EXTRACTING EXHUMATION PATTERNS FORM DETRITAL THERMOCHRONOLOGY: AN EXAMPLE FROM THE EASTERN HIMALAYA

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The Himalayan is rapidly emerging as a natural laboratory for studying intracontinental deformation related to continent-continent collision coupled with climatic-driven erosion.

The extreme topography of the Himalaya forms a barrier, differentiating climatic conditions and erosional patterns between the two sides of the belt. The interaction between crustal-tectonic and climate-erosional processes is borne out by the present day topography resulting in the bent patterns, and deep incised gorges of the major Himalayan rivers: the Indus and the Brahmaputra.

In the Eastern Himalaya, the Namche Barwa syntaxis is exhuming and eroding faster when compared with the central sectors of the belt since Late-Miocene Pliocene (Enkelmann *et al*., 2011; Zeitler *et al*., 2014). In the Namche Barwa syntaxis, cooling ages record a major exhumation pulse at ~5 Ma as young as ~10^6 a depending on the applied thermochronometer.

The sediment flux derived from the Namche Barwa area is estimated at ~70% of the total sediment flux in the Brahmaputra when reaching the foreland (Garzanti *et al*., 2004). However, the young thermochronometric signature (< ~5 Ma) downstream the Namche Barwa syntaxis seems to be suppressed by older age peaks derived from sediment components from tributaries draining the more central Himalayan rock units. This discrepancy in the modern river sediment age distributions is reflected in the syn-sedimentary basins where ages are as young as ~6-7 Ma and older.

The difference between the modern rate of sediment eroded from the Namche Barwa syntaxis and its downstream evolution is not completely understood. The implied question, then, concerns on how the detrital records can be used to assess the transient change in exhumation/erosion in a dynamic mountain belt. The present work is aimed at these outstanding questions.

The present work is aimed at these outstanding questions. For shedding new light on these issues, the following approach was followed: *i*) preliminary study of the consistency of the detrital mica $^{40}Ar/^{39}Ar$ and zircon fission tracks dating approach as tool to characterize the tectonic history of source rocks within the river network of an evolving mountain range; *ii*) development of a numerical linear inversion of the age distributions following the "mixing model" method (Braun *et al*., 2018). The method was tested on available literature data from the eastern Himalaya (Braun *et al*., 2018).

The results showed how using this technique is possible to extract averaged present-day erosion estimates and major exhumation pulses from detrital age distributions. This approach was tested for modern river sand sediments obtained from 19 river's catchments in the Eastern Alps (Fig. 1b) (Gemignani *et al*., 2017). Furthermore, Gemignani *et al.* (2018a) presented the outcomes of studies where the modern river sediments of the Eastern Himalayan were analyzed using two different thermochronometers (mica $^{40}Ar/^{39}Ar$ and zircon fission-tracks; Fig. 1b).

Understanding the tectonic evolution of the eastern Himalayan syntaxis is a key to differentiating different models of coupling between tectonics and erosion (Zeitler *et al*., 2001). The multi-proxy approach allowed to produce a synoptic cooling-age map of the eastern Himalaya that highlighted the spatial variation in exhumation rates of the contributing sources to the fluvial system (Fig. 1b). The relative present-day erosion estimates (Fig. 2) were then compared with a quantitative estimate of steady-state exhumation rates required to produce major age components observed in the detrital samples.

It was noticed that whilst the young age peak is distinctive for the studied minerals and endures many kilometers downstream, the young mica population is much more suppressed, both in proximal and distal samples. The potential effect of dilution of the analysed target minerals was addressed by looking at different grain-size fractions (Gemignani *et al*., 2018b). The grain-size variability can bias age distributions when studying large catchment areas, such as the Brahmaputra foreland. The author shows that for larger catchment areas multi grain-size analyses lead to a more complete assessment of the full spectrum of ages obtained from different sources. In particular, the analyses of smaller grain sizes (< 250 micrometers) show that previous ideas/arguments about the process of dilution of the Namche Barwa syntaxis age signal for muscovite were biased due to the measurement of exclusively the larger grain-sizes of the analyzed samples. This outcome potentially has important implications for future provenance studies.

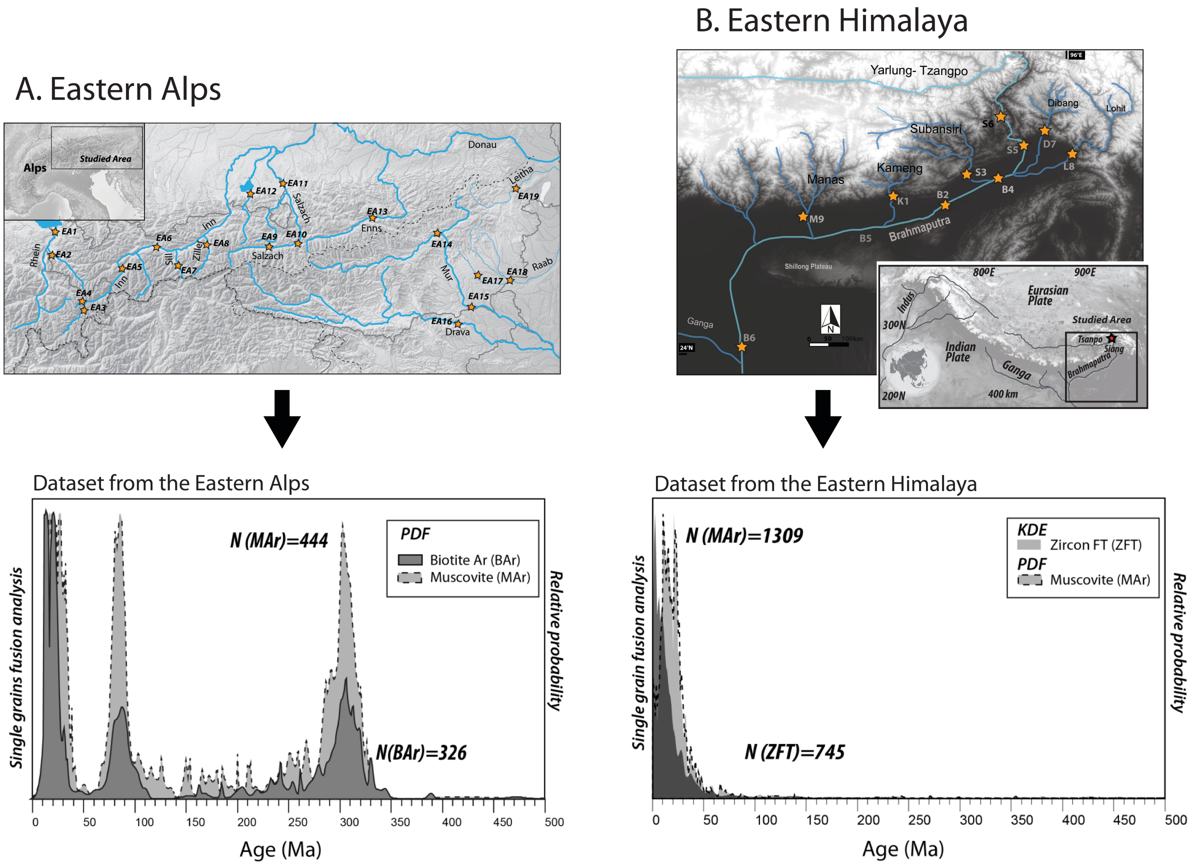

Fig. 1 - Location of the detrital river samples and probability density plots (PDPs) of the dataset from the Eastern Alps and Eastern Himalaya. A) Sample locations (orange stars), major river paths (blue), and PDPs of biotite and muscovite $^{40}Ar/^{39}Ar$ analysis from the Eastern Alps. On the X-axis the age are indicated in millions of years, on the y-axis the relative probability is displayed. B) Sample locations (orange stars), major river paths (blue), and PDP and Kernel Density Estimator (KDE) for muscovite $^{40}Ar/^{39}Ar$ and zircon fission tracks (ZFT) analysis. N = number of single grains dating analysis.

CONCLUSIONS

This PhD thesis explored the exhumation patterns of two dynamically evolving mountain ranges characterized by two distinct spatio-temporal evolutions.

The analysis of multi-proxy thermochronology shed lights on the dilution processes governing the Himalayan foreland for different target minerals. It was demonstrated that a combination of multi-proxy thermochronology, numerical modeling, and analytical technique improvement provides new opportunities to study the evolution of the transient response of mountain belts to changes in boundary conditions on geological (Ma) timescales.

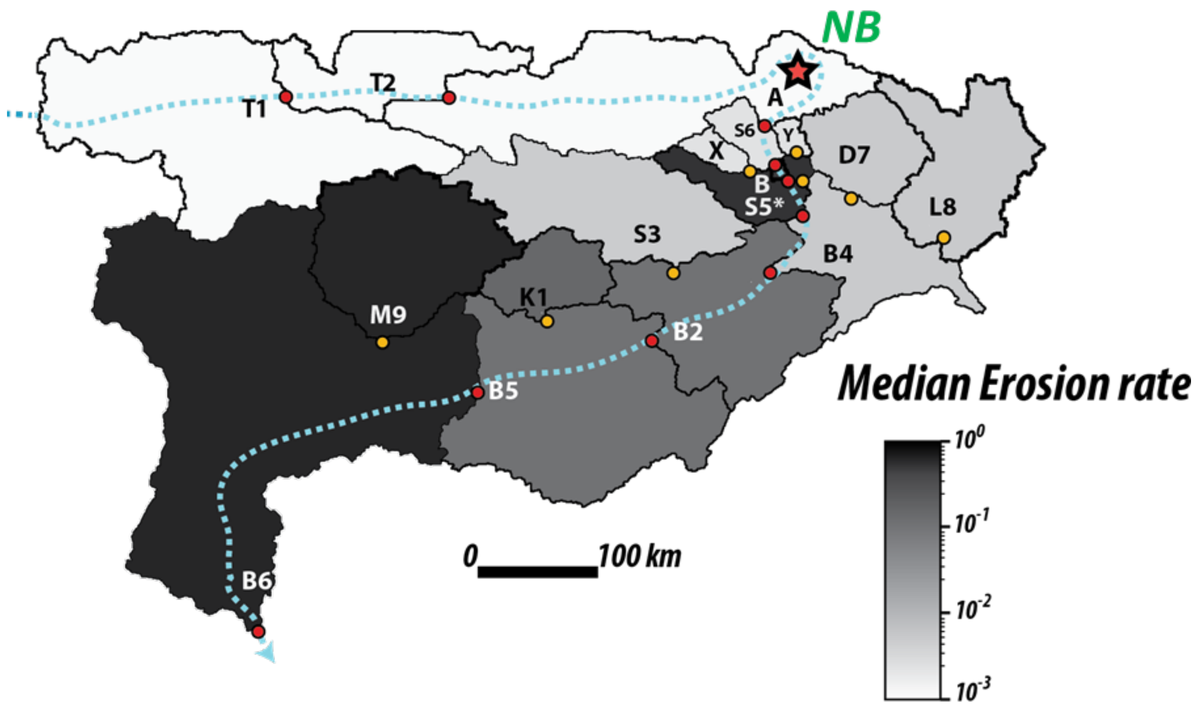

Fig. 2 - Present-day relative erosion-rate values pattern in the eastern Himalaya as predicted by linear inversion of the muscovite $^{40}Ar/^{39}Ar$ ages. The map shows catchments included in the model, shaded according to the predicted median relative erosion rates. The Tsangpo-Siang Brahmaputra is indicated by the dotted blue line. Red dots indicate samples collected from the major river trunk whereas the orange dots indicate the adjoining catchment samples. The red star indicates the Namche Barwa syntaxis.

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