from metamorphic dehydration of the underthrusting Indian basement (Lemmonier et al., 1999; Avouac, 2003). This coincidence suggests some coupling between seismicity and fluids flow.

In addition to the secular rates, we observed very interesting seasonal variation of seismicity and geodetic strain in the Nepal Himalaya (Bollinger et al, 2007; Bettinelli et al, 2007). The seismicity rate is twice as high in the winter as in the summer. Comparison with gravity measurements shows that variations of surface water storage (mainly over the Gangetic plain) is the primary cause of the observed seasonal strain variations (Betinelli et al, 2008). The induced seasonal stress variations have an

amplitude of ~2–4 kPa correlate with the seasonal variations of seismicity. We infer from this correlation ~10–20 kPa/yr interseismic stress buildup within the seismicity cluster along the high Himalaya front. Given that Earth tides exert little influence on Himalayan seismicity, the correlated seasonal variation of stress and seismicity indicates that the duration of earthquake nucleation in the Himalaya is of the order of days to month, placing constraints on faults friction laws. The unusual sensitivity of seismicity to small stress changes in the Himalaya might be due to high pore pressure at seismogenic depth.

Keywords: seismology; geodesy; tectonics; hydrology; Himalaya

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