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Miocene paleoaltimetry of the Central Alps

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Reconstructing the surface elevation, surface uplift, and relief evolution histories is fundamental to understanding the growth of mountain ranges, to explore their topographic limits, and relate these to geodynamic and Earth surface processes. Here, we aim to quantify the Miocene paleoelevation of the Central Alps through stable isotope paleoaltimetry. Stable isotope paleoaltimetry is based on a systematic decrease in the stable isotopic composition of precipitation with elevation during orographic rainout. These meteoric waters subsequently interact and exchange with hydrous authigenic, pedogenic or recrystallized minerals and can be traced through their hydrogen and oxygen isotope fingerprints in such minerals. The approach used here is to analyze stable isotope paleoaltimetry proxies of the same age both from internal parts of the Alpine orogen and from the adjacent foreland basins, to provide an estimate of the relative elevation differences at a given time. In internal parts of the orogen, we exploit the hydrogen isotopic ratio in mica porphyroclasts across the Simplon detachment. This crustal-scale normal fault developed during Neogene orogen-parallel extension in the Central Alps and has been shown to represent a potential pathway for infiltration of meteoric water. In the Swiss Molasse of the North-Alpine foreland basin we exploit the stable isotopic composition of Miocene carbonate-bearing paleosols.

In the Simplon Fault Zone, detachment-related muscovite and chlorite δD values from the brittle hanging wall provide unequivocal evidence for meteoric water interaction, with δD values of -120‰ and -130‰ respectively. In the footwall mylonites, synkinematic and recrystallized muscovite and biotite have δD values of -110‰ and -140‰ respectively and display a strongly localized pattern of meteoric water interaction. Detailed 40Ar/39Ar and fission track geochronology constrains the timing of isotopic exchange during the ductile to brittle transition of the detachment to ca. 14-15 Ma. We further analyzed time-equivalent oxygen and carbon isotopic compositions of pedogenic mudstone and carbonate concretions from deposits in the North-Alpine foreland basin. These paleosols, dated with ca. 100 ky precision, serve as our point of reference for stable isotope paleoaltimetry, since they formed at or near sea level. Here, δ18O and δ13C values vary between +19 to +27‰ (SMOW) and -7 to +1‰ respectively. Using the relative differences between meteoric water composition in the foreland and internal regions of the orogen, our isotope data are consistent with an average altitude difference of 2500 m $\pm$ 500 m during the late Miocene between the foreland basin and the internal regions, some 500-1000 m more than today. Our results do not necessarily agree with the proposition that the main formation of topography started only 5-6 Ma ago, since the Alpine elevations were higher than today already in the mid to late Miocene. Besides, the relatively high δ18O values in the North-Alpine foreland basin suggest that the Alps already acted as a bivergent orographic barrier with its highest elevations in the Simplon area and that the North-Alpine foreland basin was not in a rain shadow position.