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Constraining paleo-RH and Hydroclimate of the Messinian Salinity Crisis using paleo-water triple oxygen, hydrogen, and strontium isotopes

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Evaporite deposits form in restricted basins due to net influx of water comprising salt and net evaporation of pure water. During the Messinian Salinity Crisis (MSC) in the Mediterranean Sea a restricted Atlantic-Mediterranean connection resulted in the accumulation of giant evaporite deposits. The detailed hydroclimate evolution of this event is, however, still a matter of debate.

We present triple oxygen, hydrogen and strontium isotope data from structurally bonded water of Messinian gypsum from Cyprus [1] and re-calculate paleo-brine compositions. The water isotopic composition of these paleo-brines has exchanged with the paleo-atmosphere, which allows reconstructing paleo relative humidity (RH). Evaporitic water loss of light isotopes drives brine compositions to heavy water-isotope enriched compositions, while isotope exchange with atmospheric water vapor constantly drives the brine to equilibrium with atmospheric water vapor. The steady-state isotopic composition depends on the relative humidity of the atmosphere, providing a basis for absolute paleo-RH reconstructions.

To best approximate the hydrological conditions at which Messinian gypsum formed in marginal basins of the Mediterranean Sea, we use a two-stage evaporation model. Hydroclimatic parameters like paleo-RH are approximated using an iterative curve fitting isotope model approach, indicating slightly lower RH during the third compared to the second stage of the MSC.

The curve fitting model approximates all hydrological parameters to their 'best-fit' values. This allows for simultaneous reconstruction of the water isotope composition of the open Mediterranean Sea, providing a proxy for the proportions of continental water vs. Atlantic seawater flowing into the basin. The model implies a continental water fraction of 75–81 %. The combined oxygen and Sr isotope records indicate a persistent connection to the Atlantic supporting the hypothesis that the striking drop in $^{87}Sr/^{86}Sr$ at the beginning of MSC stage 3 is mainly related to an increased contribution of continental water with low $^{87}Sr/^{86}Sr$ and high Sr concentrations from the Paratethys. Our results show that the combination of triple oxygen, hydrogen, and Sr isotope data provides a powerful tool to disentangle paleo-hydroclimate even in such complicated hydrological settings as the Mediterranean Sea during the MSC.

[1] Deußen et al. (2024), *GCA* 375, 134-145.