

Introduction:

We consider the tuff ring complex Upsal Hogback (UH) that erupted in the Lahontan basin, NV, between 19 ka and 33.7 ka (PSV) [1] a good analogue for Jezero Crater (JC), the target for the Mars 2020 mission for the following reasons:

1. The two locations are associated with paleo-lakes that formed within closed basins or basins with limited outflow [2].
2. They share similar surficial compositions including olivine-rich units and associated secondary minerals (smectites, carbonates) [2,3,4].
3. Carbonates at both sites are inferred to have been emplaced at the margin of a lake [3,5].

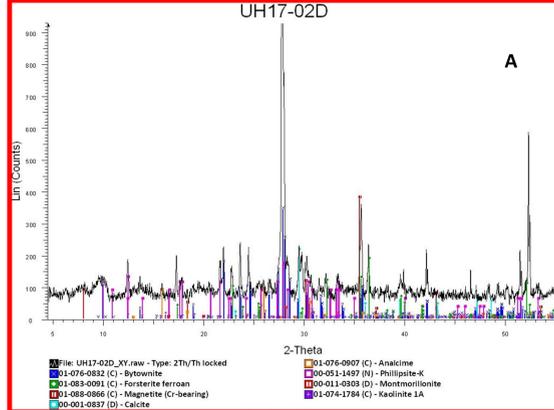
Upsal Hogback tuff rings have porous and glassy basaltic tuff with visible olivine and plagioclase. Lacustrine carbonates were emplaced on the tuff rings by upwelling of hydrothermal fluid while Lake Lahontan occupied the local basin. Analysis of Upsal Hogback tuff has revealed the presence of putatively biogenic alteration (PBA) as micro-tunnel ichnofossils in glass clasts attributed to microbial euendoliths [5] and is associated with the lacustrine carbonates.

Lacustrine Carbonates at Upsal Hogback

- Carbonates at Upsal Hogback occur most often in the form of large tufas (diameter avg. 3.4 m, SD 2.6 m) in which tuff is well indurated by calcite cement. These tufas are in the form of rings (10-60 cm thick walls) encapsulating tuff [5].
- Erosion has emplaced a desert pavement composed of tufa & basalt clasts (clasts 0.5-3 cm) on the tuff ring peaks.
- It is in the tuff preserved within the tufas that PBA has been identified.
- Calcite at Upsal Hogback is mostly pure CaCO₃, but magnesian calcite identified by bulk-powdered X-ray diffraction has also been identified in ~15% of the samples.



Figure 1: Tufas on Upsal Hogback tuff rings deposited near the paleo-shoreline from hydrothermal fluid.



| Sample | Location | Type | Carbonates | | | Palagonitic Clays | | | Zeolites | | | |
|-----------|----------|------|------------|-------------------|---------|-------------------|-----------------|----------|-------------|----------|-----------|---------|
| | | | Forsterite | Magnesian Calcite | Calcite | Nontronite | Montmorillonite | Saponite | Phillipsite | Analcime | Chabazite | Zeolite |
| SL-16-02 | SL | Tuff | | | | | | | | | | |
| SL-16-03 | SL | Tuff | | | | | | | | | | |
| SL-16-16B | SL | Tuff | | | | | | | | | | |
| SL-16-17 | SL | Tuff | | | | | | | | | | |
| SL-16-21A | UH | Tuff | | | | | | | | | | |
| SL-16-21C | UH | Tuff | | | | | | | | | | |
| SL-16-21E | UH | Tuff | | | | | | | | | | |
| SL-16-24B | UH | Tuff | | | | | | | | | | |
| SL-16-25C | UH | Tuff | | | | | | | | | | |
| SL-16-27A | UH | Tuff | | | | | | | | | | |
| SL-16-28A | UH | Tuff | | | | | | | | | | |
| SL-16-28B | UH | Tuff | | | | | | | | | | |
| SL-16-28C | UH | Tuff | | | | | | | | | | |
| SL-16-28D | UH | Tuff | | | | | | | | | | |
| SL-16-28E | UH | Tuff | | | | | | | | | | |
| SL-16-28F | UH | Tuff | | | | | | | | | | |
| SL-16-28G | UH | Tuff | | | | | | | | | | |
| SL-16-28H | UH | Tuff | | | | | | | | | | |
| SL-16-28I | UH | Tuff | | | | | | | | | | |
| SL-16-28J | UH | Tuff | | | | | | | | | | |
| SL-16-28K | UH | Tuff | | | | | | | | | | |
| SL-16-28L | UH | Tuff | | | | | | | | | | |
| SL-16-28M | UH | Tuff | | | | | | | | | | |
| SL-16-28N | UH | Tuff | | | | | | | | | | |
| SL-16-28O | UH | Tuff | | | | | | | | | | |
| SL-16-28P | UH | Tuff | | | | | | | | | | |
| SL-16-28Q | UH | Tuff | | | | | | | | | | |
| SL-16-28R | UH | Tuff | | | | | | | | | | |
| SL-16-28S | UH | Tuff | | | | | | | | | | |
| SL-16-28T | UH | Tuff | | | | | | | | | | |
| SL-16-28U | UH | Tuff | | | | | | | | | | |
| SL-16-28V | UH | Tuff | | | | | | | | | | |
| SL-16-28W | UH | Tuff | | | | | | | | | | |
| SL-16-28X | UH | Tuff | | | | | | | | | | |
| SL-16-28Y | UH | Tuff | | | | | | | | | | |
| SL-16-28Z | UH | Tuff | | | | | | | | | | |
| UH17-01B | UH | Tuff | | | | | | | | | | |
| UH17-01C | UH | Tuff | | | | | | | | | | |
| UH17-01D | UH | Tuff | | | | | | | | | | |
| UH17-01E | UH | Tuff | | | | | | | | | | |
| UH17-01F | UH | Tuff | | | | | | | | | | |
| UH17-01G | UH | Tuff | | | | | | | | | | |
| UH17-01H | UH | Tuff | | | | | | | | | | |
| UH17-01I | UH | Tuff | | | | | | | | | | |
| UH17-01J | UH | Tuff | | | | | | | | | | |
| UH17-01K | UH | Tuff | | | | | | | | | | |
| UH17-01L | UH | Tuff | | | | | | | | | | |
| UH17-01M | UH | Tuff | | | | | | | | | | |
| UH17-01N | UH | Tuff | | | | | | | | | | |
| UH17-01O | UH | Tuff | | | | | | | | | | |
| UH17-01P | UH | Tuff | | | | | | | | | | |
| UH17-01Q | UH | Tuff | | | | | | | | | | |
| UH17-01R | UH | Tuff | | | | | | | | | | |
| UH17-01S | UH | Tuff | | | | | | | | | | |
| UH17-01T | UH | Tuff | | | | | | | | | | |
| UH17-01U | UH | Tuff | | | | | | | | | | |
| UH17-01V | UH | Tuff | | | | | | | | | | |
| UH17-01W | UH | Tuff | | | | | | | | | | |
| UH17-01X | UH | Tuff | | | | | | | | | | |
| UH17-01Y | UH | Tuff | | | | | | | | | | |
| UH17-01Z | UH | Tuff | | | | | | | | | | |
| UH17-02A | UH | Tuff | | | | | | | | | | |
| UH17-02B | UH | Tuff | | | | | | | | | | |
| UH17-02C | UH | Tuff | | | | | | | | | | |
| UH17-02D | UH | Tuff | | | | | | | | | | |
| UH17-02E | UH | Tuff | | | | | | | | | | |
| UH17-02F | UH | Tuff | | | | | | | | | | |
| UH17-02G | UH | Tuff | | | | | | | | | | |
| UH17-02H | UH | Tuff | | | | | | | | | | |
| UH17-02I | UH | Tuff | | | | | | | | | | |
| UH17-02J | UH | Tuff | | | | | | | | | | |
| UH17-02K | UH | Tuff | | | | | | | | | | |
| UH17-02L | UH | Tuff | | | | | | | | | | |
| UH17-02M | UH | Tuff | | | | | | | | | | |
| UH17-02N | UH | Tuff | | | | | | | | | | |
| UH17-02O | UH | Tuff | | | | | | | | | | |
| UH17-02P | UH | Tuff | | | | | | | | | | |
| UH17-02Q | UH | Tuff | | | | | | | | | | |
| UH17-02R | UH | Tuff | | | | | | | | | | |
| UH17-02S | UH | Tuff | | | | | | | | | | |
| UH17-02T | UH | Tuff | | | | | | | | | | |
| UH17-02U | UH | Tuff | | | | | | | | | | |
| UH17-02V | UH | Tuff | | | | | | | | | | |
| UH17-02W | UH | Tuff | | | | | | | | | | |
| UH17-02X | UH | Tuff | | | | | | | | | | |
| UH17-02Y | UH | Tuff | | | | | | | | | | |
| UH17-02Z | UH | Tuff | | | | | | | | | | |
| UH17-03A | UH | Tuff | | | | | | | | | | |
| UH17-03B | UH | Tuff | | | | | | | | | | |
| UH17-03C | UH | Tuff | | | | | | | | | | |
| UH17-03D | UH | Tuff | | | | | | | | | | |
| UH17-03E | UH | Tuff | | | | | | | | | | |
| UH17-03F | UH | Tuff | | | | | | | | | | |
| UH17-03G | UH | Tuff | | | | | | | | | | |
| UH17-03H | UH | Tuff | | | | | | | | | | |
| UH17-03I | UH | Tuff | | | | | | | | | | |
| UH17-03J | UH | Tuff | | | | | | | | | | |
| UH17-03K | UH | Tuff | | | | | | | | | | |
| UH17-03L | UH | Tuff | | | | | | | | | | |
| UH17-03M | UH | Tuff | | | | | | | | | | |
| UH17-03N | UH | Tuff | | | | | | | | | | |
| UH17-03O | UH | Tuff | | | | | | | | | | |
| UH17-03P | UH | Tuff | | | | | | | | | | |
| UH17-03Q | UH | Tuff | | | | | | | | | | |
| UH17-03R | UH | Tuff | | | | | | | | | | |
| UH17-03S | UH | Tuff | | | | | | | | | | |
| UH17-03T | UH | Tuff | | | | | | | | | | |
| UH17-03U | UH | Tuff | | | | | | | | | | |
| UH17-03V | UH | Tuff | | | | | | | | | | |
| UH17-03W | UH | Tuff | | | | | | | | | | |
| UH17-03X | UH | Tuff | | | | | | | | | | |
| UH17-03Y | UH | Tuff | | | | | | | | | | |
| UH17-03Z | UH | Tuff | | | | | | | | | | |
| UH17-04A | UH | Tuff | | | | | | | | | | |
| UH17-04B | UH | Tuff | | | | | | | | | | |
| UH17-04C | UH | Tuff | | | | | | | | | | |
| UH17-04D | UH | Tuff | | | | | | | | | | |
| UH17-04E | UH | Tuff | | | | | | | | | | |
| UH17-04F | UH | Tuff | | | | | | | | | | |
| UH17-04G | UH | Tuff | | | | | | | | | | |
| UH17-04H | UH | Tuff | | | | | | | | | | |
| UH17-04I | UH | Tuff | | | | | | | | | | |
| UH17-04J | UH | Tuff | | | | | | | | | | |
| UH17-04K | UH | Tuff | | | | | | | | | | |
| UH17-04L | UH | Tuff | | | | | | | | | | |
| UH17-04M | UH | Tuff | | | | | | | | | | |
| UH17-04N | UH | Tuff | | | | | | | | | | |
| UH17-04O | UH | Tuff | | | | | | | | | | |
| UH17-04P | UH | Tuff | | | | | | | | | | |
| UH17-04Q | UH | Tuff | | | | | | | | | | |
| UH17-04R | UH | Tuff | | | | | | | | | | |
| UH17-04S | UH | Tuff | | | | | | | | | | |
| UH17-04T | UH | Tuff | | | | | | | | | | |
| UH17-04U | UH | Tuff | | | | | | | | | | |
| UH17-04V | UH | Tuff | | | | | | | | | | |
| UH17-04W | UH | Tuff | | | | | | | | | | |
| UH17-04X | UH | Tuff | | | | | | | | | | |
| UH17-04Y | UH | Tuff | | | | | | | | | | |
| UH17-04Z | UH | Tuff | | | | | | | | | | |
| UH17-05A | UH | Tuff | | | | | | | | | | |
| UH17-05B | UH | Tuff | | | | | | | | | | |
| UH17-05C | UH | Tuff | | | | | | | | | | |
| UH17-05D | UH | Tuff | | | | | | | | | | |
| UH17-05E | UH | Tuff | | | | | | | | | | |
| UH17-05F | UH | Tuff | | | | | | | | | | |
| UH17-05G | UH | Tuff | | | | | | | | | | |
| UH17-05H | UH | Tuff | | | | | | | | | | |
| UH17-05I | UH | Tuff | | | | | | | | | | |
| UH17-05J | UH | Tuff | | | | | | | | | | |
| UH17-05K | UH | Tuff | | | | | | | | | | |
| UH17-05L | UH | Tuff | | | | | | | | | | |
| UH17-05M | UH | Tuff | | | | | | | | | | |
| UH17-05N | UH | Tuff | | | | | | | | | | |
| UH17-05O | UH | Tuff | | | | | | | | | | |
| UH17-05P | UH | Tuff | | | | | | | | | | |
| UH17-05Q | UH | Tuff | | | | | | | | | | |
| UH17-05R | UH | Tuff | | | | | | | | | | |