BIOSIGNATURES IN PLEISTOCENE CAVE POOL SPELEOTHEMS. L. A. Melim[1], M. N. Spilde[2], D. E. Northup[3], and P. J. Boston [4], [1]Geology Dept., Western Illinois Univ, 1 University Circle, Macomb, IL 61455, LA-Melim@wiu.edu, [2]Institute of Meteoritics, Univ of New Mexico, MSC03-2050, 1 University of New Mexico, Albuquerque, NM 87131, mspilde@unm.edu, [3]Biology Department, Univ of New Mexico, 1 University of New Mexico, MSC03 2020, Albuquerque, NM 87131-0001, dnorthup@unm.edu, [4]National Cave and Karst Research Institute, c/o New Mexico Tech, Earth & Env. Sci. Dept., 801 Leroy Place, Socorro, NM 87801, pboston@nmt.edu.

Introduction: The Guadalupe Mountains of southeastern New Mexico and southwestern Texas contain numerous caves such as the world-renowned Carlsbad Cavern and Lechuguilla Cave. These caves contain numerous cave pools, areas of standing water that range from a few centimeters to several meters in depth. Most of these cave pools are dry today (or greatly reduced and inactive), but they were full and active during the wetter climate of the late Pleistocene (based on unpublished U-series dating). The paleo-pools are easily recognized by a waterline formed by pool minerals, mainly abiologic calcite pool spar or shelfstone. Over half of the nearly 180 pools studied in Carlsbad Cavern, Lechuguilla Cave, Hidden Cave, Cottonwood Cave and Endless Cave contain some form of biothem, or biologically influenced speleothem. The biosignatures which support this interpretation range from the macroscopic to the submicroscopic and geochemical.

Morphology: The field morphology is perhaps the least diagnostic of the biosignatures, yet it is critical to guiding sampling strategy in the protected setting of caves. When calcite grows into an open void, whether a small pore or a large cave pool, it typically coats the edges of the void and expands into the open space. There is no particular preference for up or down as the pore fluid (or pool) provides ions equally distributed. Pool spar follows this rule and coats the bottom and sides of most pools with bulbous knobs that grow in all directions. Pool fingers, on the other hand, are always pendant beneath some kind of overhang [1]. Most hang from shelfstone but others hang from the cave wall or a small overhang on pool spar (fig. 1). This pendant nature is suspect as pool fingers are entirely subaqueous, and not subaerial with dripping water like stalactites. We hypothesize that the mineralization is following streamers of biofilm or filaments, which would hang down and initiate the pendant form. Pool fingers are often found with u-loops and webulite [1], wispy mineral connectors reminiscent of drapes of biofilm, and pool merinque, an irregular growth on the bottom of pools with a peaked form (fig. 1).

Petrography: Pool fingers are laminated with clear, bladed to dogtooth calcite spar and dense micrite. Although all fingers in a given pool will be similar, the ratio of spar to micrite varies from nearly all spar to nearly all micrite. Micrite can form either as detrital fine carbonate or by the action of microbes [2]. In the cave pool environment, detrital micrite is unlikely. In addition, some samples have a clotted micrite texture, which has been shown to be microbial [3, 4]. The spar is less likely to be biologically influenced and is similar to pool spar. Thus, pool fingers may start from a pendant filament/biofilm but then continue with abiologic growth.

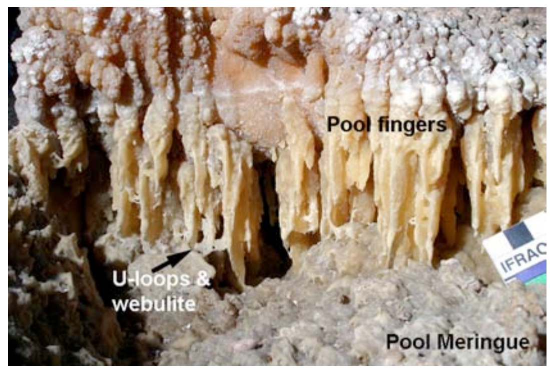

Fig. 1: Pool fingers underneath spar overhang with u-loops and webulite connecting the fingers. The pool spar on the pool bottom has been coated with peaks of pool meringue. Carlsbad Cavern. Photo by K. Ingham.

Scanning Electron Microscopy & EDS: Since we only take previously broken samples because of conservation constraints in federally managed caves, we must avoid surface contamination. Therefore, our SEM samples are etched with 10% HCl to remove 5-10 µm of material from the surface of a freshly broken chip or a thin section. This method reveals microbes and biofilm that were entombed in the calcite (fig. 2 & 3).

All pool finger samples contain some biofilm and/or filaments in both micrite and spar layers. Filaments are typically hollow tubes between 0.5 and 1.0 µm in diameter and up to 100 µm in length. The length is an artifact as the ends of individual filaments are either broken or obscured in the matrix. Some filaments are smooth but many show surface texture, most commonly reticulated [5]. The size of these filaments is consistent with a microbial origin. Biofilm occurs as thin strings and films or as irregular masses, either associated with filaments (Fig. 3) or alone (Fig. 4). In contrast, pool spar samples typically contain few or no filaments or biofilm.

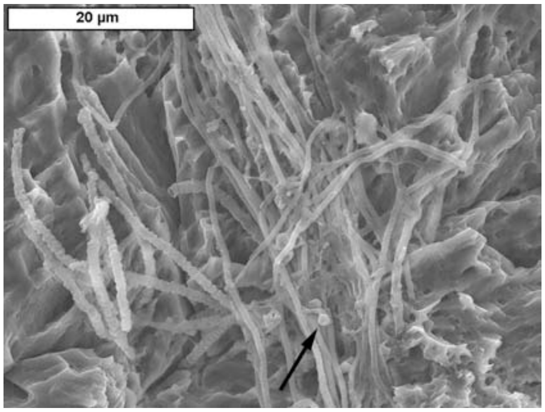

Fig. 2: Filaments and biofilm in a pool finger from Lechuguilla Cave. Arrow indicates loction of EDX in fig. 4. Sample was etched in 10% HCl prior to coating.

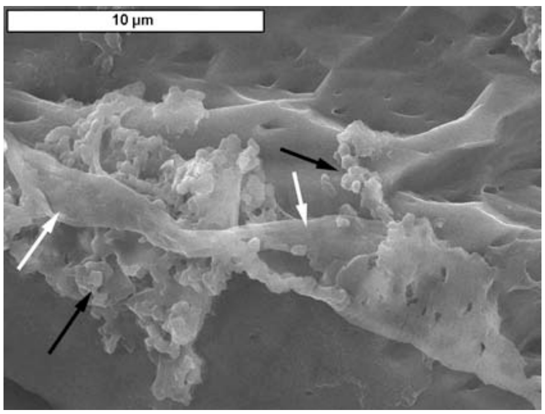

Fig. 3: Ropy (white arrows) to more irregular biofilm (black arrows) in a pool finger from Lechuguilla Cave. Sample was etched in 10% HCl prior to coating. Organic origin confirmed by EDX (not shown).

Biofilm and filaments are both easily confused with other components such as filamentous clays or, when using thin sections, the epoxy. The SEM we use is equipped with an Oxford Isis 300 Energy Dispersive X-ray (EDX) analyzer that allows analysis for C without any adjustment of the image. Hence we routinely analyze possible filaments and biofilm for excessive C above that expected for $CaCO_3$. Although the beam diameter is 50 nm, the volume analyzed is several cubic microns and thus includes the calcite matrix around and beneath the biofilm or filament. The EDX pattern of calcite alone contains Ca, C, and O with the C and O peaks subequal and 25-50% smaller than the Ca. So when a sample shows a C peak greater than O, the analyzed area must contain another source of C, presumably the biofilm or filament (fig. 4). Filamentous clays show Si, Al, and Mg instead of excess C. The epoxy has extremely high C values with traces of Cl. Both biofilm and filaments nearly always show excess C, indicating an organic orgin (Fig. 4).

The presence of organic carbon has been independently confirmed with pool finger samples containing 0.8% to 2.7% organic carbon. Presumably this organic matter is the signal of the filaments and biofilm found in SEM.

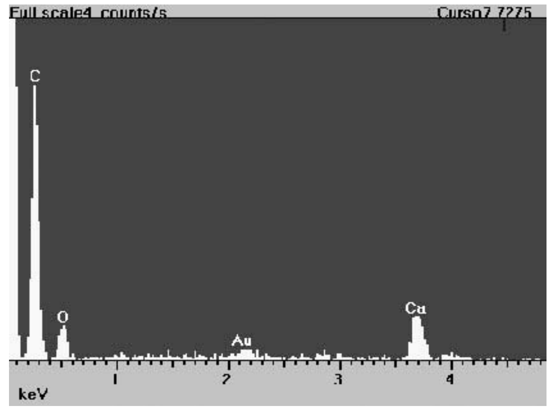

Fig. 4: EDX on biofilm and filaments in fig. 2 showing excess carbon over what is expected for calcite (see text.) The Au is from the Au-Pb coating.

Conclusions: Pool fingers are speleothems that grow subaqueously as pendants in cave pools. Their pendant form, in the absence of dripping water, suggests growth following pendant biofilm or filaments. Petrographic fabrics such as micrite to clotted micrite support a biologic component to their growth. However, the abundant calcite spar indicates abiologic growth likely also contributes. Fossil filaments, of the right size for microbes, and biofilm indicate microbes were present during pool finger growth.

The presence of fossil filaments and biofilm, entirely entombed in calcite, indicates that long term preservation of actual organic matter is possible in cave speleothems and perhaps in other materials. We speculate that this preservation is the result of rapid entombment combined with the absence of sunlight in the protected cave environment. Such preservation could be particularly significant for revealing aspects of fossil organisms in subterranean Earth environments and can serve as a model for potential subsurface biological materials on Mars and other Solar System bodies.

References:

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