LACUSTRINE CARBONATES, BASALTIC TUFF, AND PUTATIVE BIOGENIC ALTERATION: UPSAL HOGBACK, NV AS A POSSIBLE ANALOGUE FOR JEZERO CRATER. J.T. Pentesco1, M.E. Schmidt1, 1Dept. of Earth Sciences, Brock University (St. Catharines, ON L2S 3A1, Canada; justin.pentesco@brocku.ca).

Introduction: Jezero crater (JC), the target of the Mars 2020 mission, is understood to have once been a lake basin [1,2,3]. Recent interpretation of Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) data from JC has identified the likely presence of olivine, smectites, and carbonates [2,3]. Some of the carbonates (Marginal Carbonates of the Mottled Terrain unit) are hypothesized to have been emplaced in the paleo-lacustrine environment [1].

Evidence of microbial life in the form of trace-fossils in glassy basalt has been studied in comparable environments on Earth, including Ries impact structure, Germany, and tuff rings in pluvial lake basins at Fort Rock, OR, and Upsal Hogback, NY [4,5,6]. We here examine Upsal Hogback tuff rings, NV, where putative biogenic alteration (PBA) has been identified (Fig. 1) as a potential analogue to JC. Both sites have olivine, smectite, associated lacustrine carbonates, and similar geologic contexts, including lakes that desiccated.

Field Area: Two phreatomagmatic volcanoes in the Lahontan basin, standalone Soda Lake maar (SL; 1.6 km diameter) and the Upsal Hogback tuff ring complex (UH; ~5 km length), have glassy basaltic tuff in association with calcareous tufas emplaced in lacustrine settings. SL erupted <6 ka [7], after pluvial Lake Lahontan (LL) desiccated. UH erupted into LL at the end of the Wisconsin glaciation between ~19 ka and 33.7 ka (PSV) [8]. SL tufas were emplaced in that volcano’s crater lake, while UH tufas were emplaced on the tuff rings in the water of Lake Lahontan.

At least four inferred vents at UH produced a northern ring (~1 km diameter), at least two smaller overlapping central rings (UHC) and a mostly eroded southern ring (UHS) that overlaps UHC [6]. The most well-indurated tuff is found at the overlap of UHS and UHC, where higher abundances of calcite cement, tufas (Fig. 2), and palagonite alteration occur.

At both SL and UH, tufas are stratigraphically constrained to lakeshores after tuff deposition. Unlike tufas at SL, which are entirely calcareous across their interiors, tufas of UH occur as calcareous walls (10-60 cm thick) and rings (typically 0.5 – 5 m in diameter) that enclose palagonitized tuff [6].

Methods: Field work in 2016 and 2017 at SL and UH involved collecting a suite of tufa and variably altered tuff samples. Observations presented here are the result of petrographic analysis, bulk powdered X-ray diffraction (µXRD; University of Western Ontario), C and O stable isotope analysis (University of Western Ontario), and XRF of basalt at Hamilton College (Clinton, NY)[6].

Petrology & Mineralogy: UH tuff is glassy (ave. ~40 vol.%) and porous with an alkali basalt composition, visible olivine and plagioclase phenocrysts, and <2 vol.% accidental clasts. SL tuff is compositionally similar but contains as much as ~30 vol.% accidental material. UH tuff is well-indurated with calcite cement and palagonite alteration (avg. ~19 vol.% palagonite, of which 90% is amorphous gel-palagonite). SL tuff is poorly indurated and not palagonitized.

Forsterite, sodial anorthite, and chromite-magnetite oxides are primary igneous minerals identified by µXRD in UH tuff. Secondary minerals identified in UH tuff include calcite, magnesian calcite, smectites, and a zeolite assemblage (chabazite, phillipsite) consistent with low-temperature hydrothermal conditions.

Biogenic Alteration: PBA textures in the form of micro-tunnels have been identified in glassy clasts within UH tuff (Fig. 1), but not in SL tuff. Contemporaneity of PBA with a hydrothermal regime at UH is established by calcite sealing pore space and filling vesicles in which PBA are observed and by overprinting of PBA by palagonite. Micro-tunnels radiate from vesicle walls and cracks in glassy clasts and are smaller (median length of 4.1 μm) than are found at similar sites (i.e., Fort Rock, OR [5]). Observations consistent with biogenic origin are log-normal micro-tunnel length distribution [9], morphology (i.e., terminal enlargements, directionality, lack of cross-cutting tunnels, spiral filaments), appropriate size for microbial habitation, spatial distribution consistent with a low-temperature hydrothermal regime, and emplacement at an appropriate period in the substrate history [6].

Environmental Constraints: PBA at UH were emplaced while tuff was saturated in alkaline water as demonstrated by the presence of abundant calcite cement in pore space of the tuff. Sustained temperature during hydrothermal alteration of the tuff was 40-60°C based on palagonite characteristics (i.e., proportion of glass palagonitized, palagonite thickness). C and O isotope compositions of the tufas modelled [11] with modern water analogues [10] yield fluid temperature estimates during precipitation of 15-55°C.

Comparing Upsal Hogback and Jezero crater: JC and UH are comparable in mineralogy, geological context, and carbonate distribution.
**Mineralogy:** JC and UH have carbonates occurring in association with mafic minerals. At JC, spectral signatures indicate layers of coincident olivine and carbonate, some of which are interpreted as overlying smectite-bearing layers [1]. UH tuff is a basaltic tephra with primary olivine as well as smectite alteration. The tuff rings of UH are draped in a gravel composed of tufa detritus and basaltic clasts mixed with tuff, which may be similar to Mottled Terrain and Light-toned Floor units of JC [1,3].

**Geologic Context:** JC is an impact basin that was once occupied by a lake which subsequently desiccated [1]. Pluvial Lake Lahontan was extant up to the end of the Last Glacial Maximum and subsequently desiccated due to increased evaporation, a condition which preliminary evidence suggests is revealed in C and O isotopes of tufas at UH. Both JC and UH are in basins receiving eroded sediment from large and varied geologic terranes (the Martian Highlands and Sierra Nevada respectively). Like JC, UH’s lowest-lying areas are occupied by aeolian land forms.

**Carbonate Spatial distribution:** Marginal Carbonates of JC occur in a relatively narrow elevation band interpreted as the littoral area at the upper stand of a paleolake in JC [1, 12]. UH tufas occur in clusters at elevation intervals of 1250-1260 m and 1240-1242.5 m (Fig.2), and correlate with Lake Lahontan stillstand elevations [13]. At UH, low-temperature hydrothermal fluid accelerated calcite precipitation (as tufas and within pore spaces) and palagonization, while providing conditions right for microbial habitation.

**Implications:** As an analogue to JC, UH may aid in selection criteria for potential return sample candidates. While the astrobiologic potential of tufas is well established [1], additional consideration should be paid to the olivine-bearing substrate at JC, which might host evidence of microbial endoliths.


![Fig 2A: Photomicrograph of UH hydrovolcanic basaltic tuff. B: Vesicle with radiating PBA of A. (UH17-07D)](image)

![Fig. 1: UH elevation map with tufa locations in cyan as irregular shapes and circles (size exaggerated). Elevation in meters above sea level.](image)