Supplementary

A 4000-year long Late Holocene climate record from Hermes Cave (Peloponnese, Greece)

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Supplementary Data:

Data S1:

For the interpretation of the oxygen isotope data of the rainfall, it is important to note that temperature alone only has limited influence on the infiltration-weighted $\delta^{18}O$ value (Supplementary Fig. S3). Similarly, an infiltration increase only during winter time leaves the infiltration-weighted $\delta^{18}O$ value almost constant (Supplementary Fig. S2). In contrast, an infiltration increase only during the warmer period has a major impact and could explain changes of up to 2.5 ‰ (Supplementary Fig. S2). Such a situation, however, is highly unlikely given the prevailing high pressure during the summer months. Modern observations around the Eastern Mediterranean including weather stations at Athens (Fig. 3c, Supplementary Fig. 1) highlight a correlation between increasing rainfall and more negative rainfall $\delta^{18}O$ values. Such a correlation has also been found for cave related studies with a similar $\delta^{18}O$/rainfall amount slope at the Pequin and Soreq Cave sites (Bar-Matthews et al., 2003). Therefore, a likely scenario for the observed amplitude of ~1 ‰ in calcite $\delta^{18}O$ values (that could be directly transferred to rainfall $\delta^{18}O$ values due to negligible disequilibrium throughout the stalagmite growth) is a general increase or decrease in infiltration amount.

Supplementary Figures:

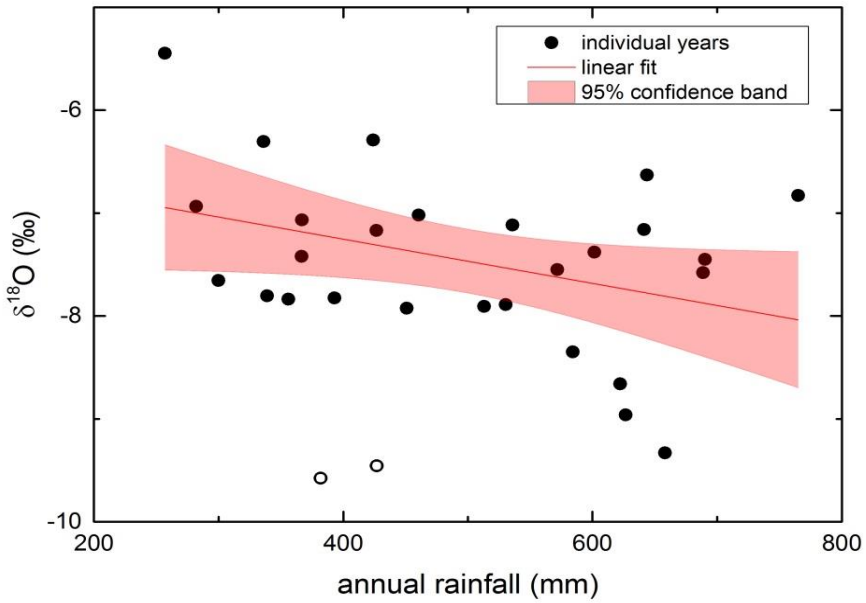


Figure S1: Annual rainfall $\delta^{18}O$ – amount relationship from IAEA weather stations at Athens (stations Hellinikon and Pendeli). Station Hellinikon Airport, Athens was scaled to station Athens-Pendeli using the corresponding means in $\delta^{18}O$. The two open circles were disregarded in the linear fit. The slope is -0.0022±0.0011 ‰/mm.

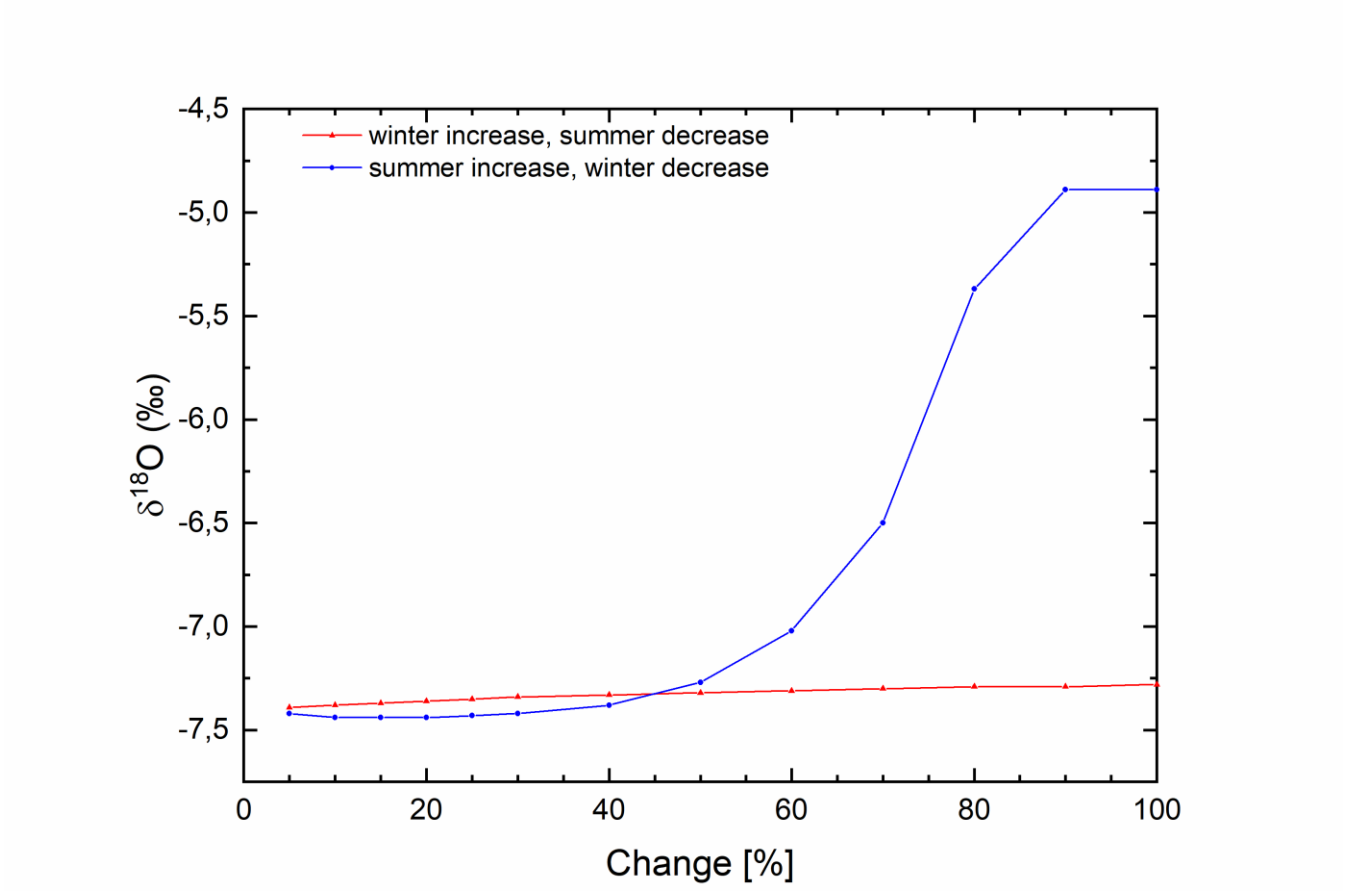


Fig. S2a: Sensitivity analysis of the infiltration-weighted water $\delta^{18}O$ values on seasonal changes. An increase in winter precipitation has little influence on the water $\delta^{18}O$ value as infiltration is already small from late spring to early autumn compared to the amounts during cold months. The strongest effect is observed for an increase in summer precipitation with coeval decrease in winter precipitation. Calculations are based on the isotope and weather data of the Athens IAEA stations.

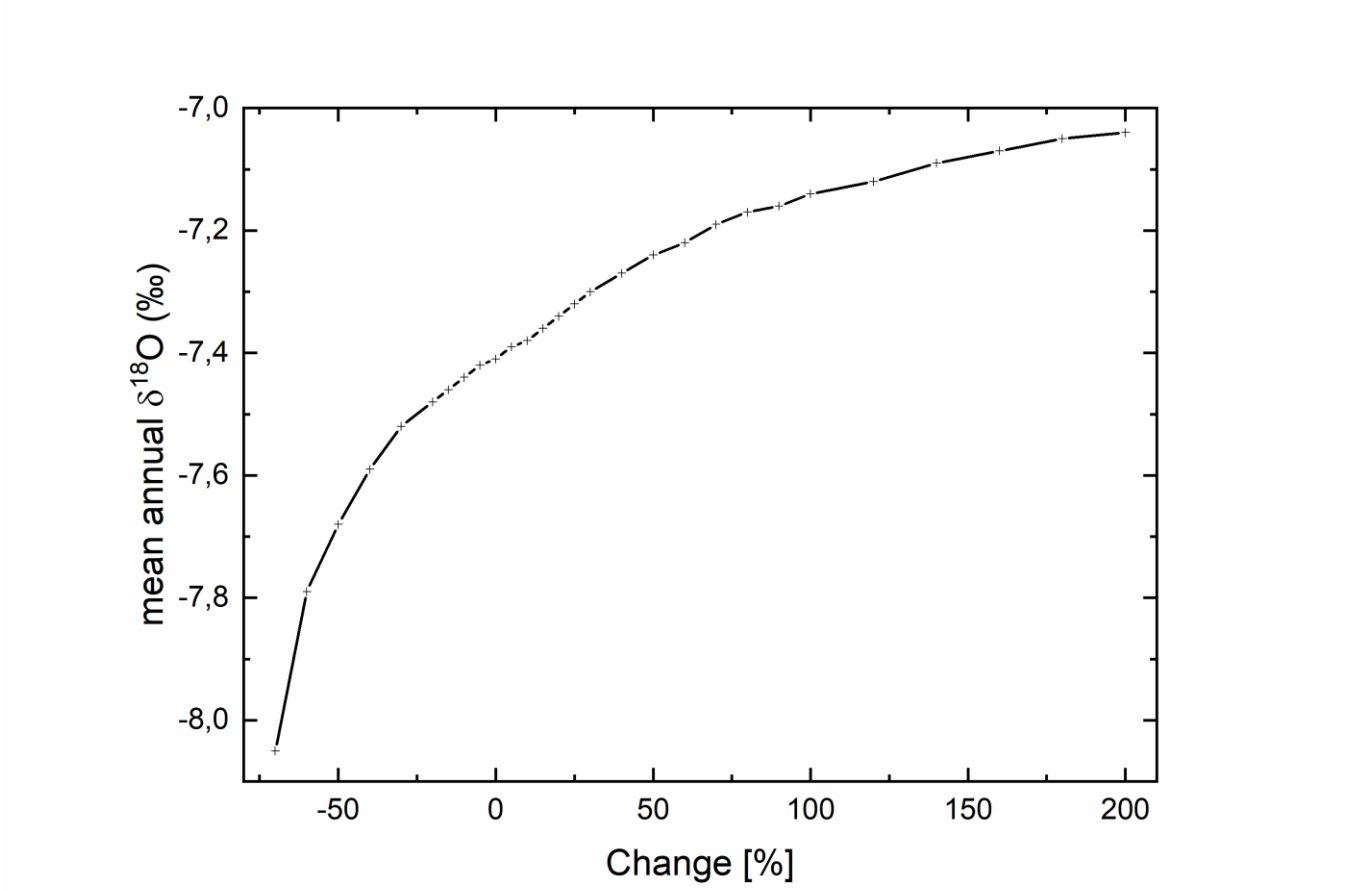


Figure S2b: Sensitivity of the infiltration-weighted annual $\delta^{18}O$ values on uniform increases or decreases in the rainfall amount (in percentage relative to today). The analysis is based on data from the IAEA weather station at Athens Pendeli.

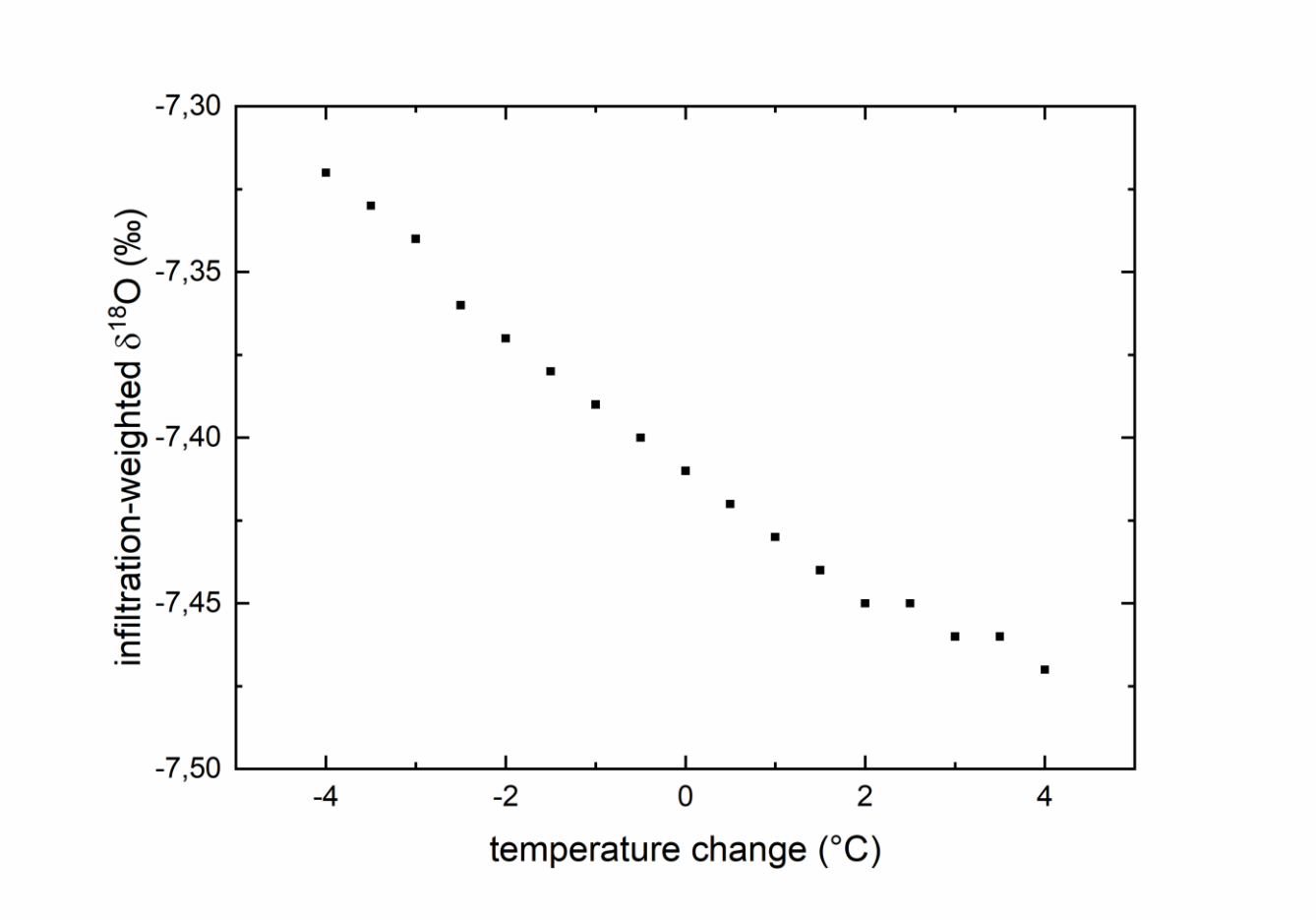


Figure S3: Influence of annual mean temperature on the infiltration-weighted water $\delta^{18}O$ values. This example has been calculated for data from Athens (IAEA-WMO, 2019) uniformly increasing or decreasing the mean annual temperature under a scenario of constant rainfall. Changes are limited within a reasonable range of inter-annual temperature variability.

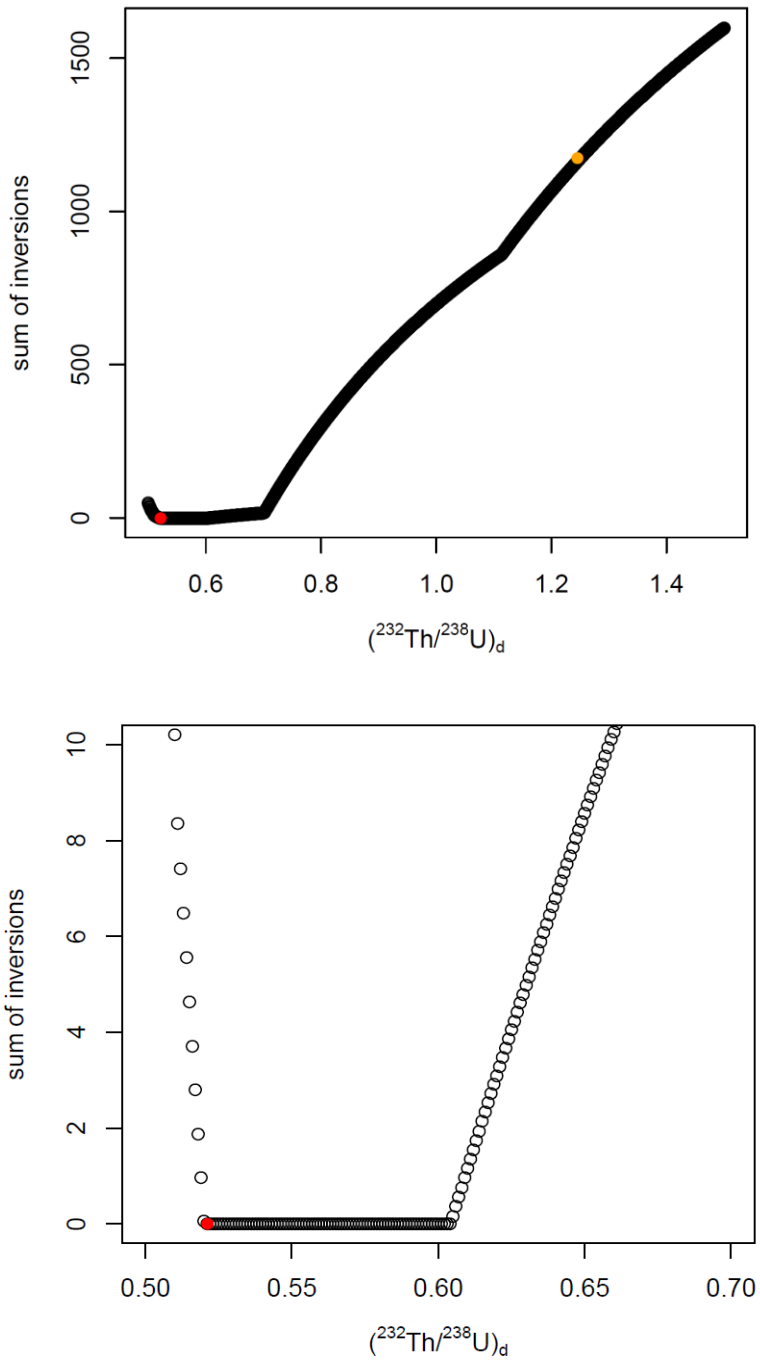


Figure S4: Determination of the detrital correction factor based on minimization of age inversions. For details, see Budsky et al. (2019). The lower panel is a detailed zoom of the minimum plateau. For values between 0.521 and 0.604, no age inversions are observed. The final value for the detrital correction in this interval (0.521) was selected related to the additional constraint of recent growth on the stalagmite top, i.e., that the topmost age allows recent stalagmite growth.

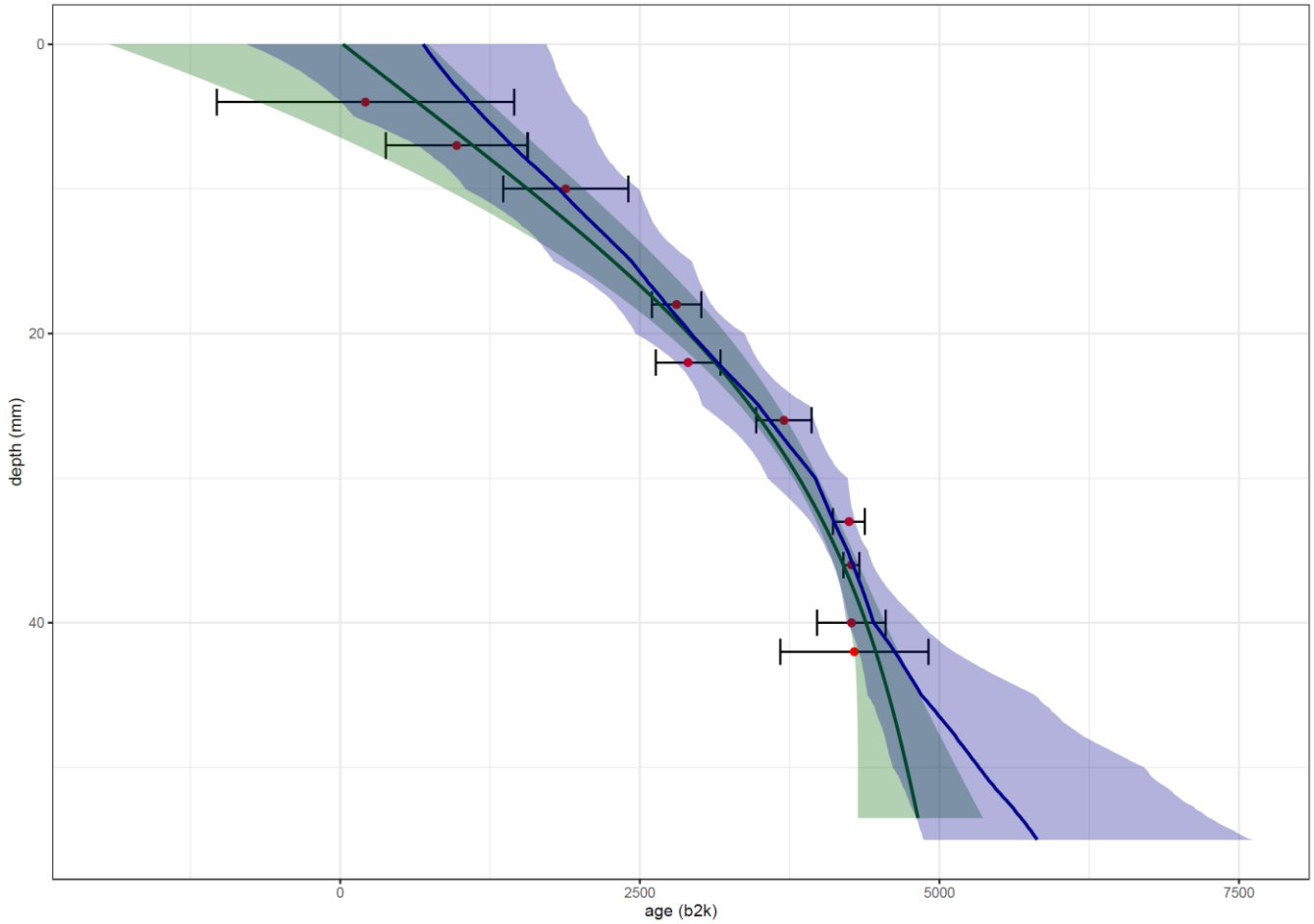
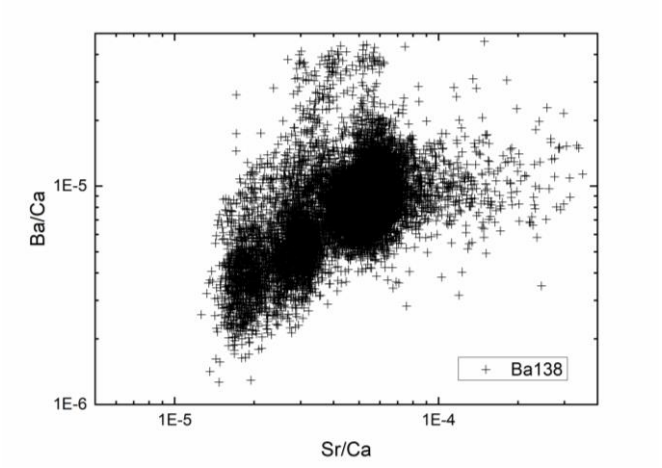
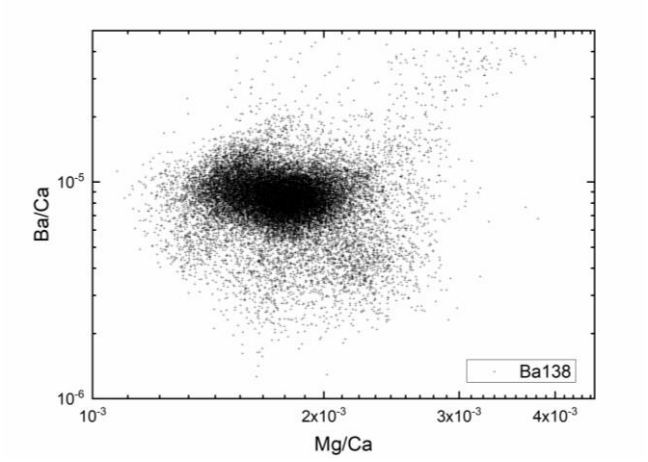


Figure S5: Comparison of the age models of stalagmite GH17-05 produced in StalAge (green; Scholz and Hoffmann, 2012) and RBacon (blue; Blaauw and Christen, 2011).





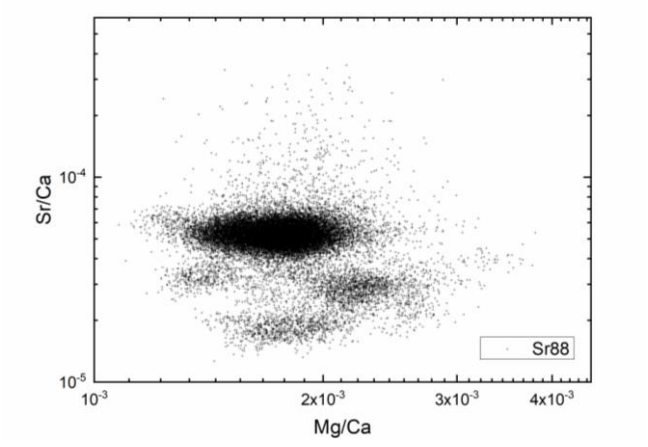


Figure S6: Crossplots of Sr/Ca, Mg/Ca and Ba/Ca ratios of stalagmite GH 17-05.

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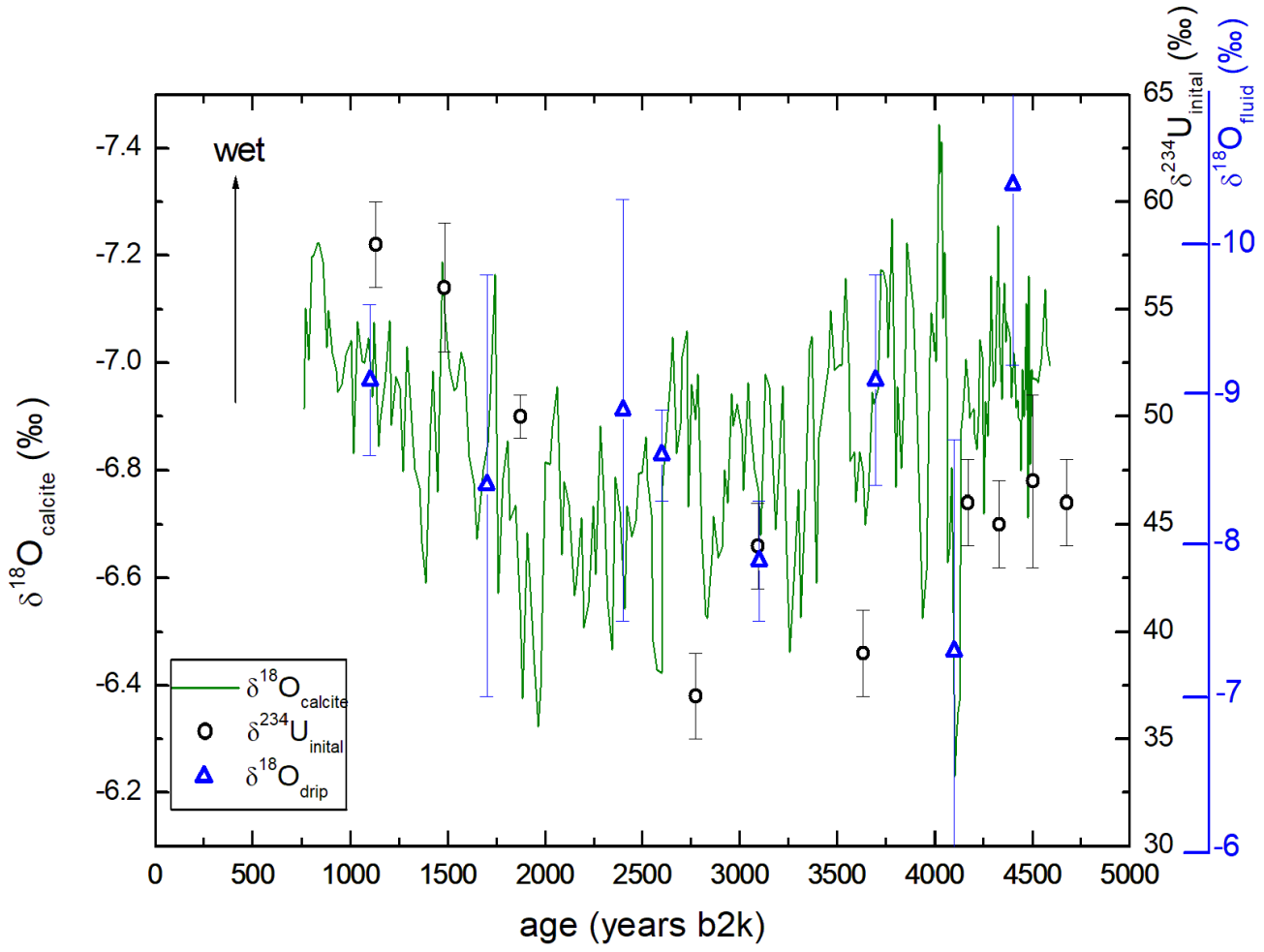

Figure S7: $^{234}U/^{238}U$ activity ratios (open black circles) of the samples used for dating relative to the calcite $\delta^{18}O$ values (green line) and the calculated drip water $\delta^{18}O$ (open blue triangles, using the clumped isotope-derived temperature).

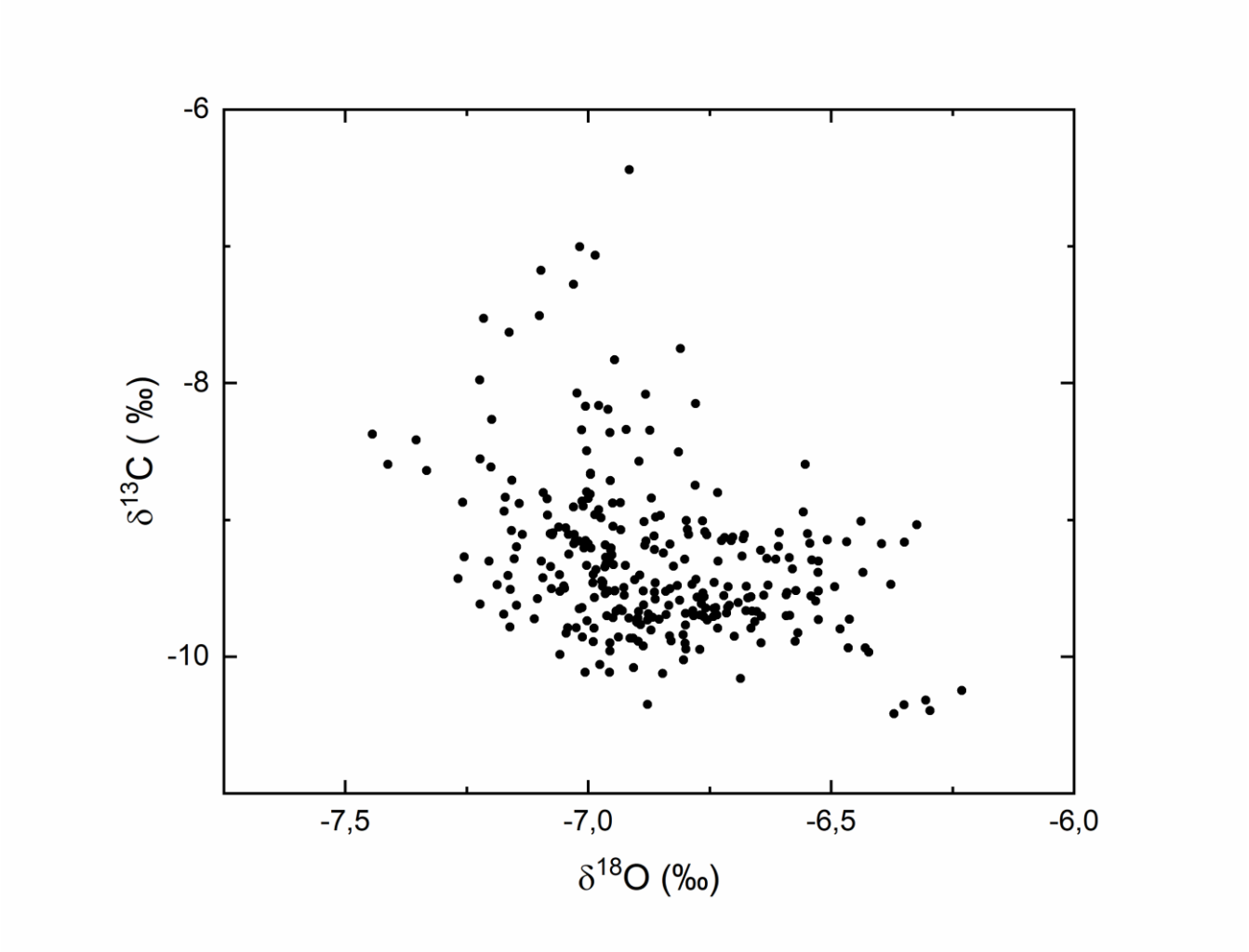

Fig S8: Crossplot of calcite $\delta^{13}C$ and $\delta^{18}O$ values of stalagmite GH17-05. Note the (weak) anti-correlation.