



Investigation of Cryogenic Cave Carbonates from Winter Wonderland Cave, Uinta Mountains, Utah, USA

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Cryogenic cave carbonates (CCC) are a unique type of speleothem associated with ice in caves. One particular type of CCC, known as CCC_{coarse}, is thought to form under transient climatic conditions when permafrost is degrading above a frozen subsurface. CCCs are the target of increasing research interest in Eurasia, but have not been widely studied elsewhere. Here we report on what we believe to be the first examples of CCC_{coarse} in North America, from the recently discovered Winter Wonderland ice cave in the Uinta Mountains, Utah. The cave, which is located at an elevation of 3140 m in Mississippian-age Madison Limestone, has a surveyed length of 245 m, about half of which is floored by perennial ice locally at least 2 m thick. Dataloggers deployed in the cave from August, 2016 through August, 2018 reveal consistent subzero temperatures with an annual mean of -2.4°C close to the entrance and -0.7°C deeper in the cave. CCCs occur as a layer of crystal aggregates 5-10 mm thick on the surface of the ice flooring the cave and on the tops of breakdown blocks emerging as the ice surface lowers through sublimation. The CCCs range in color from dirty white to orange/brown and visually resemble CCCs presented in the literature. Under SEM magnification, CCCs are resolved as globular aggregates of spheroidal bodies with a mean grain size of 20 microns. X-ray diffraction reveals that the CCCs are predominantly calcite, which is corroborated by XRF analysis confirming CaO as the most abundant oxide. Stable isotope values in the most calcite-dominated CCCs range from 1‰ to 6‰ VPDB for $\delta^{13}\text{C}$ and -14‰ to -21‰ VPDB for $\delta^{18}\text{O}$, confirming that these samples are CCC_{coarse}. These samples were collected in late August, 2018. At that time, shallow pools of water that had entered the cave during the summer were observed freezing on the ice surface. Although the sampled CCC_{coarse} were noted on the ice surface before the arrival of this newest water, Winter Wonderland Cave may present the possibility of observing CCC_{coarse} formation *in situ*. Future efforts should be focused on monitoring the fate of inflowing water and the possible formation of new CCCs.