Coupled trace element and stable isotope proxies expose alternating wet and dry climates in Iran's past

STACY A. CAROLIN[1,2]*, VASILE ERSEK[3], GIDEON M. HENDERSON[1], RICHARD T. WALKER[1]

[1]Department of Earth Sciences, University of Oxford, OX1 3AN Oxford, United Kingdom (stacy.carolin@earth.ox.ac.uk, gideon.henderson@earth.ox.ac.uk, richard.walker@earth.ox.ac.uk)

[2]Institute of Geology, University of Innsbruck, 6020 Innsbruck, Austria (*correspondence: stacyanne.carolin@oeaw.ac.at)

[3]Department of Geography and Environmental Sciences, Northumbria University, NE1 8ST Newcastle-upon-Tyne, United Kingdom (vasile.ersek@northumbria.ac.uk)

Iran is a prime location for investigating past changes in climate. It sits at the intersection of multiple atmospheric climate modes (Westerlies, Indian Monsoon, Siberian High), is an area that was at the center of human settlement and development in the ancient world, and is today particularly vulnerable to the effects of anthropogenic climate change due to its scarce water availablity and susceptibility to flash flooding and extreme dust storms. Speleothem archives offer a research path forward to investigate the response of the climate in this region to large, and sometimes abrupt, natural climate forcings. The usual speleothem climate proxy utilized is the oxygen isotopic ratio ($\delta^{18}O$). This is, however, a proxy that records multiple climate effects which can be difficult to differentiate, particularly in mid-latitudes. Evaporative effects in hot and dry regions such as Iran likely also alter water isotopes to a significant degree.

Here we present a $\delta^{18}O$ record with complementary Mg/Ca, Sr/Ca, Ba/Ca, and $\delta^{13}C$ climate proxies from northeast Iran. Between 110-70 ka, the record shows remarkably similar millennial-scale increases in $\delta^{18}O$ to those published in an Iranian stalagmite record 800 km to the west, which today receives more than double the amount of precipitation as the semi-arid northeast Iran site. The northeast Iran record also records similar duration, well-behaved increases in Mg/Ca, Sr/Ca, and Ba/Ca during these events, which strongly support coincident local drying, a finding key to interpretation of the cross-country $\delta^{18}O$ records. We further apply these multiple proxies in the northeast Iran stalagmite – stable isotopes coupled with trace elements – to investigate the response of climate in this area to the massive restructuring of global climate parameters over the penultimate deglaciation, a period for which current regional records are alarmingly scarce.