ABSTRACT
EXPERIMENTAL DETERMINATION OF THE BIOGENICTY OF MOONMILK, AND THE CHARACTERIZATION OF MOONMILK AND ITS DEPOSITIONAL ENVIRONMENT IN SPIDER CAVE, CARLSBAD CAVERNS NATIONAL PARK, NEW MEXICO

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Moonmilk from Spider Cave of Carlsbad Caverns National Park, NM (known as "Crisco") was analyzed to determine the geochemistry, fabric, depositional setting and extent of biogenicity. Crisco moonmilk is composed of filamentous, calcitic carbonate that is associated with microbes and has a greasy texture. Microbes derived from Crisco were cultured using four types of media to study their precipitates. All media types showed bacterial and fungal growth, but none produced visible precipitates. Moonmilk samples were analyzed using Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectrometry (EDS), Transmission Electron Microscopy (TEM), thin sections stained with Alizarin Red S, microprobe analysis with X-Ray maps, trace element analysis, stable isotopic analysis, and X-Ray Diffraction (XRD).

SEM examination showed a smooth, curd-like, biofilm-like texture and an organic filamentous fabric with calcite coatings and calcite rhombohedrons. The filaments are organized in a mat-like structure, with filaments oriented in all directions.

A survey of the cave shows that moonmilk only forms below a certain depth (67ft below the entrance), and that the flood line (a detrital silt coating) follows this moonmilk line. The entrance of Spider Cave is in an arroyo and has been subjected to flooding throughout its history. The areas that contain moonmilk are at the cave's lowest depths, where standing water could form.

Petrographic analysis shows three types of fabrics: Type 1 Crystalline) continuous, regular laminations that do not take on Alizarin Red S stain; Type 2 Diffuse) discontinuous, irregular laminations that stain red; and Type 3 Recrystallized) no laminations or any distinguishing features and irregular staining. Within Spider Cave, Type 1 and Type 2 form in protected, higher elevation areas, whereas Type 3 forms at the lowest elevations where they would have remained under water the longest. Most of the samples show a combination of the three types, with remnants of laminations and irregular staining; these samples are found along the main pathway, neither on the ceiling nor on the floor. EDS, trace element analysis and microprobe analysis shows that Type 1 and Type 2 samples are the most elementally diverse (calcium, magnesium, aluminum, sulfur and sodium); Type 3 and the combination samples contain smaller quantities of those elements, but have a higher abundance of carbon and oxygen. Type 2 diffuse shows the most aluminum and sulfur, as well as having more irregular layers, indicating that this type may be biotic. Type 1 is has more regular, continuous layering, indicating that this

type may be abiotic. Type 3 is the recrystallized version of Types 1 and 2, due to the longer amount of time the Type 3 samples would have remained under water.

Crystallization factors affecting the precipitation of a crystal were also considered. The temperature at which moonmilk formed is unknown, as it is not possible to date the formation of moonmilk. Atmospheric pressure has always influenced the cave, while hydrostatic pressure played a role while the cave was forming and during flooding. The water amount in Spider Cave has always been saturated, either due to flooding or saturated water vapor. Water chemistry played an important role, as the formation of moonmilk required standing water. The influx of new water through flooding would have changed the concentration of elements available, as well as allowing CO_2 to escape, which could have led to abiotic precipitation.

Spider Cave was compared to an area in Carlsbad Cavern known as Chocolate High, which is found in the same formation (the Yates Formation), contains the same parent rock (limestone and dolomite) and is at the same elevation (approximately 1260ft). Chocolate High has very small patches of moonmilk, whereas Spider Cave has roomfuls of moonmilk. The Spider Cave entrance is in an arroyo, which leads to flooding, and the areas that contain moonmilk are at the lowest elevation, so standing water can form. Chocolate High does not have a source for flooding, and it is at one for the highest elevations, so standing water cannot form. Biotic processes are indicated in the formation of moonmilk by the presence of organic filaments and a light isotopic carbon and oxygen signature.