Oxygen isotopes, stalagmites and stalactites and past climate variability

Andy Baker, UNSW, Sydney

From late 2018 in New South Wales, Year 12 students studying “Earth and Environmental Science” are learning about how isotope ratios in stalagmites and stalactites can be used to provide evidence of climate variation.

When you read on, ask yourself these questions - Could the “oxygen isotopes” lesson be useful to present to cave guides? And are students and teachers already coming to caves and asking about isotopes and speleothems? What would you say?

Specifically, in Module 7 (Climate Science) for year 12, teachers are now covering “Evidence for Climate Variation” with an “Inquiry question” of “What scientific evidence is there of climate variations in the past?” Students are asked to:

> Identify and explain more recent evidence of climate variation, including but not limited to:
>
> - ice cores containing gas bubbles and oxygen isotopes
> - dendrochronology
> - Aboriginal art sites showing now-extinct species and environments
> - human instrumental records
> - isotope ratios shown in stalagmites, stalactites and corals

What the examiners are specifically thinking of, in the last point, is oxygen isotopes in stalagmites. Because of this, I now have a two-hour lesson prepared on “oxygen isotopes” which I can give on request to Year 12 classes. It covers the whole of the “Inquiry question”, and includes material on stalagmites and stalactites.

Recently, I was fortunate enough to lead a team of international researchers in a study that looked at the oxygen isotopes of cave drip waters. This is relevant to understanding the evidence of climate variation from measurements of the oxygen isotope composition of stalagmites and stalactites. This global analysis of cave drip waters has recently been published in the scientific journal Nature Communications. Australasian show cave sites, including Yarrangobilly Caves and Wellington Caves, have made a crucial contribution

Above—Wellington rainfall water isotope sampler. Rainwater was collected at Wellington at the nearby UNSW Research Station. The sample container can be seen in the left of the photograph, behind the weather station. Rainfall samples were collected monthly from the tap at the base of the sample container. Paraffin is added to the container to prevent evaporation, cable ties provide a bird roosting deterrent.

Left—Rainwater isotope sampler, Yarrangobilly. Just behind the kiosk you can find a weather station and a precipitation isotope sampler. Samples are collected after rain or snow events by NPWS staff for analysis by the ANSTO team led by Pauline Treble.

The paper synthesises previously published studies of cave drip water oxygen isotope composition. It investigates the extent to which the drip water oxygen isotopes match that in the surface precipitation (rainfall or snow). This is an important question for researchers looking at stalagmite records of past climate using oxygen isotopes and wanting to know whether they contain a record of past rainfall, or something else.

Australian caves that feature in the global analysis are:

- Cathedral Cave, Wellington;
- Golgotha Cave, Margaret River;
- Harrie Wood Cave, Yarrangobilly; and
- Little Trimmer and Frankcombe Caves in Tasmania.

The global synthesis compares already published cave drip water and rainfall monitoring data, specifically looking at the oxygen isotope data. Drip water and rainwater molecules contain both oxygen and hydrogen (H_2O). Each of oxygen and hydrogen have more than one stable isotope, which means they have oxygen and hydrogen of slightly different masses (weight). Scientists use these small differences to work out what climate and environmental processes have affected the water on the way from the atmosphere to the cave. The oxygen isotope is particularly useful, as it is preserved in speleothems - as the oxygen in the carbonate part of calcium carbonate ($CaCO_3$). Also in the paper, we used a computer model to predict the seasonality of groundwater recharge at many of the caves, using a new hydrological model of Andreas Hartmann (Freiburg, Germany). This helps tell us whether the drip water is the average of all rainfall that falls in a year, or whether it is a record of seasonal or episodic recharge

What did it show? For most Australian mainland sites, cave drip water oxygen isotopes are expected to have a recharge signal, with the drip waters preserving the oxygen isotope composition of the precipitation during episodic or seasonal recharge. For montane sites (such as Yarrangobilly Caves) and higher latitude regions (Tasmania and New Zealand) that are cooler, they experience less soil water evaporation and this limits any seasonal bias in drip water oxygen isotope composition. The drip waters here are representative of the annual average surface precipitation.

In other words, if you were interested in analysing a speleothem sample from a cave in Australasia, what would the oxygen isotopes show? It says that the oxygen isotope composition of speleothems from most of mainland Australia is likely to record information about past recharge events, as opposed to information about the surface precipitation. The exception is the montane regions of Australia and Tasmania, as well as New Zealand, where stalagmite oxygen isotopes should preserve a record of rainfall.

And in the past? The paper also considered how recharge might change with cooler temperatures in the last glacial maximum, around 20,000 years ago. Then we use climate model data that show that mean annual temperatures would be expected to be 4C to 6C cooler. However, not much changes in terms of how we might interpret oxygen isotopes in speleothems, as mainland Australia remains warm enough to expect seasonal or episodic recharge to dominate outside of the montane regions.

Lead author and ACKMA member Andy Baker (a.baker@unsw.edu.au) is very happy to answer any questions on the research. We thank all the show caves around the world who have supported the data collection that featured in this paper.

The technical paper is titled "Global analysis reveals climatic controls on the oxygen isotope composition of cave drip water". It can be accessed for free at https://doi.org/10.1038/s41467-019-11027-w and can be reproduced with appropriate attribution under its Creative Commons licence.

Above— one of the water sampling stations at Harrie Wood Cave

Below—The photo shows the water sampling set-up at Cathedral Cave, Wellington, on a collaboration between the local council

Reference: Baker, A., Hartmann, A., Duan, W., Hankin, S., Comas-Bru, L., Cuthbert, M.O., Treble, P.C., Banner, J., Genty, D., Baldini, L., Bartolomé, M., Moreno, A., and Pérez-Mejías, C., 2019. *Global analysis reveals climatic controls on the oxygen isotopic composition of cave drip water.* Nature Communications, 10, article number 2984