Deformation and exhumation of the Higher and Lesser Himalayan Crystalline sequences in the Kumaon region, NW-Himalaya based on structural and fission-track analysis

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The crystalline rocks of the Himalayan orogen, exposed in the Kumaon Himalaya, consist of two distinct high-grade metamorphic units separated by a sequence of meta-sedimentary rocks of the Lesser Himalayan Zone (Figure 1). The northern unit corresponds to the Higher Himalayan Crystalline (HHC) sequence composed mainly of amphibolite facies to migmatitic para-gneiss. At the base, the Main Central Thrust (MCT) (locally named as Munsiari Thrust: MT) bounds the HHC, which is separated from the overlying low-grade meta-sediments of the Tethyan Sedimentary Zone (TSZ) by a gradational contact. A normal fault, equivalent to the South Tibetan Detachment System (STDS), is demarcated within the upper part of the HHC due to the presence of several normal faults. The southern unit i.e. the Chiplakot Crystalline Belt (CCB) is located within the Lesser Himalayan meta-sedimentary sequence (LHMS) of rocks to the south of the MCT. The North Chiplakot Thrust (NCT) in the north and South Chiplakot Thrust (SCT) in the south separate the CCB from the Lesser Himalayan meta-sedimentary rocks. Both the thrusts dip due NE and join to each other in the west along the Goriganga valley. The LHMS is overriding the CCB along the NCT while the CCB is overriding the LHMS along the SCT. A major NE-dipping thrust zone i.e. Central Chiplakot Thrust (CCT) breaks the CCB into two blocks along which the northern block is thrust over the southern block (Kumar and Patel 2004, Patel and Kumar 2006). The CCB mainly consists of greenschist facies rock derived from an early Proterozoic basement.

Structural results indicate that both the CCB and the HHC have undergone deformation history of pre-Himalayan (D1) to Himalayan deformations (D2/D3/D4). The prominent penetrative fabric in the CCB and the HHC, developed during the D2 reflect the ductile stage of deformation. It resulted in crustal thickening during Himalayan orogeny and became zone of rapid exhumation. The whole HHC moved along a broad ductile top-to-SW shear zone and the MCT/MT over the LHMS, while the CCB has undergone intense horizontal shortening in a NE-SW direction. It gave rise to the evolution of the CCB by emplacement over the LHMS zone along a broad shear zone developed within the duplex structure that formed south of the MCT (Patel and Kumar 2006).

Apatite and zircon fission-track data along the Darma and the Kaliganga valleys along with other published data from the CCB (Patel et al. 2007) and communicated data along the Goriganga valley (Patel and Carter, Communicated to *Tectonics*) from NW-Himalaya document bedrock cooling histories of the HHC and the CCB units exposed in the Kumaon region. Apatite FT ages range from 0.7±0.2 Ma to 2.9±0.6 Ma along the Goriganga Valley, from 1.0±0.1Ma to 2.8±0.3 Ma along the Darma valley and from 1.4±0.2 Ma to 2.4±0.3 Ma along the Kaliganga valley within the HHC. These show no relationship to either structural position or elevation. The uniform apatite cooling ages in the hanging wall of Vaikrita Thrust (VT) cluster around 0.8 Ma along the Goriganga valley, 1.5 Ma along Darma valley and 2 Ma along Kaliganga valley. In the footwall side ages are older and cluster around 1.6 Ma along Goriganga valley. Only one sample has been dated as 2.8 Ma along the Darma valley and no data is obtained in the Kaliganga valley in the footwall side of the VT. It is older than the ages obtained from the hanging wall side. Zircon FT ages range from 1.7±0.1 Ma to 4.4±0.4 Ma along Goriganga valley, from 4.0±0.2 Ma to 4.5±0.3 Ma along Darma valley and from 4.5±0.2 Ma to 5.2±0.2 Ma along the Kaliganga valley. Taking into account the sample locations with respect to MCT/MT, the data sets from all valleys in the Kumaon region show a uniform exhumation history of the HHC; and there is

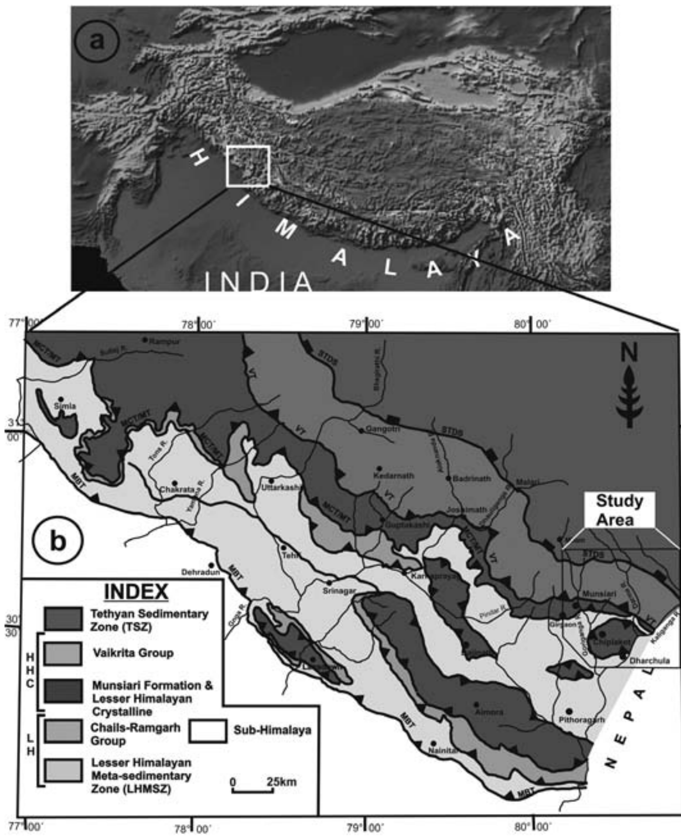

Fig. 1 (a) Geological setting of the studied area in the Himalaya (topography based on the GTOPO30 digital elevation model, U.S., Geological Survey, (b) Geological map of the Garhwal and Kumaon Himalayan region of India showing the tectonic setting of the Higher Himalayan Crystalline (HHC) and Chiplakot Crystalline Belt (CCB) in the overall lithostratigraphic framework of the region (modified after Valdiya, 1980). The study area is son in the square box. STDS: South Tibetan Detachment System, VT: Vaikrita Thrust, MCT: Main Central Thrust, MT: Munsiari Thrust, MBT: Main Boundary Thrust, HHC: Higher Himalayan Crystalline and LH: Lesser Himalaya

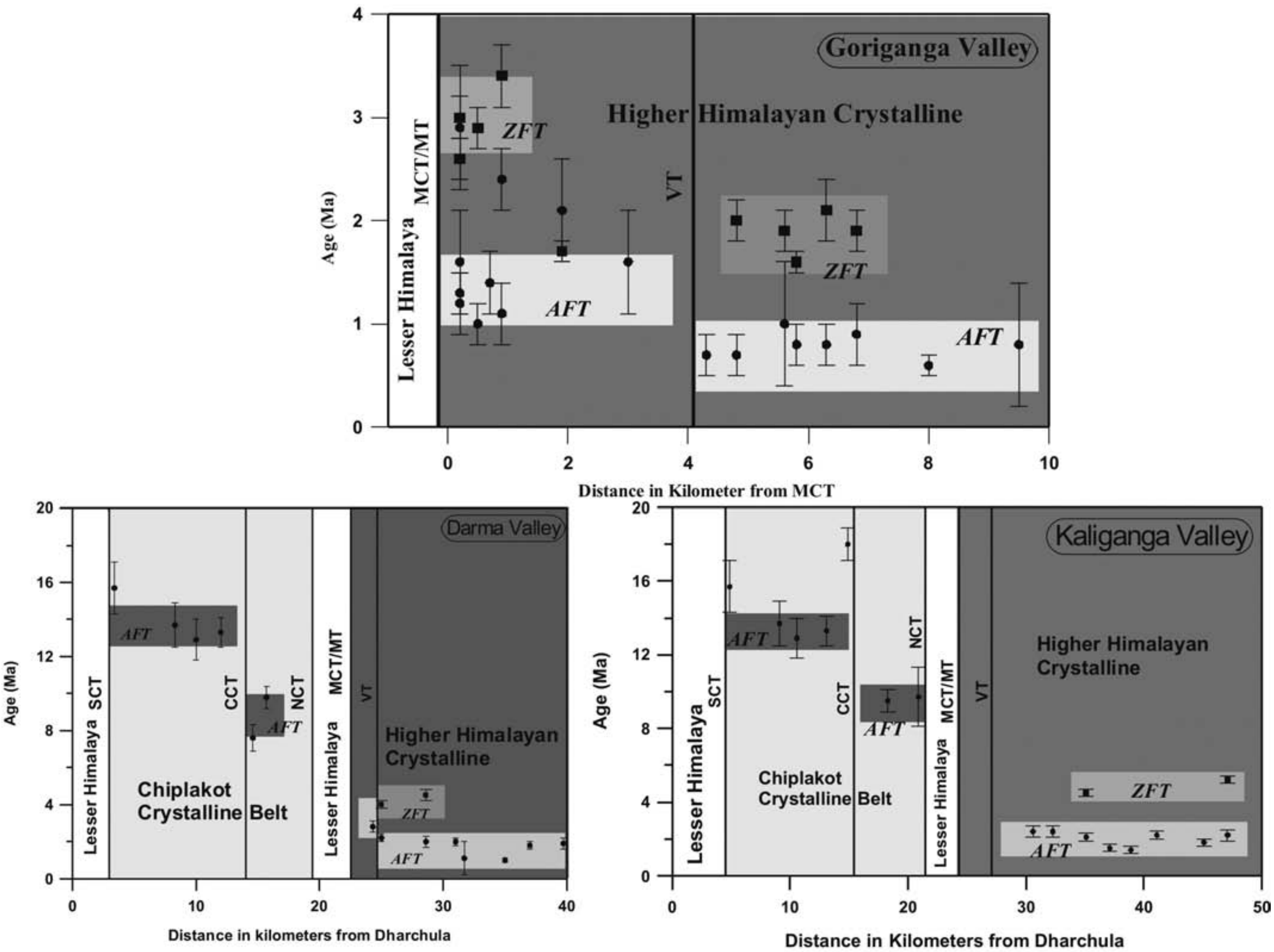

FIGURE 2. FT age Vs distance plots along the Goriganga, Darma and Kaliganga valleys in the Kumaon rigion, NW-Himalaya. Solid circles represent apatite FT ages and squares represent zircon FT ages

no change in the FT ages with distance from the MCT/MT (Figure 2). It indicates a constant parallelism between the surface and closure temperature implying a steady-state condition between topographic and exhumation since Pliocene. The distribution of the FT ages in all valleys suggests active movements along the VT that is almost synchronous along strike in the Kumaon region.

On the other hand, the AFT ages from the CCB (Lesser Himalayan Crystalline) are much older than the HHC. The ages range from 7.6 ± 0.6 Ma to 17.9± 0.9 Ma. Within the CCB, the AFT data statistically fall in two distinct groups: for southern block the ages range from 12.9 ± 1.1Ma to 17.9± 0.9 Ma, while for northern block it ranges from 7.6 ± 0.6 Ma to 9.8 ± 0.6 Ma (Patel et al., 2007). It implies differential exhumation history in the hanging wall and footwall blocks of the CCT within the CCB. It appears to be possibly due to structural-controlled erosive exhumation since middle Miocene.

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