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Quantitative paleo-humidity reconstruction during the Iberian Roman period from triple oxygen and hydrogen isotopes in gypsum speleothems

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Speleothems are valuable archives of past climate, but investigations have thus far focused mainly on carbonate flowstones and stalagmites. Here we demonstrate that stable isotope measurements (^{16}O, ^{17}O, ^{18}O, D, H) of gypsum hydration water (GHW) in a gypsum stalactite from Sima Blanca Cave in SE Spain provides a detailed record of past climate variability from 2.8 to 1.2 ka BP in southern Iberia. Unlike carbonate, all the stable isotopes of water in GHW can be measured, and isotope fractionation factors between the mother solution and GHW are insignificantly affected by temperature. We quantify changes in atmospheric relative humidity in Sima Blanca Cave during the Iron Age, the Iberian Roman Humid Period (IRHP) and the Dark Ages, from 800 BCE to 800 CE. Previous investigations on the modern climate of the cave suggest that conditions for gypsum speleothems precipitation occurs during winter, when the cave atmosphere is drier (RH$<$85%), and evaporation prevails over condensation [1]. Therefore, the δ^{17}O, δ^{18}O and δD values of dripwater in the cave reconstructed from GHW, and derived d-excess and ^{17}O-excess records, are interpreted as driven mostly by changes in winter relative humidity (RH_w) in the cave atmosphere. An evaporation isotope mass balance model is used together with Monte Carlo simulations to determine RH_w changes [2]. During the late Iron Age (800 BCE to 600 BCE) RH_w gradually increased by $\sim$15%, from 65% to 80%. Humid conditions (RH_w $\sim$75-85%) prevailed during the first part of the IRHP (600 BCE to 100 CE), peaking at 400 BCE (RH_w $\sim$85%), what is similar to the modern RH_w in the cave ($\sim$82%). RH_w decreased during the second part of the IRHP (100 CE to 500 CE) to 65-70% and slightly increased to 75-80% during the Dark Ages (500 CE to 800 CE). The Sima Blanca isotope record agree with most Mediterranean and Iberian qualitative paleoclimate archives, suggesting that hydration water isotopes in subaerial gypsum speleothems are a powerful proxy for quantitative paleo-humidity reconstructions.

[1] Gázquez et al. (2017). Chem. Geol. 452: 34–46; [2] Gázquez et al. (2018). EPSL 481: 177–188.