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Topography and rainout in the central European Alps during the late Neogene (8-6 Ma)

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Late Miocene global climate and vegetation dynamics have been called upon for changes in erosional and accretionary flux, surface elevation as well as precipitation and erosion dynamics in many of the world's major mountain ranges. Yet, despite over 200 years of scientific enquiry in the European Alps one of the most important controls for Earth surface and climate feedbacks, the surface elevation history is still largely elusive. Reconstructing surface elevation therefore not only adds to the growing body of Alpine geologic data but also contributes to identifying the various feedbacks that exist among wedge dynamics and global and regional climate change.

We present a novel application of hydrogen isotope-based paleoaltimetry that explores the hydrogen isotope values of meteoric water in late Neogene (8-6 Ma) clay gouge-bearing faults from the AlpTransit Tunnel (central Alps, Switzerland). The underlying concept is the systematic relationship between elevation and the hydrogen isotopic composition of orographic rainout that we aim to recover from synkinematic fault-bounded clay minerals. Modern data of isotopes in precipitation from various subsurface exposures in the central Alps show that extensional fracture networks sample meteoric water on decadal to centennial time scales and effectively capture the hypsometry of the overlying massif.

Similarly, meteoric water percolated downward within these faults during late-Neogene extension. K-Ar dating of illite documents that brittle faulting and gouge formation occurred between ca. 8-6 Ma at T=100-250 °C. Hydrogen isotope data from mixed illite/smectite clay gouge reveal that meteoric water had hydrogen isotope values 10-20 permil lower than observed at the highest elevations in the area today. Given the global climatic changes since the Late Miocene these data are consistent with mean elevations of the central Alps exceeding the modern by more than 1000 m between 8-6 Ma.

The results of our study are twofold: 1) Our hydrogen isotope data when considered in the context of changes in surface elevation are consistent with paleoaltitudes in the central Alps that attained elevations exceeding modern elevations during protracted orogen-parallel extension in the late Miocene and 2) it is likely that 8-6 Ma brittle faulting played an important role in exhuming rocks in the high central Alps, yet thermochronological data from the Simplon footwall suggest that this time interval was characterized by intermediate exhumation rates immediately preceding accelerated Plio-/Pleistocene exhumation and denudation. Given the tectonic evidence of persistent fault-related exhumation throughout the Miocene, we speculate that the 8-6 Ma paleoelevations may be characteristic for the central Alps during a time interval of global climate-driven changes in vegetation and precipitation patterns. Such an interpretation is consistent with postulated Mio-/Pliocene changes in wedge dynamics from accretionary to dominantly erosive flux and re-localization of focused erosion and exhumation in the external massifs of the central Alps sometime during the late Miocene/Pliocene.