BIOTIC INFLUENCE ON SPELEOTHEM MORPHOLOGY C.A. Lakrout[1], E.J. Goldfarb[1], T.R.R. Bontognali[2,3,4], and N. Tisato[1] , [1]Jackson School of Geosciences; The University of Texas at Austin clakrout@utexas.edu. [2]Space Exploration Institute [3]Environmental Science Center; Qatar University. [4]Department of Environmental Sciences; University of Basel.

Introduction:

Researchers are interested in bio-mediated mineral formations in subterranean environments. Studying life in harsh conditions can provide information about habitability and mineral-life interactions in extreme environments. These can be analogues for life-related processes on other planets.

One example of such a harsh environment is a cave in France (Asperge), which contains mineral deposits (speleothems) called helictites (Figure 1A). Helictites grow in an area of Asperge with little water, no light, and heavy concentration of metals in the rocks. Such an environment would not appear to favor life.

Two specific helictites morphologies from Asperge are of interest for our research and are known as acicular and tubular. The former is made of aragonite with fibrous elongated crystals and is not hollow [1] (Figure 2A). The latter is composed of calcite crystals that form a relatively hollow tube with distinctive hexagonal crystals (Figure 2B). These formations are of interest because they are seemingly rare and, until 2015, the mechanism leading to their genesis was unclear.

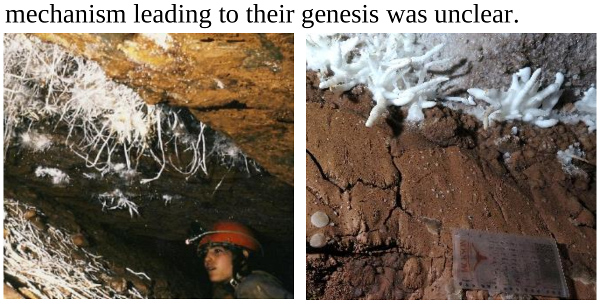

Figure 1A (left): Speleothems in Asperge, France [2]. Figure 1B (right): Speleothems in Breezeway, Colorado. Notice the surrounding white dots in the soil.

The Asperge speleothems were analyzed by Tisato et al. in 2015 who proposed that the formation of tubular concretions is orchestrated by life [2]. However, relatively little is known about the origin of these biologically-mediated deposits. Similar speleothems to those from Asperge have been observed in a cave in Colorado (Breezeway; Figure 1B). Proving a common nature for both the Breezeway and Asperge speleothems would provide a strong argument for the bio-mediated formation of helictites.

Here, we report analyses on speleothems from Breezeway. Such a cave has even less water than Asperge, no light, and the helictites appear to grow on a paleo-laterite, a paleo soil with a high concentration of iron and aluminum. We show that just like Asperge, Breezeway contains helictictes that are associated with distinctive bio signatures.

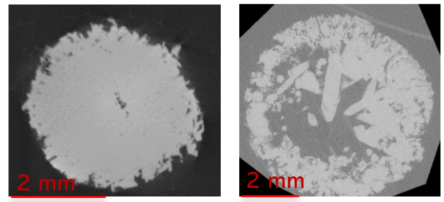

Figure 2A (left): Acicular sample from Breezeway. Inside of the speleothem is filled in.
Figure 2B (Right): tubular sample from Breezeway. Inside is hollow.

Hypothesis:

Due to the morphological similarity, we hypothesize that like the speleothems in Asperge, the mineral deposits from Breezeway have formed biotically. We can prove this by examining micro-computed tomography (micro-CT) scans, high resolution images, morphologies of our speleothems and analyzing for biotic films, textures, and chemical elements.

Materials Methods:

We collected 36 samples from Breezeway in May 2017. All samples were collected from the floor of the cave. On five of these samples we performed the following analyses:

1) X-ray diffraction to study mineralogy of the speleothems;
2) Micro-CT to study morphologies of speleothems;
3) Scanning Electron Microscopy (SEM) to investigate the presence of biofilms and biologically mediated structures;
4) SEM Energy Dispersive Scanning (SEM-EDX) to analyze the mineralogy of specific micrometric volumes of the samples.

Micro-CT scans were captured with a voltage of approximately 200 kV and a current of approximately 85 µA. Apparent voxel size is 18.5 microns per voxel. The scan was corrected for beam hardening. [3]

Sample mineralogy was measured from X-ray Diffraction (XRD). A few milligrams of an acicular and tubular sample were hand ground and placed on a tray and analyzed with a voltage of 45 kV and current of 40 mA. The sample patterns were recorded from 4° to 60° with a 0.02 stepsize.

Scanning Electron Microscope (SEM) analyses were performed with a Zeiss at the Bureau of Economic Geology UT Austin at multiple image scales, with EHT at 4 kV.

Results:

Visual inspection of in-situ concretions reveal the presence of millimetric bristled white dots (Figure 1B) covering the walls. Such dots, like in the case of Asperge, are present only in proximity of the speleothem site and have been identified as bio colonies [2].

XRD analyses indicate that acicular and tubular samples are composed of aragonite and calcite, respectively, similar to the Asperge speleothems.

The CT scans highlight the tubular and acicular nature of the speleothems. Given the large hole in the tubular concretions we can rule out that they formed abiotically [2]. On the other hand, acicular concretions present a micrometric center-tube supporting the hypothesis that acicular speleothems form abiotically [2]. In these scans, we can observe that calcite crystals of tubular concretions are covered by a “low-density” layer. Such a layer is tens of microns in thickness and was further investigated with SEM imaging.

SEM imaging of tubular samples revealed the presence of biofilms and mineral structures likely related to biological activity (Figure 3). Such features covering the calcite crystals are the “low-density” layer observed with the CT-scan. Few evidences of biological activity on acicular speleothems were also collected.

Discussion:

In the SEM images and EDX analyses of the tubular samples, we observe what we interpret as calcite “construction-sites” covering calcite crystals (Figure 4). It appears that crystals are in the process of growing by addition of calcite flakes. Small filaments create bridges between the calcite “flakes” within the “low-density” layer and the calcite crystals (Figure 3). Probably, these filaments are extracellular polymeric substances (EPS), which is a remnant of microbial life activity [4].

On most of the acicular sample surfaces no EPS was observed, and we see pristine aragonite needles. However, on an acicular sample, we observed what appears to be EPS. Such EPS is in the proximity of weathered Aragonite. We suggest that such EPS might represent the initial stages of the microbial colonization of an abiotic speleothem.

Conclusion

This research furthers the understanding that life exists in extreme environments. Understanding how life can thrive in these conditions is a starting point for the study of life on other planets. This research offers evidence of how life could manifest in the rock record. Given that caves are present on Mars and other planetary bodies, we suggest a potential way to search for past or present evidence of life in the geological record.

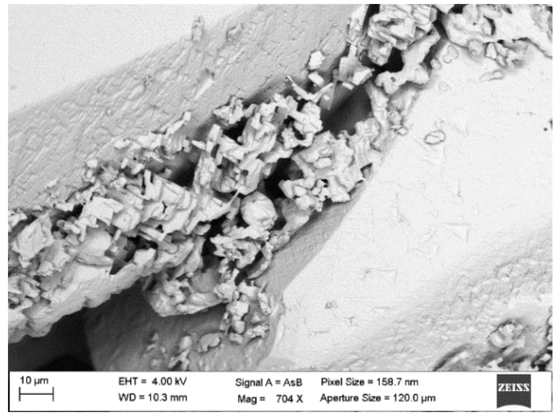

Figure 3: SEM image of tubular Breezeway sample.

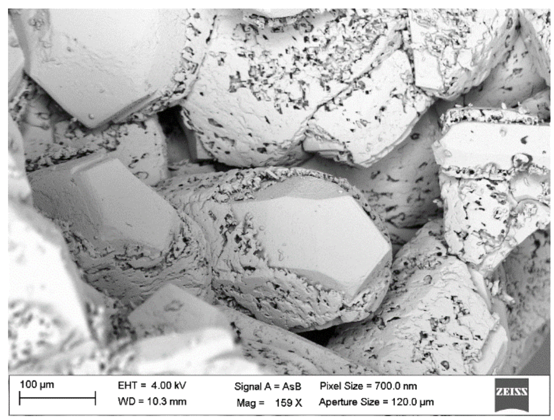

Figure 4: SEM image of tubular Breezeway sample.

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References:

[1] Self C.A. and Hill C.A. (2003) *Journal of Cave and Karst Studies, 65.2,* 130-151. [2] Tisato N. et al. (2015) *Scientific reports, 5,* 15525. [3] Ketcham R.A. and Carlson W.D. (2001) *Computers & Geosciences, 27.4,* 381-400. [4] Al Disi Z.A. et al (2019) *Marine Chemistry, 216,* 103693