INTERACTIONS BETWEEN ATHABASCA VALLES FLOOD LAVAS AND THE MEDUSAE FOSSAE FORMATION: IMPLICATIONS FOR LAVA EMPLACEMENT MECHANISMS AND THE TRIGGERING OF STEAM EXPLOSIONS.

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Introduction: Small (sub-kilometer diameter) cratered cones occur in southwestern Elysium Planitia, Mars, and are located atop the <20 Ma Athabasca Valles Flood Lava (AVFL) [1,2,3]. These landforms concentrate within southern Cerberus Palus and an adjacent valley formed by the southward retreat of the Aeolis Planum Medusae Fossae Formation (MFF) from Hesperian to Amazonian-age lava flows to the north, that we refer to as the Aeolis Trough. The cratered cones within the region of interest, spanning from 137–149°E to 0–5°N, are interpreted to be volcanic rootless cones (VRCs). VRCs are the products of steam explosions and we infer that their formation was due to the transfer of heat from the AVFL to an underlying water-bearing substrate. However, contrasting cone morphologies in Cerberus Palus relative to those observed in association with yardangs in the MFF, imply differences in the triggering mechanisms as well as subsequent phreatic and/or phreatic explosion processes. Examining VRCs in this region is therefore important for determining the geologically recent distribution of water within Elysium Planitia and how local environmental conditions can affect the development of lava-induced steam explosions on Mars.

Methods: This project involved photogeological mapping of relevant geologic units and hydrovolcanic landforms using ArcGIS software. For basemaps, we utilized a regional mosaic of Mars Reconnaissance Orbiter Context Camera (CTX) imagery that spans from 140-176° E and 0-12° N, with a resolution of 6 m/pixel. This mosaic was created by Jay Dickson at the Bruce Murray Laboratory for Planetary Visualization, using a non-destructive image processing method [4]. High Resolution Imaging Science Experiment (HiRISE) imagery was combined with the CTX mosaic to provide higher resolution observations at .3 m/pixel. These data sets were combined to generate a 1:100,000 scale map of the major geological units in the study area, with feature classes of each category of hydrovolcanic landform. The final map is presented in a Mars equidistant cylindrical projection using the D_MARS datum and an East positive geographic coordinate system.

Results: Two distinct morphological archetypes of VRCs are found in the study area. Broad cratered, symmetrical VRCs are present primarily throughout the distal end of Cerberus Palus, while elliptical VRCs are present everywhere along the AVFL-MFF contact. Also present are 'thin-rimmed rings', analogous to spatter rims, along the western border of Cerberus Palus, where the AVFL interacted with a substrate of Amazonian-Hesperian volcanics (AHv), and 'pitted terrain' along the southern margin of Aeolis Trough, where the AVFL interacted with MFF material. Figure 1 shows the various hydrovolcanic landforms observed in the study area and displays the diversity of morphologies.

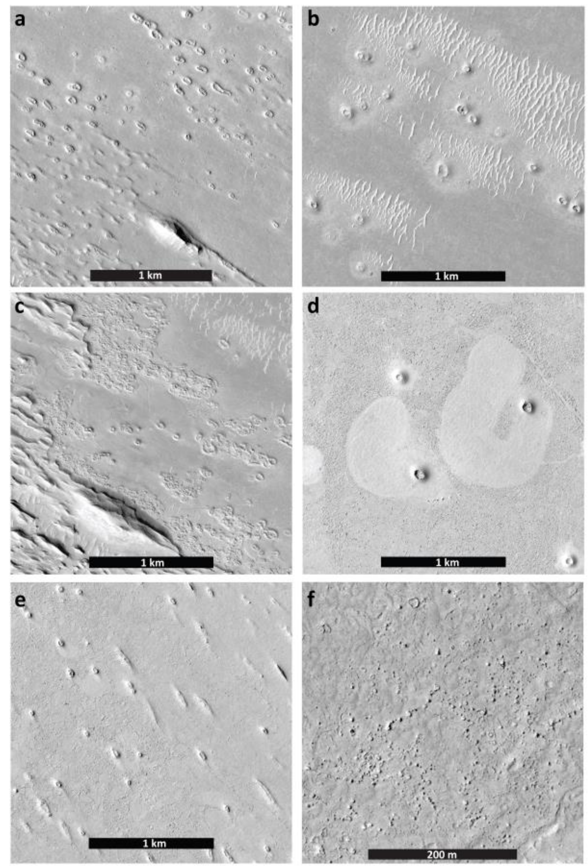

Figure 1. *(a) Elliptical VRCs in the Aeolis Trough. Flood lava has draped small meso-yardangs, leaving a combination of lava covered mounds and cratered cones. The orientation of the cratered cones is nearly uniform and parallel to yardang orientation. HiRISE image PSP_002622_1820. (b) Symmetrical cratered cones in the Aeolis Trough. Cratered cones are located primarily in the middle portion of the trough and surrounded by light colored material, interpreted to be ash aprons. Transverse aeolian ridges are present near cones, possibly comprised of eroded and redistributed MFF material. HiRISE image ESP_036220_1820. (c) Pitted terrain in the Aeolis Trough, adjacent to high-standing MFF material. VRCs are amalgamated within this pitted terrain. HiRISE image ESP_ 013355_1815. (d) Symmetrical cratered cones in southern Cerberus Palus. Cratered cones are enveloped by smooth, polygonal surfaces, which lie below the surrounding rough, blocky surfaces. These cones have steep, smooth walls, and meter-sized boulders*

within their summit craters. HiRISE image ESP_037222_1820. (e) Elliptical cratered cones in southern Cerberus Palus, adjacent to Zephyria Planum. Small kipukas are also visible where lava has embayed some of the meso-yardangs, leaving islands of high-standing yardang material. HiRISE image ESP_054615_1820. (f) Thin rimmed rings of spatter in southern Cerberus Palus, at its western margin. Thin flows of lava drape the AHv substrate. There is no indication of tephra ejecta or fragmented substrate material. HiRISE image ESP_054681_1835.

A total of 12,471 cratered cones were identified, with sizes ranging from 4–140 m in basal diameter and 4–100 m in crater diameter, and ratios of crater to cone diameters ranging from 0.45–0.7. The cratered cones found within the Aeolis Trough are generally elliptical in shape and oriented parallel to the direction of neighboring MFF yardangs (Fig. 1a). These cratered cones are generally surrounded by aprons of light colored material, resembling tephra deposits, and contain meter-size boulders within their summit craters. There is a strong concentration of cratered cones along the southern margin of the trough, where lava comes into contact with Aeolis Planum, embaying and draping MFF material. Few cratered cones are observed in the center of the trough; these landforms are more symmetrical in shape and also display aprons of light colored material (Fig. 1b). There is an additional morphologically distinct phreatic-type landform located in the Aeolis Trough, which we have termed 'pitted terrain'. This landform is comprised of rimmed pits found in patches of higher standing terrain, presumably remnant MFF material, that were embayed by lava (Fig. 1c).

Interpretations: Within the study area there are two distinct cratered cone morphologies. The two morphological types of cratered cones are both interpreted to be VRCs, formed by steam explosions that deposited tephra onto the surface of the lava. In the medial section of southern Cerberus Palus, VRCs exhibit radial symmetry, having broad summit craters that are commonly partially infilled with boulders that collapsed down from the crater rims. This implies that the crater rim material was competent, consistent with it being composed of welded spatter. All of these symmetrical cones generally overly smooth, light colored surfaces with polygonal textures, resampling the surface of a lava pond [5,6] (Fig. 1d). Along the eastern margin of southern Cerberus Palus, where AVFL has embayed the MFF deposits of Zephyria Planum, cratered cones exhibit the same characteristics as those in the Aeolis Trough: elliptical shape and orientation parallel to neighboring MFF yardang directions (Fig. 1e). Along the western margin of southern Cerberus Palus, where AVFL has draped the AHv substrate, there are 'thin-rimmed rings,' comprised of hollow, positive relief circular rims, up to a couple meters in diameter (Fig. 1f).

Conclusions: In southern Cerberus Palus, we infer that the formation of the symmetrical VRCs was controlled by the 'fill and spill' style of lava emplacement [7]. Lava ponded to a depth of ~45 m [8] may have acted to subtly raise the boiling point of the substrate volatiles. However, when lava drained from Cerberus Palus into the Aeolis Trough, the reduction in pressure may have triggered the superheated water to flash to steam, thereby destabilizing the base of the lava crust and leading to subsequent phreatomagmatic explosions as liquid lava mixed with wet substrate below. In contrast, 'thin-rimmed rings' located along western margin of southern Cerberus Palus, may have been triggered by the accumulation and release of steam escaping towards flow margins. The low energy, single bubble bursts through the thin lava thus resulted in thin rings of spatter, rather than more the highly fragmented and dispersed material associated with the phreatomagmatic explosions. However, the presence of spatter implies some involvement by molten material, rather than a purely phreatic explosion. Where the AVFL interacted with the MFF material in southern Cerberus Palus and the Aeolis Trough, VRCs preferentially formed atop lava draped meso-yardangs. The lithological properties of the MFF (namely its high porosity [9]) may have allowed for lateral transport of steam towards the peaks, or hulls, of the meso-yardang. Steam accumulating within these peaks could have been confined by under the competent capping layer of the yardang hulls until the steam pressure reached a critical point, leading to explosive release of the steam pocket and the formation of a VRC landform through a phreatic process. Lastly, the 'pitted terrain' located in the Aeolis Trough was created as a by-product of a mechanism similar to hydrothermal venting [10], where steam generated in the lava heated substrate escaped explosively through high stands of less consolidated MFF material, constructing rimmed pits of fragmented material.

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