THE BANDELIER TUFF AS A POTENTIAL MATERIAL ANALOG OF THE MEDUSAE FOSSAE FORMATION, MARS, AND THE CAMPO DE PIEDRA POMEZ IGNIMBRITE, ARGENTINA.

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Introduction: The Medusae Fossae Formation (MFF) is a large Martian deposit suggested to consist of friable pyroclastic material due to extensive erosion and low radar returns identified with remote sensing [1,2]. Previous studies have recognized the Campo de Piedra Pomez Ignimbrite (CPPi) as a terrestrial analog for the MFF based on the presences of eolian erosional landforms (e.g. yardangs) in both locations [3]. Recent quantitative analysis of yardang morphology and material properties in the MFF and CPP suggest that the erosion resistance of the MFF is unusually high considering its low density and friability. [4] This may reflect unusual petrographic textures like those identified in the CPP (Fig. 1), although direct comparison with Martian tuffs is not yet possible [5]. Studying other terrestrial tuffs may constrain which formation processes can create relatively strong, low-density tuff.

The Bandelier Tuff (BT) is a large, well-studied, accessible deposit in Los Alamos, NM with units having a broad range of mechanical properties overlapping the tuffs in other studies and the projected properties of the MFF [4,6]. The comparison here of the Bandelier Tuff with tuffs in the previous study will contrast the different processes occurring at each locality and suggest ways to further our understanding of yardang formation and the properties of purported extraterrestrial pyroclastic materials.

Geologic Setting: *Medusae Fossae Fm.* The MFF was deposited over a 2.1 million km^2 equatorial region of Mars, possibly after erupting from Apollinaris Patera (Fig. 2) during the Hesperian-Amazonian transition. [1] Little to no water has weathered the MFF throughout its erosional history although more water was present during emplacement. [1] Significant differences from terrestrial analogs include the likely influence of ash fall, post-depositional reworking, and presumably basaltic composition. [7]

There are three unconformity-bounded member units in the MFF with the lower layers being more eroded. [1] It is not clear from remote sensing whether these members are cooling units or if there are more unconformities outside the currently available data.

Campo de Piedra Pomez. The CPP is a 249 km^2 rhyodacitic ignimbrite deposited at 70ka in the Puna region of Argentina in a back arc extensional setting [8]. The aridity, altitude, and resulting dominance of eolian erosional processes create an ideal Mars analog site. [4]

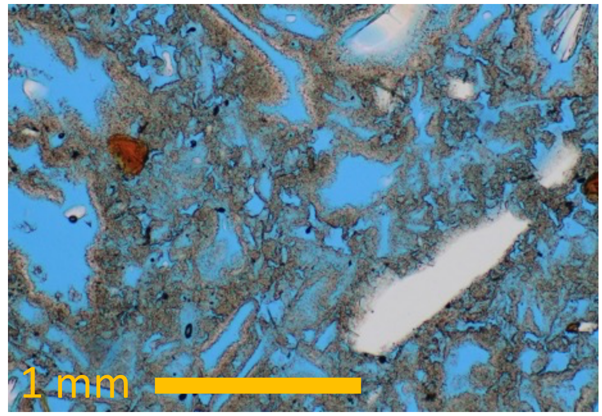

Figure 1 - Thin section of ignimbrite sample from the largest yardang in the CPP exhibiting an unusually porous (54%) texture with average strength (4 MPa). Comparing this with similar tuffs would help to assess whether this texture could cause the low density observed in the MFF. Blue color is pore space.

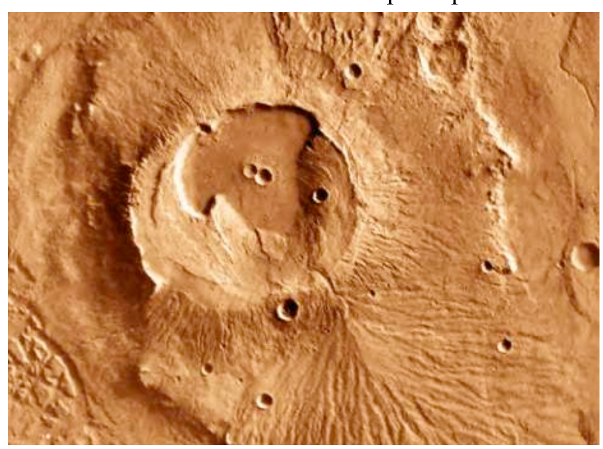

Figure 2 - Appolinaris Patera, Mars (80 km wide caldera). Possible MFF source. © Calvin J. Hamilton

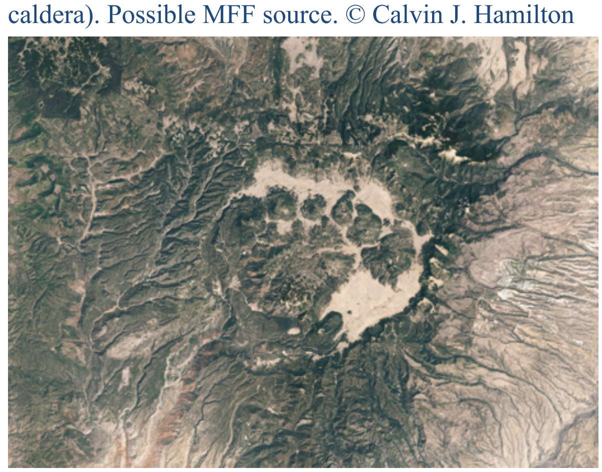

Figure 3 - Valles Caldera, NM (22 km wide). Source of Bandelier Tuff. Image: NASA Earth Observatory

The CPPi is dominated by one cooling unit intervened with an extended pause in eruption [8]. The resumed eruption unconformably overlies the prior flows in some areas [8]. Lithics from another eruption obscures the majority of the CPPi [8]. Almost the entire exposed deposit is devitrified with vapor phase crystallization and is only very slightly welded, akin to the ignimbrites described by the term ‘sillar’ [4].

Other tuffs (Rosada and Galan) in the region of the CPPi are strongly welded and older with large "megayardangs" that have similar sizes to Mars yardangs. These terrestrial megayardangs were not analyzed by [4] because of their proximity to water bodies and broader shapes that reflect a stronger influence of water-driven mass wasting.

Bandelier Tuff. The BT was laid down on the flanks of Valles Caldera (Fig. 3) as 400 km^3 of rhyolitic ignimbrite in three events between 1.8 and 1.2 Ma as part of a rift zone. The bottom two cooling units (La Cueva and Otowi) are mostly nonwelded while the prominent top one (Tsherige) has several layers with slight to dense welding and sometimes vapor phase crystallization that alters the erosional profile of outcrops. Although the intervening climate has been rainy and continental, the enormous size and plurality of units make BT analogous to the MFF if the units are shown to have similar properties. Furthermore, fluvial pyroclastic members between cooling units represent a potentially useful analog for discriminating such sediments from primary pyroclastic deposits on Mars.

Material Properties and Erosion: *Medusae Fossae Fm.* Penetrating radar was recently used to quantify the uppermost density of the MFF as 1.765 g/cm^3 (±0.105), corresponding to basalt with 51% porosity [2]. Using an automated shape analysis and sample testing, [4] regressed relations between CPPi yardang morphometry and the strength, porosity, and density of CPPi samples. Applying those relations to MFF yardang morphometry suggests the MFF has a density of 1.19 g/cm^3 (±0.02), porosity of 52.04% (+1.41, -1.37), and compressive strength of 0.64 MPa (+0.84, -0.36). That porosity is the only property matching [2] may not be surprising considering that porosity is strongly correlated with the mechanical properties that determine erosion resistance [4,9,10].

Campo de Piedra Pomez. CPPi materials were measured as having a density of 1.26 g/cm^3 (±0.13), porosity of 49.51% (±0.43), and compressive strength of 4.88 MPa (2.86) [4]. Despite having low strength, the CPPi appears more resistant to erosion than comparably strong soils and nonwelded tuffs. [4] attributes this to the sillar-type textures (Fig. 1) that create rock-like fracture behavior even with soil-like strength, density, and porosity. However, further study is needed to describe the erosion resistance in terms of mechanical properties and corresponding formation processes.

Bandelier Tuff. Unit 4 of the Tsherige is non- to partially welded and has a compressive strength of 2-12 MPa [6,9]. The absence of sillar textures could provide an important contrast to CPP samples for future measurements of erosion resistance.

Welded sections of the BT are typically measured in terms of seismic velocity for geotechnical purposes [10]. Deriving comparable values like compressive strength from these measurements and applying these methods to partly welded tuffs would enable non-invasive testing of sensitive sites like the CPP and Bandelier National Monument.

Fluvial undercutting of the BT stratigraphy creates dramatically elongated ‘potrero’ mesas extending from the upper slopes of the caldera. [5] The morphological similarity between potrero mesas and some terrestrial megayardangs [4] warrants study of the criteria for distinguishing megayardangs on slopes from potrero mesas bounded by wind-straightened valleys [11].

Conclusions: To precisely identify features formed in pyroclastic materials throughout the solar system, it will be necessary to better understand the properties of similar materials formed under various conditions on Earth. Future studies of formations like the BT and CPP using methods such as sample tomography [12], Finite Element Analysis [13], thermal modeling [14]. ultrasonic measurements [10], and landform evolution modeling [11] will aid the identification of more analogs, enhance heritage preservation [15], and inform comprehensive research of surface processes.

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