Time constraints on partial melting and deformation of the Himalayan Crystalline Sequence, Nyalam Tibet: implications for orogenic models

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The processes leading to the formation of the Himalayan belt are still vividly debated. For some, the main process is that of a crustal wedge with Indian rocks being underthrusted in the lower plate and deeply buried, before to be accreted to the upper plate and then overthrusted and exhumed (e.g., Mattauer, 1986). Following numerical experiments analysis, a second class of models considers that the main process is that of a lower crustal melted layer expulsed outwards from beneath Tibet (e.g., Jamieson et al, 2006). Both models intend to explain the main geological characteristic of the High Himalaya: a zone of high-grade metamorphic rocks (the Himalayan crystalline series [HCS]) overthrusting less metamorphosed rocks along the Main central thrust (MCT), and overlain by unmetamorphosed rocks above the South Tibet detachment (STD). The internal structure and the Oligo-Miocene inverse metamorphism and high degree of melting observed in the HCS, have been interpreted as characteristic of either an accretionary prism, tectonic wedging, or Lower channel flow.

We present new structural, U-Th/Pb and Ar/Ar data along the Nyalam section across the HCS. From south (bottom) to north (top) we distinguish four tectono-stratigraphic units between the main central thrust (MCT) and the south Tibet detachment system (STDS). Unit 1 corresponds to the MCT zone and contains the upper MCT, unit 2 shows migmatitic othogneiss, units 3 contains in situ migmatites and marbles, and unit 4 consists of paragneiss and marbles intruded by leucogranites. The top of unit 4 is the ~ 300m thick STD shear zone. 15 new U-Th/Pb ages in monazites and zircons of magmatic rocks from units 2, 3 and 4 (Fig. 1) indicate : a) Intrusion of N-S steep dykes between 15 and 17.5 Ma; b) Prograde metamorphism (M1) occurred at ~35 Ma followed by onset of partial fusion (M2) at ~30 Ma in units 2 and 3; c) End of partial melting at ~18 Ma in unit 2 and ~20 Ma in unit 3; d) 7 new Ar/Ar ages of micas in late N-S gashes span between 18 and 5 Ma (Fig. 1) and suggest fast cooling right after the end of partial melting in unit 2.

When combined with published P-T results, Ar/Ar, AFT, ZFT data from Nyalam as well as published results from the Lantang and Dudh Kosi Valleys these data imply that: a) magmatic rocks of unit 4 are produced in units 1, 2 and 3; b) ductile deformation was restricted to the base of unit 1 (MCT 1) and the top of unit 4 (STD shear zone) after ~17.5 Ma, more specifically motion ended at ~13 Ma on the STD and ~9 Ma on the MCT; c) Partial melting ended several Ma before the end of motion on the MCT and the STD. In Nyalam, these structure never where the boundary of a partially molten channel; d) A first phase of rapid cooling occurs right after the end of partial fusion (at ~20 Ma in Dudh Kosi and ~17 Ma in Nyalam) (FC1, Fig. 1) prior to or during the intrusion of the last dykes that seal any ductile deformation in between the MCT and STD; e) A second phase of rapid cooling from ~16 to 13 Ma corresponds to the exhumation of the STDsz footwall up to near surface (FC2, Fig. 1); f) The third, and last, rapid cooling event since ~5 Ma (FC3, Fig. 1) only affects the southern part of the section (units 1 and 2); g) The STDsz has a more complex geometry than the straight low-angle fault often depicted. We propose that it follows flat and ramps, rooting south of the South Tibetan domes and that it initiated at ~24.5 Ma with a total offset of ~40 km.

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Several of these observations are barely compatible with the lower crustal channel flow model for the exhumation of the HCS. We rather propose a wedge model where HCS partial melting results from decompression above the MCT with an erosion and deformation front located at least ~100 km south of the present day exposure of the MCT in Langtang, Nyalam and Dudh Kosi sections. Shaping of the South slope of the high Himalaya took place since less than 5 Ma and is related to erosion triggered by uplift above a ramp of the MHT not to focussed erosion linked with the main exhumation of the HCS.

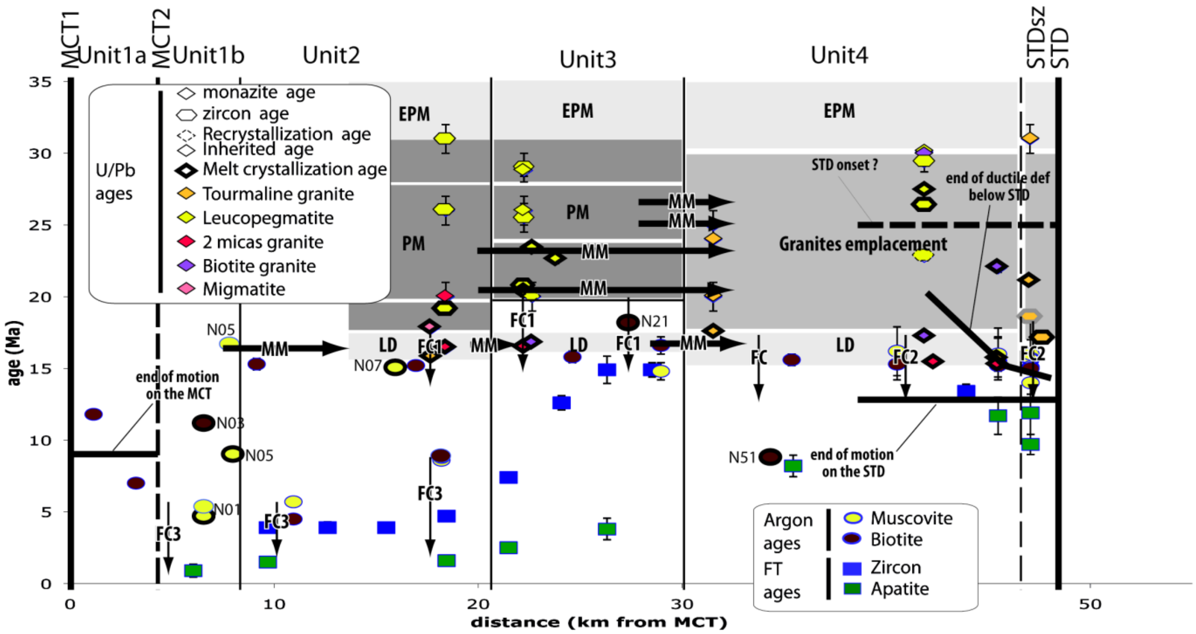

Figure 1. Available ages plotted as a function of the distance from the MCT along the Nyalam cross-section. Symbols colour / shapes refer to the geochronological / mineral systems and the type of rock. U/Pb data from units 2, 3 and 4 are from this study. Ar/Ar data are from Maluski et al. (1988), Wang et al. (2006), and this study (N standing for T11N samples). Zircon fission track data from Wang et al. (2010). Apatite fission track (AFT) data from Wang et al. (2001) and Wang et al. (2010). Grey area are interpretation: EPM: early prograde metamorphism, PM: partial melting, LRM: late retrograde metamorphism, LD: late undeformed dykes. The black arrows show fast cooling periods (FC), and inferred melt migration (MM).

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