HABITABILITY OF CONTINENTAL HYDROTHERMALLY ALTERED BASALTIC TUFF: ENVIRONMENTAL CONSTRAINTS FROM PLUVIAL LAKE VOLCANISM IN CARSON DESERT, NV.

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Introduction: Putative biogenic alteration (PBA) of basaltic glass has been documented in oceanic environments [1,2] subglacial environments [3], and more recently in a continental lacustrine setting [4]. Trace fossil evidence of microbial alteration occurs as tubular and granular microborings, especially in pillow lava rinds [5]. Identification of biogenic alteration in palagonitized phreatomagmatic basaltic tuff from Upsal Hogback, Nevada corroborates recently identified habitable environments and provides an opportunity for further constraints on habitable conditions.

Field Site: Upsal Hogback (UH) is a series of four overlapping tuff rings (~5.5 km^2) built by phreatomagmatic eruptions into pluvial Lake Lahontan near Fallon, Nevada in the Carson Desert, Basin and Range Province between 25 kya [6] and 8.6 k.y. BP [7]. UH tuff rings are low lying; elevations vary ≤ 50 m. The largest is the northernmost tuff ring at ~1.5 km diameter, the 3 southern tuff rings are 350 m to 1.2 km diameter. Tuff at UH is ash and lapilli rich, indicating a highly efficient eruption typical of a wet environment, subsequent palagonitization results from hydrothermal alteration. The southern 3 tuff rings have a high density of calcareous mounds (tufa) and veins, which are evidence of hydrothermal fluid interacting with alkaline lake and groundwater.

Methods: Samples of UH basaltic tuff from within and external to tufa outcrops were collected. Attention was given to tuff within tufas where samples were collected at points adjacent to the tufa wall, at one half the radius of the tufa, and at the center of several larger (3-10 m) tufa outcrops. Standard petrographic analysis yielded textural and mineral assemblage information. Mineralogy was determined by bulk powder X-ray diffraction (pXRD) performed with a Rigaku SmartLab 3kW diffractometer at Brock University at 40kV and 44mA, with 0.0100 degree step. In addition, micro X-ray diffraction (µXRD) on polished thin sections (PTS) was performed on a Bruker D8 Discover diffractometer with a 300 µm beam diameter at Western Ontario University [8]. Raman spectroscopy was performed on PTS at the Royal Ontario Museum with a Horiba JY LabRAM ARAMIS using a 633 nm He-Ne laser; results to be presented at LPSC.

Field Observations: The tuff has features typical of wet eruptions, such as bomb sags and poorly sorted, well bedded surge deposits. Tuff beds are normally and

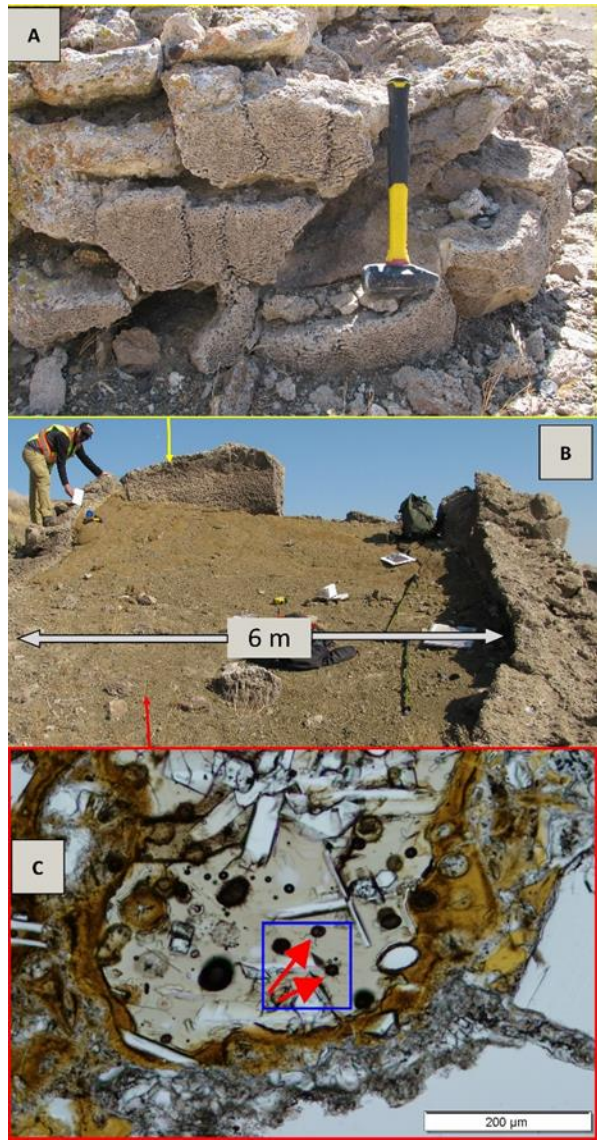

Figure 1 A: calcareous tufa wall; B: tufa outcrop UH17-02; C: tuff PTS (UHI17-04B), scale bar 200 um; red arrows to PBA from vesicles (see fig. 2)

reversely graded corresponding to increasing and decreasing explosivity, respectively. Lapilli-rich coarser layers are typically thinner (1-2 cm) than fine ash-rich layers (up to 10 cm). The orange-brown tuff commonly includes visible glass, sometimes comprising as much as 50% of the rock, with olivine and plagioclase phenocrysts. Fine clay encrustation on glassy clasts and

Figure 2 Putative biogenic alteration from multiple vesicles in basaltic glass (sample SL-16-24A)

within vesicles is consistent with incipient palagonitization.

Induration of the tuff is greatest in tufa outcrops, and is weak elsewhere. Carbonate walls of tufas are 20-50 cm thick. Tufas vary in size from <1 m to several meters and frequently occur in clusters and in linear chains. Linear carbonate walls of the same morphology also form with no apparent closure.

Petrography/Mineralogy: UH tuff includes approximately 50% volcanic glass, basaltic vesicular lapilli, and olivine and plagioclase phenocrysts (150-1000 µm). Secondary calcite precipitation is most pervasive in tuff within tufas and occurs at pore space as well as in vesicles in glass connected by cracks to the shard periphery. Palagonitization varies from less than 10% to over 80% indicating variable temperature maxima and duration of aqueous alteration [9]. Opaque phase microcrystallization was identified by Raman spectroscopy as magnesiochromite.

pXRD and µXRD results. In addition to confirmation of primary igneous forsterite and Na-rich anorthite, fine-grained and poorly crystalline secondary minerals were identified by XRD. The carbonate cement is pure calcite. Palagonite constituent clays include saponite, montmorillonite, and nontronite and frequently occur with chabazite. The mineral assemblage is consistent with the alteration temperature including a period of temperatures from 25-75^{o}C [10].

Putative Biological Alteration: Of 14 tufa associated tuff samples, all include evidence of PBA of a granular type. Of those samples, ten also include ≥ 5 µm long microtunnels (Figs. 2,3). Of these, 4 samples have putative biogenic microtunnels which have clear morphology and/or are consistently observed in

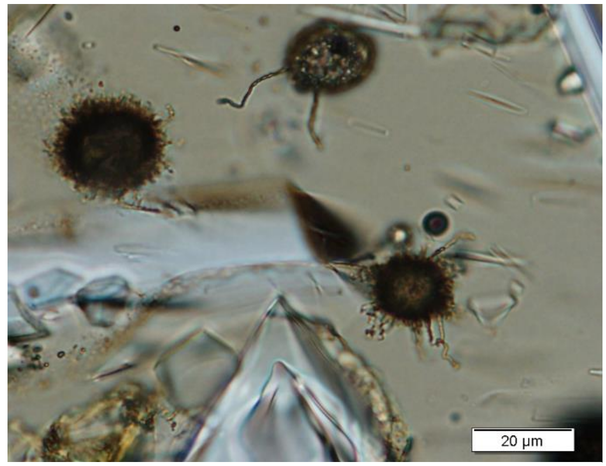

Figure 3 Putative biogenic alteration from vesicles in glass, scale bar 20 um (sample UH17-04B)

sideromelane clasts throughout the sample. All occurrences of PBA are accompanied by occurrence of both palagonite and calcite. Morphology of PBA from this site is most often simply bulb-type textures from vesicles, but occasional spiral and bifurcating microtunnels are also observed. PBA is minimal and only in granular form, or not present at all in unpalagonitized samples from poorly cemented tuff.

Planetary Implications: Identification of microbial alteration textures in this lacustrine phreatomagmatic setting provides evidence that microbial life may exist in environments analogous to plausible paleoenvironments on Mars. Evidence from magnesium carbonates identified in Nili Fossae indicate neutral to alkaline water conditions during the Hesperian period [11], which may be chemically comparable to intracontinental terminal alkaline lakes. Where palagonitic clays and carbonates can be identified, it is likely that conditions provided an opportunity for life to have existed. Basaltic tuff is known to be a good substrate to support microbial life [2] whereby energy and nutrients are made available via its dissolution. Identification of basaltic tuff with appropriate hydrothermal alteration may increase the likelihood of finding evidence of microbial life. Under appropriate conditions, these environments may prove to host life both on Earth and Mars.

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