Neogene Paleoelevation and Paleoclimate of the Central Alps – Linking Earth Surface Processes to Lithospheric Dynamics (Alpine Paleoelevation-Paleoclimate Experiment APE)

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The project aims to constrain $\delta^{18}O$ and δD based palaeoelevation estimates by coupling high- and low-elevation stable isotope precipitation records (δ-δ approach) and quantifying and correcting for any palaeoclimatic impact on the observed $\delta^{18}O$ and δD records. We address this challenge through an integration of isotope-enabled climate model (ECHAM5-wiso) simulations with stable isotope and clumped isotope data collected from the foreland basin and high-elevation regions of the Alps. New insights into the elevation history may help to constrain the timing of slab inversion and/or tearing in the Western/Central Alps and its impact on surface elevation.

Preliminary results of alluvial megafans of the Swiss Molasse Basin (Fig. 1) reveal that 1) low-elevation distal $\delta^{18}O$ values of pedogenic carbonate that serve as proxy for $\delta^{18}O$ of ancient rainfall are higher than previously assumed and more adequately reflect low-elevation $\delta^{18}O$ values for palaeoelevation reconstructions; 2) Mid-Miocene Δ_{47}-derived soil carbonate formation temperatures show higher temperatures than previously assumed; 3) the combination of low elevation $\delta^{18}O$ and Δ_{47} data with high elevation $\delta^{18}O$ and δD data argues for mid-Miocene Central Alpine elevations exceeding 3500 m. ECHAM5-wiso simulations have been conducted with 1) altered boundary conditions based on palaeogeographic reconstructions of the Last Glacial Maximum (LGM) and the Pliocene, and 2) different topographic scenarios for the Alps. Results from those simulations (Fig. 2) show that long-term climate change may affect $\delta^{18}O$ of precipitation with a similar magnitude that changes in Alpine topography. For example, the climatically induced modeled $\delta^{18}O$ in precipitation changes in the Pliocene attain the same magnitude as the model results that are based on a reduction of Alpine topography by 50%, while climatically induced $\delta^{18}O$ changes in the LGM are similar to changes produced by increasing Alpine tomography to 150%. Consequently, the palaeoclimate signal in measured $\delta^{18}O$ from geologic archives must be adequately constrained for $\delta^{18}O$ – based palaeoaltimetry.

Our results emphasize the requirement of the δ-δ approach and the importance of a careful choice of sample locations for paleoaltimetry reconstructions. In summary, the combined data and modeling approaches not only permit important methodological advances but also allow the disentangling of climatic and surface uplift signals in the geologic stable isotope record.

Our combined model-proxy approach bridges spatial and temporal scales of environmental change over the Alps and establishes a surface elevation record that informs the debate about the timing of slab inversion and/or tearing in the Western Alps, and serves as a point of reference for thermochronology and geo-dynamic modelling studies. Our results suggest that models that investigate the coupling between tectonics and erosion, and the crust-mantle processes responsible for shaping the European Alps need to take into account that surface elevation of the European Alps attained maximum values no later than the middle Miocene. This study directly contributes to Research Themes 1, 2, 3 and Activity Fields E, F of the 4D-MB priority research program.

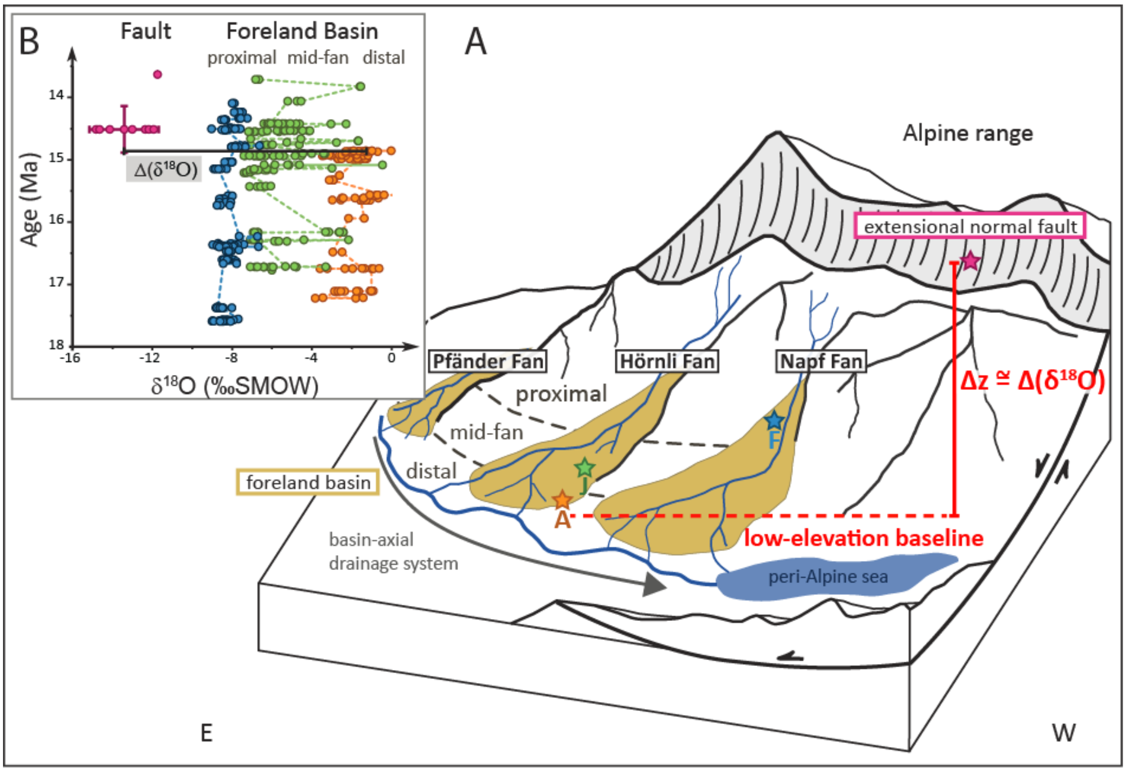

Fig. 1: ***(A)*** *When compared to low-elevation oxygen isotope records from the Molasse foreland basin stable isotope compositions from hydrous, synextensional fault zone minerals reflect the difference in elevation (Δz) between foreland and high-Alpine regions.* ***(B)*** *The Molasse megafans, however, show distinct differences with decreasing $\delta^{18}O$ from distal to proximal depositional environments, consistent with presence of internal relief. Collectively, $\delta^{18}O$ and Δ_{47} document that previously established low-elevation reference points from proximal fan settings led to an underestimation of Alpine paleoelevations.*

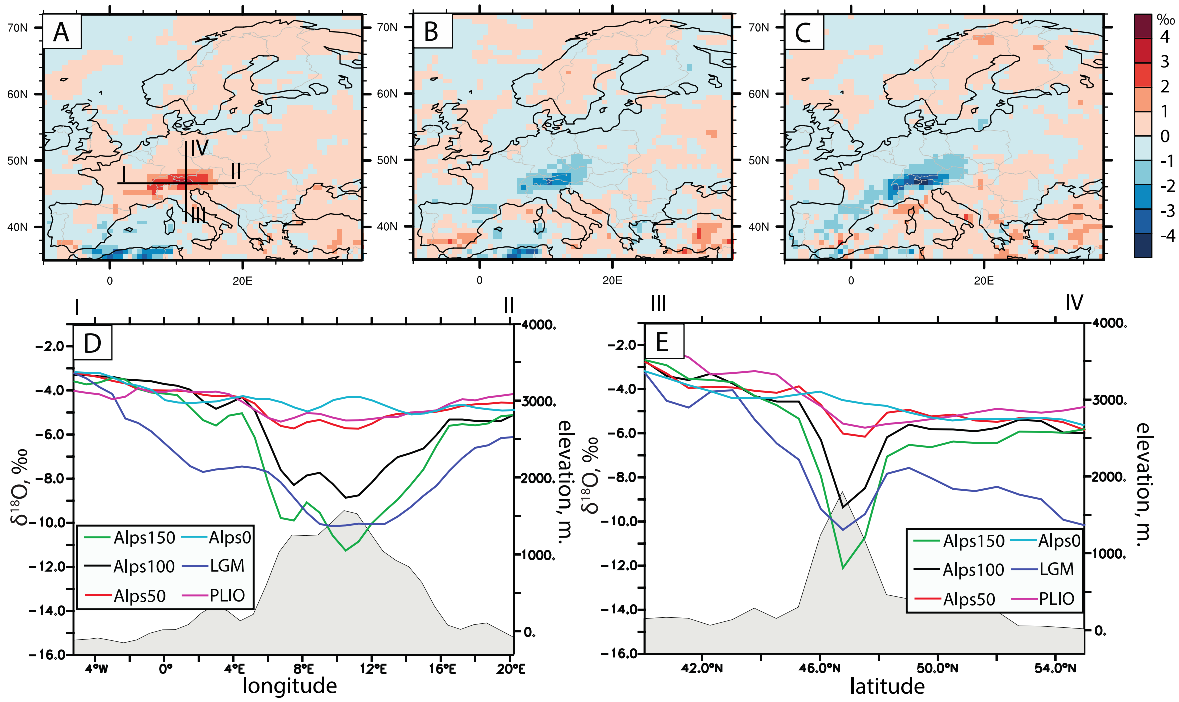

Fig. 2: *ECHAM-wiso simulated summer differences in $\delta^{18}O_p$ between:* ***(A)*** *Alps100 - Alps150,* ***(B)*** *Alps100 - Alps50, and* ***(C)*** *Alps100 - Alps0. Summer $\delta^{18}O_p$ cross-Alps sections averaged* ***(D)*** *between 46 °N and 47 °N and* ***(E)*** *between 9 °E and 10 °E for sensitivity and paleo simulations.*

Publication List:

Botsyun, S., Ehlers, T.A., Mutz, S.G., Methner, K., Krsnik, E., Mulch, A., [In Review]: Opportunities and challenges for paleoaltimetry in "small" orogens: insights from the European Alps, *Geology*.

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Methner, K., Campani, M., Fiebig, J., Löffler, N., Kempf, O., **Mulch, A.** [in review]: Middle Miocene long-term continental temperature change in and out of pace with marine climate records, *Scientific Reports*.

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Methner, K., Chamberlain, C. P., Bajnai, D., Campani, M., Fiebig J., Kempf O., **Krsnik E.**, Löffler, N., **Mulch, A.**, 2019: Terrestrial temperature response to middle Miocene northern hemisphere climate change: Case studies from Central European and continental North American paleosols, *Geophysical Research Abstracts*, Vol. 21, EGU2019-7910.

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