



Flowstone compositions as indicators of centennial fluctuations of hydrological balance in Central Europe during the late Holocene

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Flowstones formed from springs in the Baradla and Béke Caves, North-east Hungary were drilled at several locations, and their sites were monitored for temperature, CO₂ level in cave air, water and carbonate compositions for three years. The monitoring results suggest that the carbonate precipitated close to equilibrium with the local water. The non-systematic distribution of stable isotope and chemical compositions along sections on the surfaces of flowstone occurrences indicate irregular formation and the possibility of hiatuses within the flowstones' edifices. Approximately ~40 cm long drill cores were extracted from the „Nagy-tufa” flowstone of the Béke Cave (BNT-2 core) and the Havasok flowstone of the Baradla Cave. U-Th dating efforts resulted in very large age uncertainties for the BNT-2 core, owing to detrital Th contamination. Therefore, in addition to the U-Th dating, AMS radiocarbon analyses were conducted to establish reliable age-depth models. The raw ¹⁴C ages were corrected for the dead carbon fraction (dfc) using radiocarbon results obtained for samples that yielded also accurate U-Th ages. Calibration and age-depth modeling have been performed using the OxCal v4.2.4. software. The data prove that the flowstones in the studied caves were formed contemporarily, covering the last ~4 ka with two major hiatuses around 3.5 and 1 ka BP. Inclusion-hosted water contents, stable carbon and oxygen isotope compositions of carbonate, and hydrogen isotope composition of inclusion-hosted water as well as Si contents were determined for the two cores and compared with regional paleoclimate records for the period of 3.5 to 1 ka BP. The water contents, $\delta^{13}\text{C}_{\text{carb}}$ values and Si contents show correspondence with paleoprecipitation proxies from Central Europe to western Anatolia, while the paleotemperature estimates obtained using the $\delta\text{D}_{\text{water}}$ values were in agreement with temperature reconstructions derived from paleobiological proxies from nearby lake sediments. The inferred paleohumidity variations agree also with water level changes of Lake Balaton (Western Hungary) assumed on the base of settlement migrations revealed by archeological excavations. These correlations indicate that the flowstone data provide valuable information about the regional water balance fluctuations for the late Holocene.

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