Recent Advances in Radiogenic Isotope Mass Spectrometry: Implications for Reduced Environmental Impact of Speleothem Paleoenvironmental Studies

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ABSTRACT

Records reconstructed from measured geochemical parameters within speleothems are playing an increasingly important role in the reconstruction and understanding of past climates and environments. The first significant records of this type were published over thirty years ago, since when improvements in analytical technology have on one hand reduced sample size demands and on the other hand increased the number of analyses undertaken. Because all geochemical analyses are essentially destructive techniques, conflict can arise regarding the relative importance of speleothems' intrinsic values within caves versus their scientific value once removed.

Most published speleothem paleoenvironmental records to date have been based on the analysis of whole stalagmites, partly because of their generally high suitability for stable isotope analysis and partly because they are the most straightforward means of recovering a continuous interval of speleothem deposition from a cave. A few researchers have instead targeted core samples of flowstones, hoping to obtain longer more continuous records, but also because the visual impact of such sampling on the cave environment is hopefully lower. Unfortunately the sample size demands required for uranium-thorium dating have been such that recovery of core samples large enough to be useful has been very difficult.

Many of the parameters of interest such as stable isotope ratios (particularly oxygen and carbon) and trace element contents (eg. magnesium, strontium, uranium) can now be measured on samples as small as a few hundred micrograms or indeed even by laser ablation or other micro-beam techniques. This has reflected a slow but steady improvement in the capabilities of available analytical technologies, but leaves the actual dating of speleothems as the last common analysis type requiring significant amounts of sample. For a speleothem paleoenvironmental record to have any significance it must be placed against time, which almost always requires the use of a radiometric dating technique such as uranium-thorium.

Uranium-thorium disequilibrium dating was first undertaken using alpha-spectrometry, a technique which in most cases required hundreds of grams of speleothem for a single date. Since the late 1980's alpha-spectrometry has given way to thermal ionization mass spectrometry, which produces more precise ages from typically two to five grams of sample. It is this advance which has made flowstone coring viable as a sampling technique, but only where long, large diameter cores can be taken. Here I will review and report progress in adapting the relatively new technique of multi-collector inductively-coupled plasma mass spectrometry (MC-ICP-MS) to the uranium-thorium dating of very small speleothem samples.

MC-ICP-MS U-Th dates at the University of Melbourne are giving good precision on samples containing less than ten nanograms of uranium, which in practice means that only a few hundredths of a gram of speleothem are required to date most samples. This advance means that time-resolved paleoenvironmental records can be reconstructed from flowstone core samples of as little as 10mm in diameter even where the speleothem growth rate is of only a few millimetres per thousand years. A case study from a 22mm flowstone core sample from New Zealand spanning the last 150,000 years will be presented and contrasted with an earlier study from the same location requiring one metre of 50mm core sample. Details of a new portable electric drilling system for recovering 10mm and 22mm core samples will also be presented with discussion of drill site impact and rehabilitation techniques.