Tectonics vs. erosion: evidences from apatite fission track and Rb-Sr (Biotite and Muscovite) thermochronology, Arunachal Himalaya

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Thermochronology has been extensively used to study the interplay between tectonics and erosion in recent years. Numerous works have been carried out in the Himalaya to explain this phenomenon with one school of thought giving more emphasis on tectonic exhumation (Burbank et al. 2003, Jain et al. 2000, Kumar et al. 1995), while other emphasizing on climatic control (Huntington et al. 2006, Thiede et al. 2004). Most of the earlier works made their conclusion based on a limited corridor study selected from this 2500 km long mountain range. In our present attempt, we give a comparative overview of different sector with similar tectonic setting and diverse climatic condition. So, in order to give a clearer picture we have taken up Apatite Fission Track (AFT) thermochronology and Rb-Sr thermochronology of bedrock samples of Arunachal Himalaya, which is one of the rainiest places on earth so as to compare with climatically stable western sector of this orogen.

Regional geology

The Himalayas represents the classical example of continent collision tectonics between Indian and Eurasian plates. In this orogen, the Arunachal Himalaya occupies the easternmost sector between longitude 91º 31´ and 96º 0´ E including the Eastern Himalayan Syntaxis (Singh 1993, Yin et al. 2006). The syntaxis also includes the major Siang Antiform

In Subansiri valley (Figure 1) the Siwalik belt belonging to Cenozoic foreland basin rises abruptly over the Holocene Brahmaputra alluvium along the Main Frontal Thrust (MFT) (Figure 1) and is overridden by the pre-Cenozoic sedimentary sequence along the Main Boundary Thrust (MBT) in the north. The low grade metasediments of the Khetabari Group (Lesser Himalaya) are overridden by the medium to high grade Daporijo Gneiss of the Himalayan Metamorphic belt (HMB) along the folded Main Central Thrust (MCT); its southernmost exposure has been called as the Tamen Thrust. The contact is locally folded into an overturned fold as if the Lesser Himalayan quartzite-phyllite succession is overlying the gneiss. Along the strike, the thrust is intermittently exposed along road section from Tamen to Daporijo, where quartzite-phyllite succession of the Khetabari Group invariably underlies the Daporijo Gneiss. The quartzite and phyllite are intensely crushed and mylonitized all along the road section, where these dip towards NNW beneath the gneisses. Along the ENE-flowing Sipi River – a tributary of the Subansiri River, the Sipi Quartzite of the Menga Window is overridden by the Daporijo Gneiss at this confluence with a locally-folded

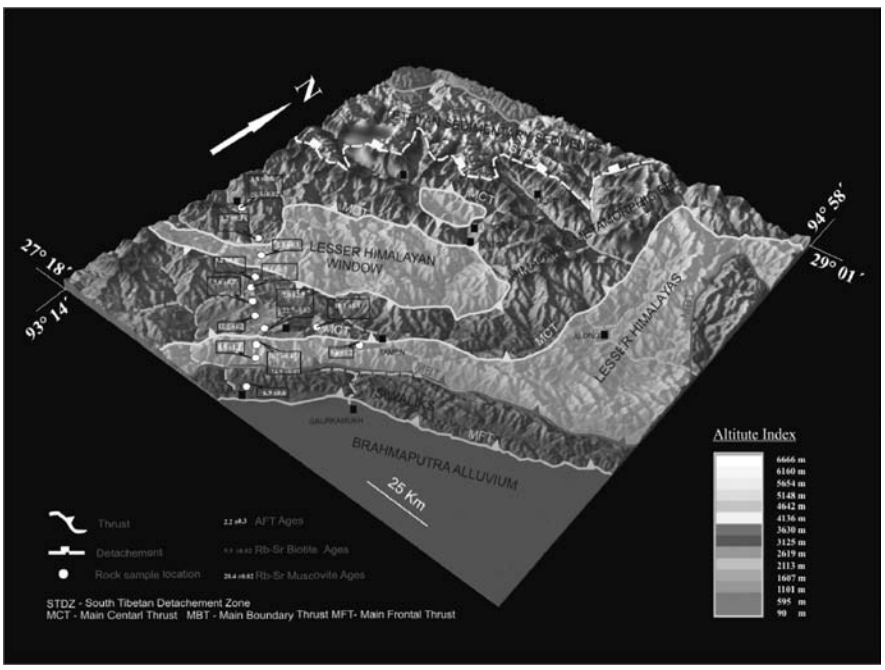

FIGURE 1. 3D perspective view of the Subansiri Valley, Arunachal Himalaya (90M SRTM from www.srtm.csi.cgiar.org) (Thakur and Jain 1974). From south to north this mountain belt is characterized by the Siwaliks, the Lesser Himalayas, the Himalayan Metamorphic belt (HMB), the Indus Tsangpo Suture Zone and the Trans-Himalayan units. The tectonic units trend E-W in the western parts and swing to NE–SW before bending abruptly to NNW–SSE along the Siang gorge.

contact. The Main Central Thrust (MCT) is exposed around Taliha, where low grade metamorphosed quartzite-phyllite alterations of the Sipi Quartzite are overridden by garnetiferous and kyanite-sillimanite schist/gneiss. The thrust is folded into a synform between Taliha and Baching and is again exposed around Nacho, where the underlying quartzite-phyllite sequence underlies the metamorphics of the HHC within a window.

AFT results and interpretation

AFT ages from bedrock samples in the Subansiri River catchment region from the Siwalik belt in the south to the Higher Himalaya, show spatial variation and have no positive correlation with elevation. Correlation the FT ages with the local tectonic setting highlights the overall thermotectonic evolution of this part of the orogen. The FT ages range from 2.1±0.3 Ma to 12.2±1.2 Ma, with youngest samples coming from the Lesser Himalayan window exposed within the HMB. The ages increase as the samples are analysed away from the core of the window (Figure 2), thus indicating that the folding has affected the cooling events in this part of the orogen. However, the ages vary relatively asymmetrically on the northern and southern limbs of the window. In the northern parts, the MCT hanging wall samples have young ages of 2.2±0.3 and 3.5±0.3 Ma. In the south, the Daporijo Gneiss yielded the AFT age of 5.2±0.6 Ma in the immediate vicinity, while the ages become as old as 12.2±1.2 Ma down south. Two Lesser Himalayan quartzite samples have AFT ages of 9.6±1.8 and 8.5±1.2 Ma, while a granite body intruding this unit has the AFT age of 4.7±0.4 Ma. Therefore, the Daporijo Gneiss cooled much earlier than the HHC rocks. The entire cooling pattern of the HMB is affected by folding of the HHC and subsequent exposure of the Lesser Himalayan window. The samples in immediate vicinity of the Tamen Thrust, both from underlying and overlying package, show no significant variation in the AFT ages. These ages suggest resetting of the AFT clock at different geologic times and variable cooling rates across the lithounits of the Eastern Himalaya during the late Miocene.

The Rb-Sr biotite ages of the gneisses from the present section range from 9.2 to 18.7 Ma. The Lesser Himalayan granite (LHG) body around village Potin yields the maximum age with 18.7±0.02. In the Daporijo Gneiss, the ages vary from 11.1±0.02 to 14.8±0.02 Ma. But two samples from the HHC exhibit similar and younger ages of 9.2±0.02 and 9.5±0.02 Ma. Interestingly, the one sample each from the LHG, DG and HHC yields Rb-Sr muscovite age of 24.9±0.02, 22.7 ±0.02 and 20.4± 0.02 respectively (Figure 2).

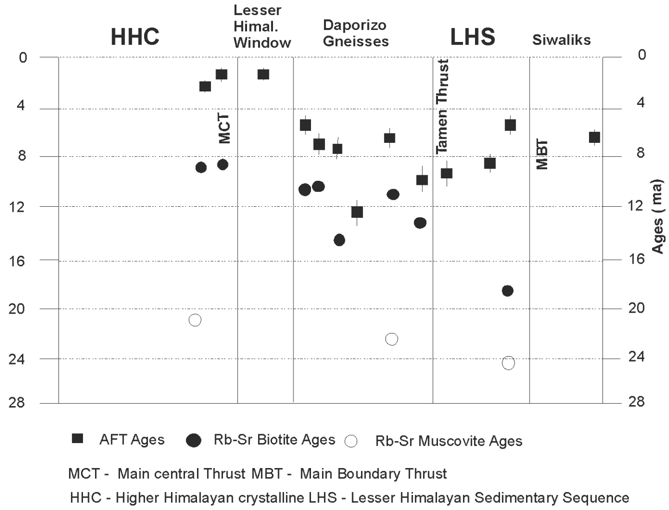

FIGURE 2. AFT, Rb-Sr biotite and muscovite)age profile along Kimin–Koloriang section.

These ages suggest resetting of the AFT and Rb-Sr biotite and muscovite clock in different geologic times and exhibit variable cooling rate across the lithounits of the Eastern Himalaya. As indicated by the Rb-Sr muscovite ages, the lithounits in both the LH and HMB cooled uniformly during early Miocene. The pattern begins to differ slightly as it reach the Rb-Sr biotite closure temperature, in which the LH sequence cooled earlier than the package which constitute the present the DG and the HHC. But, as cooling approach the Apatite annealing zone, the different packages shows different cooling pattern, with maximum cooling rate in the LH window and the HHC, and a much slower cooling rate in the DG and LH sequences. The exhumation rates, calculated with simple assumption of geothermal gradient of 30ºC/km, is fastest within the window zone with 1.9±0.8 mm/yr during 2.1 Ma to Present, and that of the HHC is 1.56±0.52 cm/yr during 20.4±0.02–9.5±0.02 Ma, 1.17±0.29 cm/yr during 9.5 to 3.5 Ma

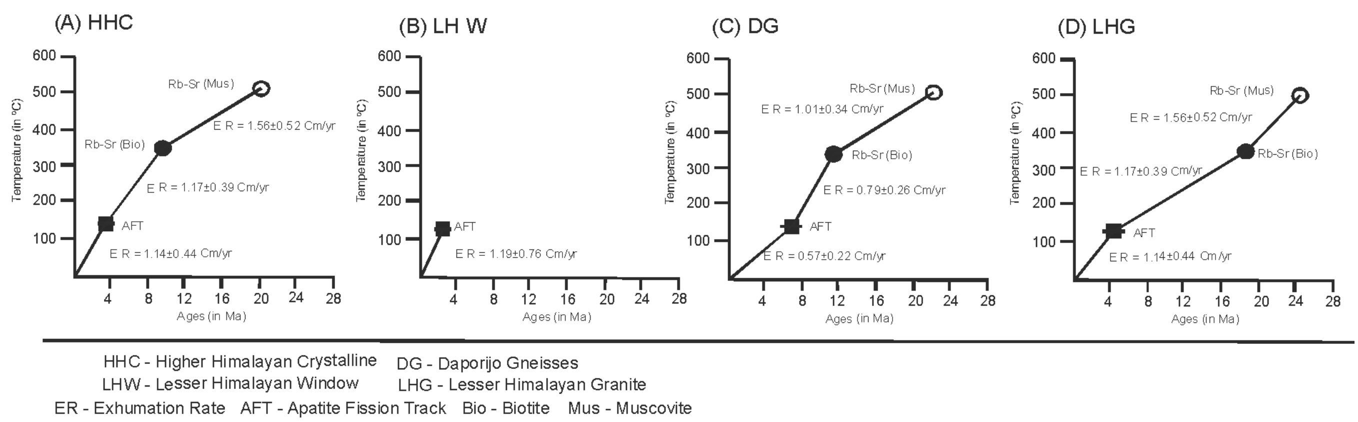

FIGURE 3. Exhumation pattern in different Lithounits of Kimin–Koloriang section

and 1.14 cm/yr thereafter (Figure 3). Within the DG, co-existing mineral pairs indicate exhumation rate of 1.01±0.34 cm/yr during 22.7 Ma to 11.8 Ma, 0.8±0.26 cm/yr during 11.8 to 7 Ma and 0.57±0.32 cm/yr thereafter. The rate is much slower in the Lesser Himalayan metasediments with 0.5 cm/yr since 7.6 Ma. The LHG exhumed at a rate of 0.76±0.25 cm/yr during 24.9 Ma and 11.8 Ma. The rate decreases to 0.4±0.13 cm/yr 18.7 Ma and 4.7 Ma but increases again to 0.85±0.35 cm/yr during 4.7 Ma to Present. The overall exhumation rate beginning in early Miocene is slower in the DG and LH sequence and fastest in the HHC and LH window. The AFT and Rb-Sr biotite and muscovite ages suggest the thrusting and crustal folding control the exhumation in Arunachal Himalaya.

References

Burbank DW, AE Blythe, J Putkonen, B Pratt-Sittaula, E Gabet, M Oskin, A Barros and TP Ojha. 2003. Decoupling of erosion and precipitation in the Himalayas. *Nature* 426: 652–655

Huntington KW, AE Blythe and KV Hodges. 2006. Climate change and Late Pliocene acceleration of erosion in the Himalaya. *Earth Planetary Science Letters* 252: 107–118

Jain AK, D Kumar, S Singh, A Kumar and N Lal. 2000. Timing quantification and tectonic model of Pliocene-Quarternary movements in NW Himalaya: evidences from fission track dating. *Earth Planetary Science Letters* 179 (3-4): 437-451

Kumar A, N Lal, AK Jain and RB Sorkhabi. 1995. Late-Cenozoic-Quaternary thermo-tectonic history of Higher Himalayan Crystalline (HHC) in Kishtwar-Padar-Zanskar region: Evidence from fission track ages. *Journal of Geological Society of India* 45: 375–391

Singh S. 1993. Geology and tectonics of Eastern Syntaxial Bend, Arunachal Himalaya. *Himalayan Geology* 4(2): 149-163

Thakur VC and AK Jain. 1974. Tectonics of the region of Eastern Himalayan syntaxis. *Current Science* 43 783–785

Thiede RC, B Bookhagen, JR Arrowsmith, ER Sobel, and MR Strecker. 2004. Climatic control on rapid exhumation along the Southern Himalayan Front. *Earth and Planetary Science Letters* 222: 791–806

Yin A, CS Dubey, TK Kelty, GE Gehrels, CY Chou, M Grove, and O Lovera. 2006. Structural evolution of the Arunachal Himalaya and implications for asymmetric development of the Himalayan orogen. *Current Science* 90(1-2): 195-206