Miocene paleoaltimetry of the Mt. Everest region

A. Gébelin[1], A. Mulch,[1,2,3], C. Teyssier[4], M.J. Jessup[5], R.D. Law[6], M. Brunel[7], and M.A. Cosca[8]

[1]Biodiversity and Climate Research Centre (BiK-F), Senckenberganlage 25, 60325 Frankfurt/Main, Germany
[2]Institut für Geowissenschaften, Goethe Universität Frankfurt, Altenhöferallee 1, 60438 Frankfurt/Main, Germany
[3]Senckenberg, Senckenberganlage 25, 60325 Frankfurt/Main, Germany
[4]Earth Sciences, University of Minnesota, Minneapolis, MN 55455, USA
[5]Dept. of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996, USA
[6]Dept. of Geosciences, Virginia Tech, Blacksburg, VA 24061, USA
[7]Géosciences Montpellier UMR 5243, Université Montpellier 2, 34095 Montpellier, France
[8]USGS Central Mineral and Environmental Resources Science Center, Denver, USA.
aude.gebelin@senckenberg.de

The elevation history of the Mount Everest region is key for understanding the tectonic history of the world´s highest mountain range, collisional tectonics, orogenic plateau development, onset of summer Asian monsoon, global climate change and biotic changes in Central Asia. The evolution of topography represents a complex function of regional and local climate, as well as surface and tectonic processes and it is inherently difficult to reconstruct. However, stable isotope paleoaltimetry, based on the systematic relationship between the oxygen ($\delta^{18}O$) and hydrogen (δD) isotope compositions of rainfall and elevation, permits to address this challenge of coupled tectonic and climatic research.

Most paleoaltimetry studies focus on geologic archives in sedimentary basins and to some extent neglect the role of orogen-scale deformation zones in the overall long-term landscape history. In absence of sedimentary deposits within the highly erosive Himalaya, we use the hydrogen isotope ratios (δD) of hydrous minerals that crystallized in the South Tibetan detachment (STD) shear zone during deformation (Fig. 1).

Synkinematic biotites collected systematically over 200 m of structural section from the STD into the underlying mylonitic footwall at Rongbuk Valley reveal a very constant pattern of mid Miocene $^{40}Ar/^{39}Ar$ plateau ages. The same minerals exchanged isotopically at high temperature with D-depleted water (δD_{water} = -150 ±5 ‰ equivalent to $\delta^{18}O_{water}$ = -20.0 ±1.0 ‰) that originated as high-elevation precipitation and infiltrated the crustal hydrologic system at that time [1].

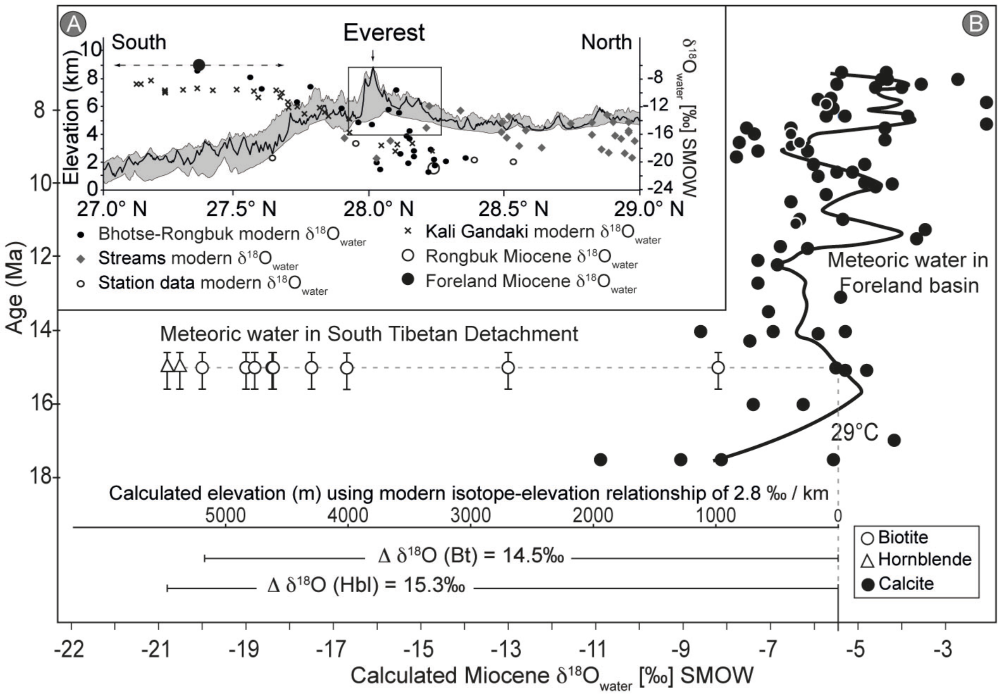

Figure 1: **(A) Present-day $\delta^{18}O_{water}$ values along an elevation profile across Mount Everest.** Grey area represents the elevation of a 20 km wide swath along the section with a clear $\delta^{18}O_{water}$ –elevation relationship (-2.8 ‰/km) which forms the basis of our analysis. Present-day precipitation collected at Rongbuk ($\delta^{18}O_{water}$ ~ -21‰) is similar to the lowest Miocene (ca. 15 Ma) $\delta^{18}O_{water}$ values indicating similar elevations at that time.
(B) Miocene paleoaltimetry reconstruction of Mount Everest. Calculated meteoric water compositions at high elevation (South Tibetan Detachment) have distinctly lower $\delta^{18}O_{water}$ values than age-equivalent rainfall at low elevation (Foreland basin). This difference in $\delta^{18}O_{water}$ of ca. 14.5 ‰ is consistent with a Miocene paleoelevation of the Everest region in excess of 5000 m. Foreland Basin data from [3]; [4]; [5]; South Tibetan detachment: data from [1].

Novel to our approach is to eliminate possible climate impacts on our paleoelevation estimate by comparing our high elevation hydrogen isotope record from the STD to age-equivalent oxygen isotope ratios within pedogenic carbonate from near sea level Siwalik foreland basin paleosols that record Miocene rainfall conditions in the

Himalayan foothills (Fig. 1). The relative difference between mid Miocene meteoric water compositions in the Siwalik foreland ($\delta^{18}O_{water} \approx -5.5 \pm 1.0‰$ based on $\delta^{18}O$ of pedogenic calcite) and the high elevation STD ($\delta^{18}O_{water} \approx -20 \pm 1‰$ based on δD of biotite) is $\Delta\delta^{18}O_{water} \approx 14.5 \pm 1.0$ ‰ which is consistent with mean elevations of ~5200 m for the Everest region at ~15 Ma.

These similar-to-modern Miocene mean elevations have various implications: 1) If Himalayan topography indeed plays a pivotal role in controlling monsoonal rainfall patterns on the Indian subcontinent [2], presence of a high Himalayan range at ~15 Ma indicates strengthening of the Asian summer monsoon earlier than previously thought; 2) Mid Miocene high elevation Himalayan topography must have influenced mid Miocene rainfall patterns on the Tibetan plateau including the presence of a strong Himalayan rain shadow.

[1] A. Gébelin, A. Mulch, C. Teyssier, M. J. Jessup, R.D. Law, and M. Brunel, The Miocene elevation of Mount Everest, Geology, (2013), doi:10.1130/G34331.1.
[2] W.R. Boos and Z. Kuang, Dominant control of the South Asian monsoon by orographic insulation versus plateau heating, Nature 463, 218-222 (2010), doi:10.1038/nature/08707.
[3] J. Quade and T.E. Cerling, Expansion of C_4 grasses in the Late Miocene of Northern Pakistan: evidence from stable isotopes in paleosols: Palaeogeogr., Palaeoclimatol., Palaeoecol., 115, 91-116 (1995).
[4] J. Quade, J.M.L. Cater, T.P. Ojha, J. Adam, and T.M. Harrison, Late Miocene environmental change in Nepal and the northern Indian subcontinent: Stable isotopic evidence from paleosols: Geol. Soc.Am. Bull., 107,1381-1397 (1995).
[5] A. Leier, J. Quade, P. DeCelles, and P. Kapp, Stable isotopic results from paleosol carbonate in South Asia: Paleoenvironmental reconstructions and selective alteration: Earth Planet. Sci. Lett., 279, 242-254 (2009), doi: 10.1016/j.epsl.2008.12.044.

Key words: stable isotope paleoaltimetry, $^{40}Ar/^{39}Ar$ thermochronology, Asian summer monsoon, Himalaya, Mount Everest, South Tibetan Detachment