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Paleoaltimetry and surface uplift of the Neogene Central Alps: a hydrogen stable isotope study from the Simplon Fault Zone.

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The tectonic, sedimentary, geochronologic and geodynamic histories of the Alps have long been a matter of scientific enquiry. However, the history of development of the most striking feature of this orogen, its elevation and topography, is still poorly established, even though this is the most intensely studied mountain range on Earth. Since the coupling of internal dynamics and surface processes is directly related to the geodynamic evolution of an orogen, reconstructing the surface elevation history is, however, critically important. Here, we present the first results of a hydrogen isotope based paleoaltimetry study from the Neogene Central Alps (Simplon Fault Zone, Switzerland). From a geodynamic point of view, the Neogene represents a major period of orogen-parallel extension. This regional extension induced large-scale surface uplift and exhumation of the internal regions associated with the development of crustal scale extensional detachments, such as the Simplon Fault Zone (SFZ) in the Central Alps. This well exposed low-angle detachment developed during continued convergence, and is characterized by a continuous exhumation history from 19 to 3 Ma, with a transition from ductile shearing to localized brittle deformation at ca. 14 Ma.

Stable isotope paleoaltimetry is based on the observation that there is a systematic change in the stable isotopic composition of precipitation with elevation during orographic rainout. Crustal-scale extensional detachments have been shown to represent potential pathways for infiltration of surface derived (meteoric) water that may be able to penetrate across the brittle-ductile transition within the actively extending detachment. During extensional shearing, this meteoric water will inevitably interact and exchange with hydrous synkinematic minerals and hence can be traced through its (often) unique hydrogen isotope fingerprint in such minerals. We exploit the hydrogen isotopic compositions of (paleo-)meteoric waters in recrystallized micas across the detachment from the mylonitic footwall to the fractured hanging wall of the SFZ through space and time. Muscovite and biotite δD values from the hanging wall provide unequivocal evidence for meteoric water interaction (δD = -120‰ -130‰) while synkinematic and recrystallized micas in the footwall become rapidly rock-buffered, generally with only slight variations in δD toward meteoric values (δD = -50‰ to -80‰). The isotopic data clearly document the infiltration of meteoric fluids into the brittle upper plate of the hanging wall over the entire length of the fault zone, while the discrete detachment marking the contact between hanging wall and footwall appears to have been an important barrier to meteoric fluid flow. Detailed geochronology, including ^{40}Ar/^{39}Ar on white micas and fission track dating on zircon and apatite across the SFZ, constrains the timing of isotopic exchange during the late brittle history of the detachment to be between 14 and 5 Ma.

The results of our study are twofold: 1) Similar to detachments delimiting the metamorphic core complexes of the North American Cordillera, the SFZ detachment seems to have acted as a conduit for meteoric water to depths corresponding to the brittle-ductile transition and 2) our hydrogen isotope data, when considered in the context of changes in surface elevation of the central Alps, is consistent with paleoaltitudes that attained elevations of 2400 m or more during the late Miocene.