



## **Integrating modern monitoring, cave mapping, and seasonal resolution trace element records in recent speleothems to interpret speleothem climate records from the last millennium to the penultimate glacial cycle in Northwest Spain**

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Speleothems offer outstanding new capabilities for paleoclimate studies, yet each cave system may have its own idiosyncrasies which affect the interpretation of speleothem data. We describe several examples of monitoring and process studies from cave systems in Northwest Spain and how these studies inform interpretations from the fossil speleothems.

Oxygen isotopes in rainwater range from 0 to -12 permil (SMOW) and are not correlated with amount (at constant temperature) or with temperature (at constant amount) or with either variable in the entire dataset. Generally summer precipitation has higher isotopic ratios. Winter precipitation, which is the largest contributor to the local moisture budget, shows a positive correlation between oxygen isotopic composition and the daily NCEP NAO index. In a speleothem covering the last 1000 years from Pindal Cave, lower average oxygen isotopic ratios during the second part of the Little Ice Age may reflect either a greater dominance of winter precipitation or winter atmospheric circulation patterns more similar to NAO negative state.

Dripwater Mg/Ca ratios as well as Mg contents are higher during drier seasons, consistent with increased water residence time and in some cases with higher degrees of prior calcite precipitation. In speleothems Mg/Ca indicates net precipitation balance, and is coherent with orbital cycles, except in two situations. Caves directly on the seacoast have a large Mg contribution from dry deposition of marine aerosols which could also vary with distance to the coast and density of vegetation, and one cave exhibits a threefold variation in Mg content in the host bedrock and changes in hydrological routing may affect Mg/Ca in the speleothem.

In LA-ICPMS analyses of recent speleothems, annual cycles are evident in Sr/Ca, Ba/Ca due to seasonal changes in water residence time in the karst rock and the saturation state of dripwaters, and in Y/Ca as Y is released during autumnal flushing of organic acids produced by decaying vegetation. In the stalagmite GUILL, annual cycles occur over 500 years but are absent in the most modern 20 years when eucalyptus was planted over the site. Following eucalyptus planting, Y/Ca ratios are lower and constant, Sr/Ca and B/Ca ratios are higher than at any other time in the past 500 years, but Mg/Ca are comparable. We infer that in the new Eucalyptus regime there is no longer an autumnal pulse from decomposing organics (evergreen, leaves resistant to degradation) and that elevated Sr and Ba content arises from saturation state effects and not merely greater leaching of silicate bound elements in the soil/karst system since the latter would also affect Mg.

We have identified several cave systems where extreme precipitation events cause activation of normally dry cave channels and the deposition of fluvially-transported detrital minerals in the speleothems. These caves yield speleothems which can contain up to 3 wt % SiO<sub>2</sub> present as fine quartz sand and silt which are abundant in the catchments. The abundance of this detrital component in the speleothem decreases with altitude and distance above and away from cave channel confirming its fluvial association. High detrital Th and young age makes these speleothems extremely difficult to date using U/Th. A few U/Th dates were obtained by gently crushing portions of the calcite to obtain sand-sized cleavage fragments, and separating the cleanest fragments for dating. Assuming within each stalagmite a constant dead carbon contribution for intervals containing comparable carbon isotopic composition of calcite enables us to increase the number of dated points with carbon-14 dates. Laser induced breakdown spectroscopy is used to characterize the Si/Ca ratio along the stalagmite growth axis and estimate changes in the frequency of flood deposition of detrital minerals.