Science and Technology Group Annual Report FY2019

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1 Introduction

Paleoclimate signals recorded in Donnehue's Cave stalagmites

Extensive work in Donnehue's Cave (Midwestern USA) has revealed several important aspects about this cave system which is at the core of my paleoclimate study of this region. In order to better understand the sources of the measured variations in the chemical composition recorded in speleothems from this cave, I utilized analytical methods that are complimentary to each other. Great care needs to be taken in interpreting the data obtained, as the processes affecting the recorded signal in speleothems can vary drastically even within short periods of time. Stable isotopes of carbon ($\delta^{13}C$), for example, may be accurately interpreted only following a thorough understanding of the local conditions, such as: changes in predominant vegetation type above the cave, water residence times, kinetic fractionation, and bedrock composition (Fairchild et al., 2006), etc.

One aspect that became clear as I focused on key speleothems from various geological periods is that the $\delta^{13}C$ records show very similar behavior in all the stalagmites, regardless of their age/geologic period during which they precipitated. Amongst these behaviors, the most notable are the higher variability and higher amplitude of the $\delta^{13}C$ than the $\delta^{18}O$ record, and the correlation with Mg (another possible proxy for rainfall amount, as well as for prior calcite precipitation (PCP), which increases during drier periods and longer water residence times in the epikarst), which is, as expected, not maintained throughout the growth period.

Paleoclimate effects on cave development.

An additional advantage of a study that examines multiple possible connections between the speleothem data and regional or larger scale paleoclimate is the chance to correlate the development of the cave with the paleoclimate, for instance, by correlating the age of detrital layers in the stalagmites with flood periods and with the age of cave sediment deposits. Trace elements may be used to identify the source of the floodings, and perhaps to indicate whether they were related to local hydrology alone, or to a larger scale event.

2 Activities and Findings

Paleoclimate signals recorded in Donnehue's Cave stalagmites

I compared $\delta^{13}C$ to Magnesium (Mg) concentrations in order to better identify periods of aridity and increased PCP, and Phosphorus (P) and Yttrium (Y) together with confocal microscopy to identify periods with higher input of organic material (resulting from changes in the vegetation and soil above the cave) in the speleothem growth layers. Figure 1 shows the detailed profiles of these data for the basal part of stalagmite DC28. The age for this record is ca. 61,000 years BP at the base and ca. 58,000 BP at its upper part. To facilitate any relevant correlations between the fabric of the stalagmite, its $\delta^{13}C$ record and its trace element composition, I superimposed the confocal image on the scan of the stalagmite.

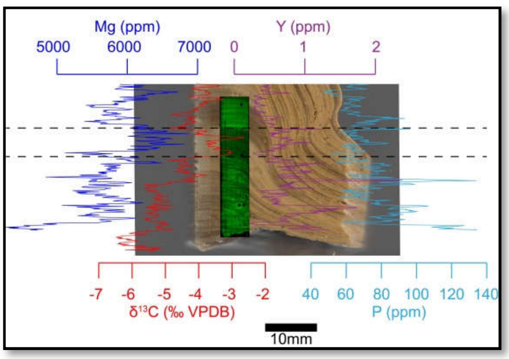

Figure 1. Basal part of DC 28 with superimposed confocal microscopy image (in green), $\delta^{13}C$ record (‰ VPDB), and Mg, Y and P concentrations (ppm). Dash lines mark the low fluorescence interval described in the text. The $\delta^{13}C$ track starts few mm lower than the TE scan

The confocal image shows well developed columnar calcite with annual growth bands couplets. There is one distinctive lower fluorescence interval (marked by dash lines in Figure 1) which coincides with a strong positive correlation between $\delta^{13}C$ and Mg. A significantly decreased availability of organic material, as indicated by the low fluorescence of these layers, supports the use of the Mg concentration for this interval as a proxy for drier conditions and enhanced prior calcite precipitation.

Phosphorous and Yttrium are generally associated with organic material coming through the feeding drip water (Borsato et al., 2007). Vegetation dieback during the autumn season in temperate climates often results in an injection of phosphorous from the soil into the cave through drip water (Borsato et al., 2007). But P may also be associated with microbial mats that fill speleothem pores caused by dissolution, and associated with prolonged periods of lower drip rates (Frisia et al., 2012). The P and Y concentrations in my record (Figure 1) are highest at the basal part of the stalagmite, which segment also displays strong fluorescence. In order to determine the various sources of P and Y in DC28, my future work includes an SEM examination of this stalagmite in order to check for the presence of bacterial mats, and possibly a chemical mapping of key parts of the stalagmite.

Paleoclimate effects on cave development

The growth intervals of 2 stalagmites at different locations within the lower and the upper passages of Donnehue's Cave correlate with warmer phases and increased precipitation in otherwise cold and dry periods. The key growth phases are from ca. 170,000 to 154,000 years BP for DC 1 (upper passage) and from 300,000 years BP to 170,000 years BP for DC49A (Panno et al., 2016). Detrital layers within these stalagmites indicate periodic flooding in the cave, which culminated with extreme flooding events at ca. 247,130 years B.P. and at ca. 140,240 years B.P. (both of these confirmed by OSL dating of massive sediment deposits, in Panno et al, 2016). Work is in progress to examine the source of trace elements in the stalagmite layers during these periods.

3 Collaborations

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