Structure of the Crust and Upper Mantle and Seismic Sources in the Himalaya-Tibet Region: Summary of Results from the Hi-CLIMB Experiment

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The 2002-2005 Hi-CLIMB (Himalayan-Tibetan Continental Lithosphere during Mountain Building) field experiment deployed 233 broadband seismic stations in the Himalaya-Tibet region. The centrepiece of the project was a closely spaced, 800-km-long linear array of broadband seismometers extending northward from the Ganges Basin (27°N), across the Himalayas, the Yarlung Tsangpo Suture (YTS), and the Banggong-Nujiang Suture (BNS) to the central Tibet (34°N). A sparser network of stations in Nepal and southern Tibet flanked the main linear array. By now, various studies have been published by different groups based on the Hi-CLIMB data set. Here we present a summary of the results related to crustal and upper-mantle structure and seismic sources, both conventional and non-conventional.

Using the linear seismic array we have constructed images of the crust and upper mantle beneath the Himalaya and the southern Tibetan Plateau (Nábělek and others, 2009; Vergne and others, 2005; Wittlinger and others, 2009). The images reveals in a continuous fashion the Main Himalayan thrust fault as it extends from a shallow depth under Nepal to the mid-crust under southern Tibet. Indian crust can be traced to 31°N. The crust-mantle interface beneath Tibet is anisotropic, indicating shearing during its formation. The dipping mantle fabric suggests that the Indian mantle is subducting in a diffuse fashion along several evolving sub-parallel structures. Reverse south-verging processes appear to have formed the lower crust and upper mantle north of 31°N.

The Main Himalayan thrust (MHT) fault, the detachment along which the India plate descends beneath the Himalaya and southern Tibet, is characterized by a velocity decrease, extending from shallow depths under Nepal to mid-crustal depths in the Lhasa Block. Beneath Nepal, the MHT partially underthrusts low-velocity sediments from the Ganges Basin under the Lesser Himalaya formations (Vergne and others, 2005). The sharp velocity decrease associated with this part of the MHT possibly reflects the presence of water released from the underthrust sediments and trapped beneath by clay-bearing fault gauge. The induced over-pressure of the trapped fluid decreases the fault strength and enables low-angle thrusting in this zone characterized by large earthquakes. In contrast, the velocity decrease associated with the deeper, creeping section of the MHT is probably caused by increased ductility and local partial melting.

The Moho is a prominent conversion seen along the entire profile. In the south, it dips gently from a depth of 40 km beneath the Ganges Basin on the Indian Plate to 50 km beneath the Himalayas. North of the Great Himalaya, the Moho deepens more rapidly, reaching a depth of 70 km north of the YTS. From this point, in the Lhasa Block, the Moho signal is at a constant depth over the next 200 km. The Moho becomes less clearly defined in the Northern Lhasa Block. It reappears as a strong interface north of the BNS, under the Qiangtang Block, but at a shallower depth of about 65 km.

These changes in crustal thickness do not correlate with the topography in the region between the Greater Himalaya and the YTS. This lack of relation indicates that the region is in regional isostatic compensation involving high density (high velocity) lower crust and mantle and support from flexural strength of the Indian plate. The thinner crust of the Qiangtang Block appears to be compensated by a lower density and lower velocity mantle and thus is distinctly different from the southern Lhasa Block.

The lowermost crust in the southern Lhasa Block is characterized by strong velocity-depth gradient and can be traced, albeit much less clearly, to shallower depths under Nepal. On the basis of gravity anomalies, this lower-crustal layer, probably of amphibolitic composition beneath Nepal, has been at least partially transformed into eclogite due to high-grade metamorphic reactions (Hetényi and others, 2007).

Modelling gravity and the shape of the subducted Indian crust (Hetényi and others, 2006) shows that (1) the effective elastic thickness (EET) of the India Plate decreases northwards from 60–80 to 20–30 km as it is flexed down beneath Himalaya and Tibet; (2) the only resistant layer of the India Plate beneath southern Tibet is the upper mantle, which serves as a support for the topographic load and (3) the most abrupt drop in the EET, located around 200 km south of the MFT, is associated with a gradual decoupling between the crust and the mantle.

Continuous seismic data recorded along the steep, narrow and deeply incised channel of the Trisuli River show clear seismic noise amplitude correlation with both regional meteorological and hydrological data along the river (Burtin and others, 2008). Seasonal increase in river-induced noise coincides with the strong monsoon rainfall and the rapid melting of snow and ice in the high elevations. The seismic noise exhibits a time hysteresis of the noise amplitude versus the water level suggesting that vibrations generated by bed-load transport are the main mechanism for the noise generation. This suggests that, if calibrated, seismic noise may be used to monitor the river bed load in a continuous fashion.

The Hi-CLIMB data have been also use to locate debris flows (Burtin and others, 2008), unusual low-frequency events (Vergne and others, 2008) and regional earthquakes (Baur and others, 2008).

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