High resolution earthquake location and 3-D velocity imaging of crust beneath the Kumaon Himalaya

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The seismological record and recent space-geodetic measurements suggest a significant seismic potential for the Kumaon-Garhwal Himalayan region. The region has several recent, deadly, moderate earthquakes, the most prominent being the Uttarkashi (1991 Oct 20, 30.75ºN 78.86ºE, M 6.6) and Chamoli (1999 March 29, 30.41ºN 79.42ºE, M 6.8) earthquakes. The major Himalayan faults are the Southern Tibetan Detachment (STD), the Main Central Thrust (MCT), the Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT). The Main Central Thrust in this region is a zone bounded by the Munsiari thrust (MT) in the south and the Vaikrita thrust (VT) in the north. Existing knowledge suggests that apart from sporadic outliers, most of the seismicity in the Himalaya is very well clustered in a narrow zone of MCT.

We operated a network of 46 broadband digital seismographs from April 2005 to June 2008 (Figure 1) in the Kumaon-Garhwal Himalaya region, in order to study the seismicity pattern, earth structure, fault geometry, earthquake mechanics and dynamics of the earthquake system. These stations were operated in two phases: (i) a NE-SW directed linear array of 20 stations for an initial period of 18 months from April 2005 with a couple of stations off the profile, and (ii) a laterally distributed network operating for around 18 months. We used 350 local earthquakes with at least 8 P and 5 S phase readings and an azimuth gap <180° to generate a 1-D reference velocity model for the region using VELEST. Using this velocity model, we relocated 1400 earthquakes recorded by at least 5 network stations. The geographical distribution of seismicity is shown in Figure 1. While the majority of earthquakes follow the trend of the MCT zone, we also observed earthquakes beneath the Ganga basin, the Lesser Himalaya, and the Higher Himalaya, continuing north of the STD. Figure 2 shows the depth distribution of earthquakes along a NE-SW section. Though the majority of earthquakes have their hypocenter in the upper crust (above 20 km), a significant number of them are located in the middle and lower crust. This pattern has been further verified by joint hypocenter and 3-D velocity imaging. Figure 3 shows the velocity-depth section along the profile with earthquakes plotted on it. Unlike in the Nepal Himalaya, we have no reliable observations of earthquakes in the mantle suggesting a lateral diversity in the rheological properties of Indian lithosphere underthrusting the Himalaya. We discuss the implication of the imaged velocity pattern in seismogenesis in the region.

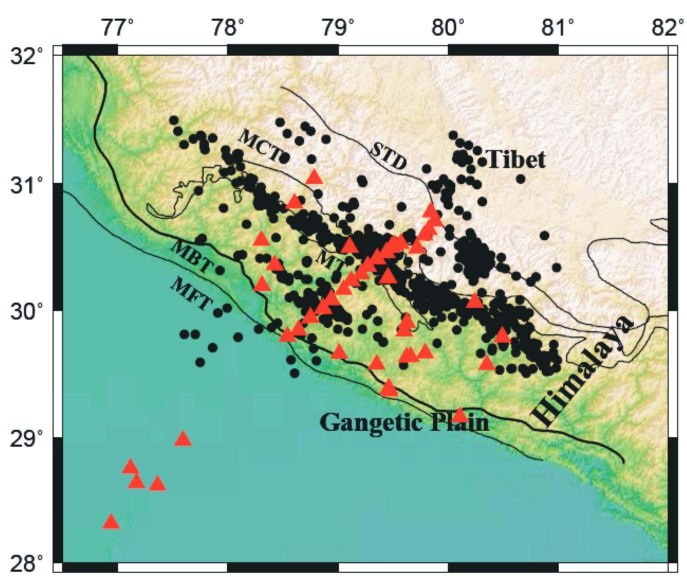

Figure 1: Location of broadband seismographs (red triangles) and distribution of earthquakes (filled circles) in the Kumaon Himalaya region. Major tectonic features are identified in the text.

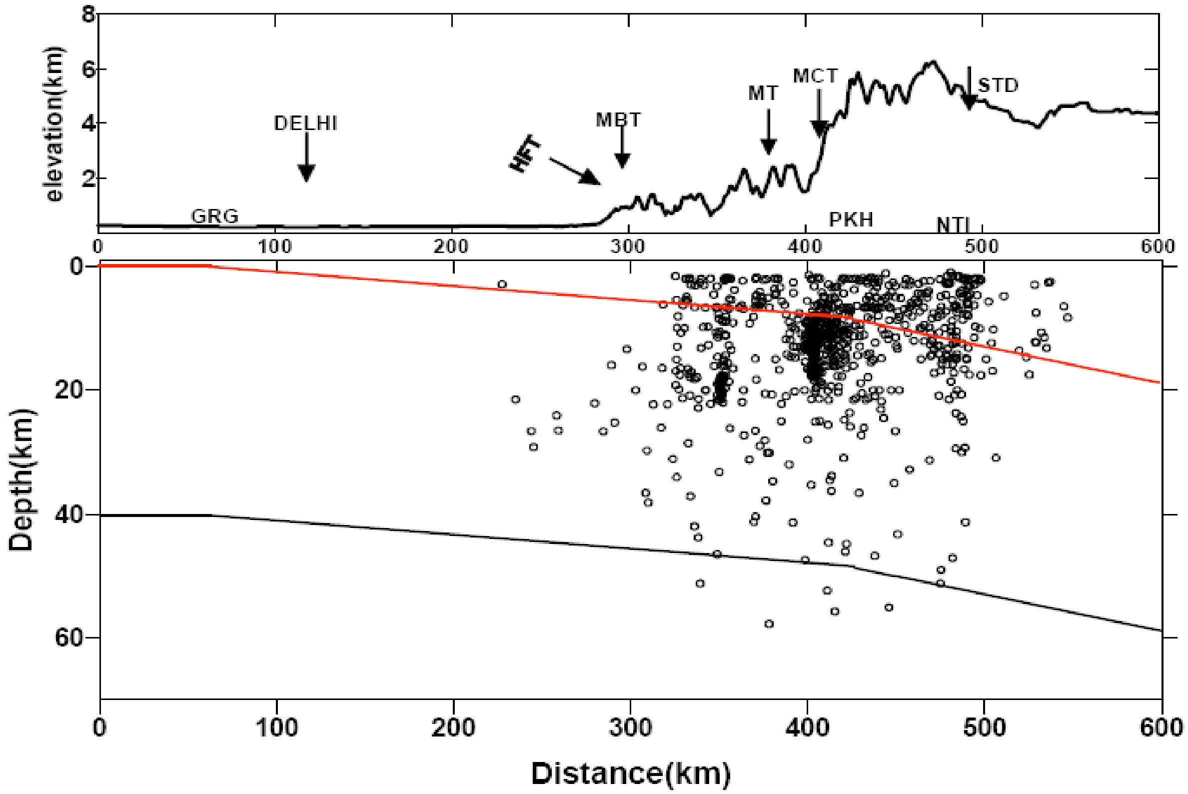

Figure 2. Earthquake locations in arc-normal cross-section for 1400 earthquakes recorded by the network. Earthquakes with at least 5 P and 3 S phase reading were relocated. Moho is mapped using receiver-function modeling. Also shown are the topography and the location of selected stations.

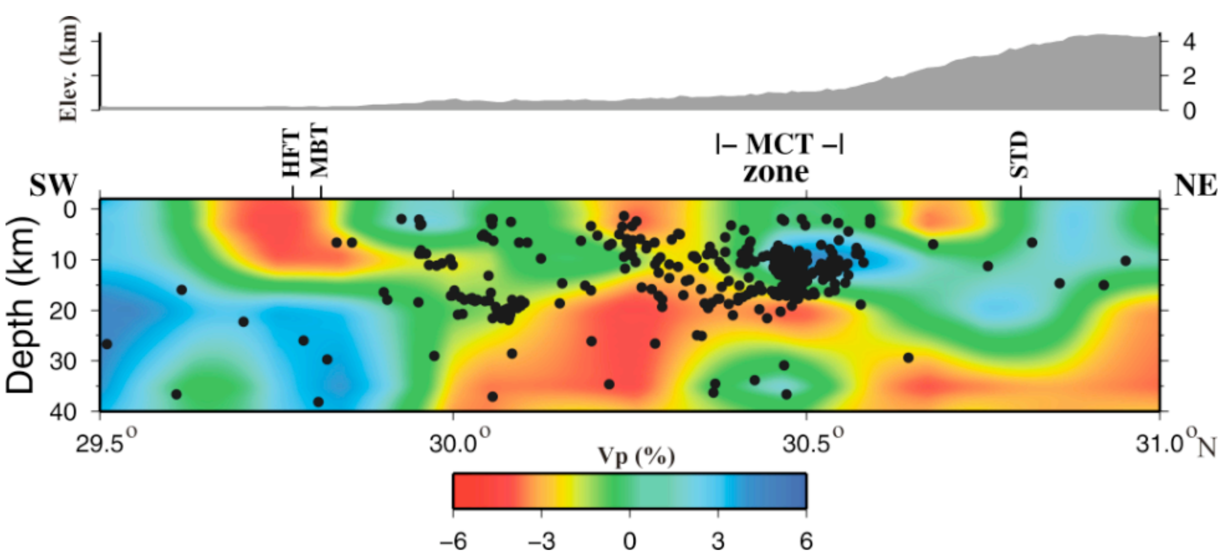

Figure 3. P wave velocity-depth section along a NE-SW profile aligned with the array of seismic stations. Also plotted is the location of earthquakes on the velocity image.

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