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TRACES OF HYDROTHERMAL VENTING ON MARS

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Introduction

Hydrothermal venting is a common process in volcanically active regions on Earth. Geysers, fumaroles, hot springs or black smokers on the ocean floors are some of the most prominent surface expressions of hydrothermal venting and require an abundant amount of (ground-)water for their formation. Large hydrothermal vent complexes of a slightly different origin have been described on Earth e.g. in the Karoo Basin in South Africa ([1], [2]), in the Vøring and Møre basins off mid-Norway ([3], [4]) and in the Gilf Kebir region in southwestern Egypt ([5], [6]). Here, basaltic magma intruded in sedimentary strata and lead to contact metamorphism and the mobilization of volatiles from the sediments. As a consequence, sediment pipes and dykes formed acting as conduits for sediments and fluids were rapidly transported to the surface where fluid expansion and decompression lead to small-scale phreatic eruptions and late stage sediment volcanism. The topographic expression can be a depression or a crater indicating collapse and brecciation in the conduit zone and early phreatomagmatic activity. Small volcanic cones and domes are often associated with late stage sediment volcanism and erosion may later exhume deeper parts of the vent complexes, leading to a wide variety of landforms. We examined several regions on Mars where similar processes of hydrothermal venting through sedimentary strata may have occurred indicating that hydrothermal venting in lava-sediment settings could have been widespread on Mars.

Hydrothermal venting in Aeolis Planum

A large area of proposed hydrothermal venting was found north of Aeolis Planum. Here the Medusae Fossae Formation (MFF) material that composes the Aeolis Planum plateau borders a large NE-SW oriented valley that was filled by Amazonian lava flows from the Cerberus Fossae, thereby covering and surrounding Aeolis Planum-MFF material.

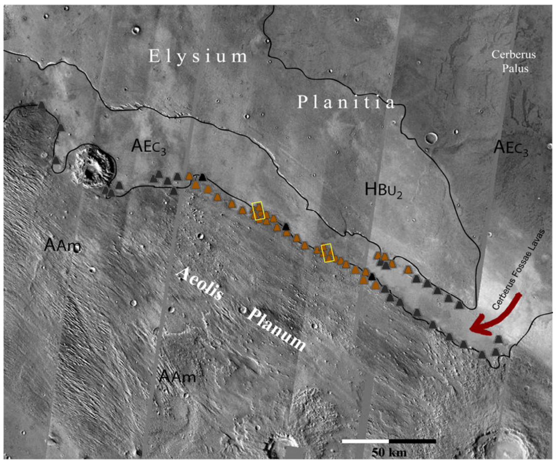

Figure 1: Themis IR daytime mosaic of the study area (credits: NASA World Wind; map units after [7]). Black and brown triangles mark the position of cones.

Along the lava-MFF contact zone numerous pitted cones and ridges of various morphologies can be found (Figure 2). The cones cluster mainly along the southern edges of the shallow valley and can only be found in association with outcrops of Aeolis Planum-MFF material. A large number of cones sit on top of or are surrounded by the Cerberus Fossae lavas. They are the largest cone structures and are mainly found in the regions furthest away from the Aeolis Planum borders. The cones often contain nested craters of sometimes distinctly different morphological appearances. Smaller cones and elongated pits sit on top of the ridges that dominate the southern part of the area close to Aeolis Planum. A third group of cones is found sitting on top of isolated mesas of Aeolis Planum material that have been embayed but not overflowed by lava or on terraces of Aeolis Planum material close to the lava contact. They are

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distinctly brighter than the surrounding lava surfaces, showing a similar albedo to Aeolis Planum material and a wide diameter range.

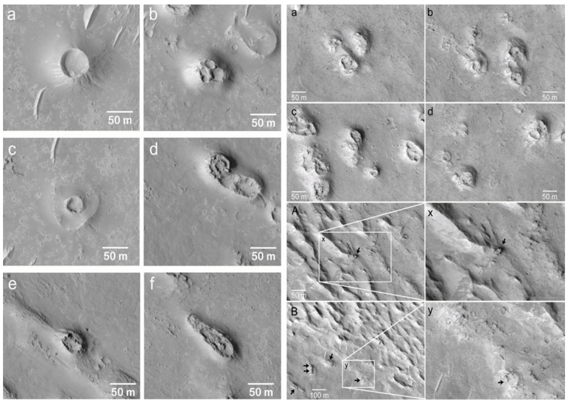

Figure 2: Examples of different cone morphologies (left, a-f) Right: Cones on isolated mesas and terraces of Aeolis Planum material that were surrounded but not overflown by lava (HiRise PSP_002622_1820, PSP_003756_1825).

We propose that the processes leading to the formation of the observed features in the study area proceeded as follows:

(1) Lava flooding and pseudocrater formation

Voluminous lava flows from the Cerberus Fossae flooded the study area and covered and surrounded fine-grained Aeolis Planum-MFF material. Pseudocraters formed by steam explosions similar to the pseudocrater clusters elsewhere in Elysium Planitia.

(2) Hydrothermal venting in Aeolis Planum material

The lava embayed and surrounded topographic highs across a wide area, forming many little contacts with Aeolis Planum-MFF material. Along these contacts the heat of the lava mobilized volatiles in the fine-grained material (e.g. by dehydration of hydrated minerals or mobilization of ground- or pore ice). Similar to hydrothermal vent complexes on Earth, this may have caused hydrofracturing in the material and the formation of pipes and dikes that transported the volatiles to the surface, where rapid decompression caused phreatic explosions and the formation of cones composed of Aeolis Planum material. This is an important difference to the pure pseudocraters that are mainly composed of tephra and welded spatter generated by the explosive break-up of the lava surface. The smaller pits and elongated cracks on top of ridges are caused by less explosive steam venting through the lava surface. The large variety of cone morphologies in the study area can thus be explained by the two processes acting synchronously forming a spectrum of cones ranging from pure pseudocraters to cones formed by hydrothermal venting through Aeolis Planum-MFF kipukas.

Hydrothermal venting in other regions on Mars

The described process of hydrothermal venting on Mars requires lava intruding into or covering and surrounding volatile rich sedimentary strata. This might have been common in the geologically more active and climatically warmer past of Mars history. Noachian and Early Hesperian aged sedimentary deposits have been identified in numerous places on Mars [8] some of them in close proximity to volcanic centers. However, resurfacing and erosion has strongly modified these units and any morphologic traces of early hydrothermal venting will probably be lost. We are currently investigating two other possible regions of hydrothermal venting, in the Phlegra Montes and north of Olympus Mons. Both regions lie in Amazonian-aged units and show similar morphologic characteristics as well as a similar geological setting to the Aeolis Planum vents. This could indicate that young volatile-rich deposits are widespread on Mars and processes of hydrothermal venting continued throughout most of Mars history.

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