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Stable (δ18O) and clumped (Δ47) isotope geochemistry reveal Central European temperature and rainfall seasonality across the Middle Miocene Climate Transition

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Temperature and rainfall patterns, as well as their seasonality, determine the evolution of biomes and ecosystems and thus, reconstructing these parameters in the geologic past is crucial for paleo-environmental and paleo-ecological studies. Here we combine carbonate stable isotope (δ18O, δ13C) and clumped isotope temperature (T(Δ47)) data obtained from pedogenic carbonates. Pedogenic carbonates preserved in paleosols typically form in the warm months after the rainy season. Thus, Δ47-temperatures of pedogenic carbonates are typically thought to reflect warm month mean/summer temperatures (WMMT), whereas δ18O values serve as an indicator of local rainfall. The integration of these proxies, in conjunction with sedimentological and paleontological data, is a powerful tool for assessing paleoenvironmental and paleoclimate conditions.
The Alpine foreland molasse provides a high-resolution (ca. 100 ka precision) paleosol record (ca. 17.5 to 14.0 Ma) and covers a period of global warming during the Mid-Miocene Climate Optimum (MCO) and the onset of the Miocene Climate Transition (MCT). Our T(Δ47) record from the Swiss molasses basin shows temperatures between ca. 22°C and 35°C during the time interval of the MCO, with a minimum temperature of at ~23°C at 16.4 Ma. This is followed by a rapid major temperature drop to about 16°C after ~14.5 Ma, resulting in a halving of soil temperatures within only 200ka. Our T(Δ47) record shows two temperature decreases similar in timing to marine isotope stages Mi-2 and likely Mi-3 (MCT). This indicates that the Swiss Molasse Basin recorded global climate changes associated with atmospheric CO_2 changes.
Interestingly, Δ47 temperatures are similar to WMMT of other proxy records of this region (e.g. paleobotany, δ18O of enamel), but shift to mean annual temperatures at the onset of the MCT. We interpret this shift as a change in timing of carbonate formation to cooler seasons as a consequence of a shift in rainfall seasonality (wet-dry cycling). We therefore argue that the Δ47 temperatures in the molasse paleosols not only reflect global temperature changes, but also include a seasonal temperature change and that the pedogenic carbonate formation shifted from summer to spring/fall season.