POSSIBLE TRACES OF HYDROTHERMAL VENTING IN AEOLIS PLANUM, MARS. J. K. Lanz[1] and M. B. Saric[1], [1]Institut für Planetologie, Universität Stuttgart, Herdweg 51, 70174 Stuttgart, Germany; julia.lanz@geologie.uni-stuttgart.de.

Introduction: Small cone-shaped features have been identified in several regions on Mars, e.g. in Isidis Planitia, Elysium Planitia, Amazonis Planitia, Acidalia Planitia, southern Utopia Planita, in the Cydonia Region, in Cerberus Planum, around Phlegra Montes and on several volcanic flanks. They vary greatly in size and morphology and have been compared to terrestrial features of various origins namely (1) cinder cones (e.g. [1]), (2) tuff cones or tuff rings (e.g. [2]), (3) rootless cones (pseudocraters) (e.g. [3], [4]), (4) pingos (e.g. [5] or (5) mud volcanoes (e.g. [6]). They are often associated with volcanic centres and large lava fields or cluster in regions where the volatile content of the Martian regolith was/is supposedly high. It is generally assumed that (ground-) water or ground ice was a trigger or driving force of cone formation. They could therefore, be an important indicator of the history of water on the planet.

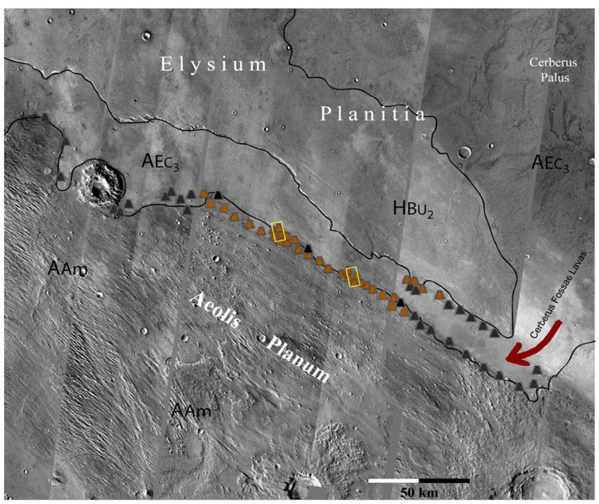

Figure 1: Themis IR daytime mosaic of the study area (credits: NASA World Wind; map units after *Tanaka et al., 2005*). Black and brown triangles mark the position of cones; the yellow rectangles in the image show the position of HiRise images used in this study.

Aeolis Planum Cones: We have studied a large valley bordering Aeolis Planum to the north that exhibits numerous small cones of various morphologies (see Figure 1). Lava flows from Cerberus Palus that originally emanated from discrete locations along the Cerberus Fossae filled the depression, entering from the SE and flowing in a NW direction along the northern border of Aeolis Planum [7]. The cones cluster mainly along the southern edges of the shallow valley and can only be found in association with outcrops of Aeolis Planum-Medusae Fossae Formation material. Cones throughout the area can be loosely separated in three different types that are related to three different geological settings.

Type 1: 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. They are morphologically diverse and include both smooth-surfaced cones and cones with a rather rough and jagged appearance. The cones often contain nested craters of sometimes distinctly different morphological appearances (Figure 2).

Type 2: Smaller cones and elongated pits sit on top of the ridges that dominate the southern part of the area close to Aeolis Planum (Figure 2).

Type 3: 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 (see Figure 3). They are distinctly brighter than the surrounding lava surfaces, showing a similar albedo to Aeolis Planum material (Figure 3) and a wide diameter range. The cones are often more irregularly shaped than type 1 or 2 with adjacent craters overlapping each other.

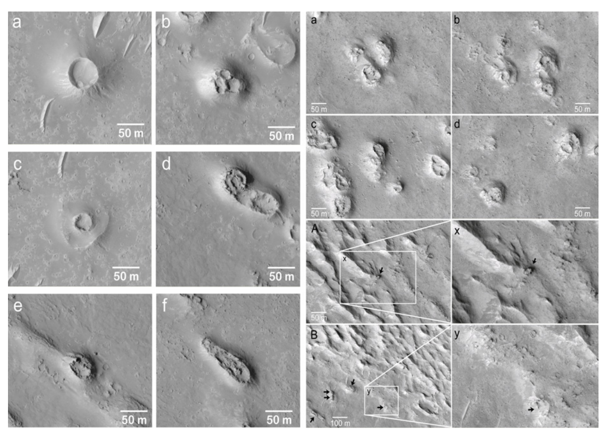

Figure 2: Examples of different cone morphologies **Left**: (a-d) type 1 cones, (e-f) type 2 cones; **Right**: Cones on isolated mesas and terraces of Aeolis Planum material located at the Aeolis Planum border (type 3 cones); (a-d) Cones on top of kipukas of Aeolis Planum material that have been completely embayed by lava. (A, B) Cones sitting on top of Aeolis Planum terraces; x and y are close-ups of the cones (Images: HiRise PSP_002622_1820, PSP_003756_1825).

Interpretation: The most noticeable differences of the Aeolis Planum Cones (APCs) to other cone structures on Mars are their characteristic changes in morphology, their assembly with pitted ridges and their close correlation to Aeolis Planum material. The cones on top of mesas and kipukas of Aeolis Planum-Medusae Fossae Formation material are particularly striking, and such features have not previously been described for Mars.

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. Pseudocraters in the study area concentrate along the southern and northern borders of the valley, though pseudocratering is most prominent in the south and along the northeastern borders of the valley. In the north their number decrease rapidly from east to west, and most of the northern borders are cone-free. The central parts of the valley are almost completely free of pseudocraters except for a few examples of cone clusters around isolated remote remnants of Aeolis Planum material.

(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 (Type 2 APCs) are caused by less explosive steam venting through the lava surface. The ridges, showing the exact same orientation as the yardangs on the Aeolis Planum surfaces, are simply remnants of Aeolis Planum material covered by a thin lava blanket at the very edges of the lava flow. Here mobilized volatiles and steam could escape more easily through the thin lava coverage preventing larger steam explosions.

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. The pure pseudocraters can form farther away from the contact zone (Type 1 APCs) and end where the thickness of the lava reaches a level that prevents pseudocrater formation. The Type 3 Aeolis Planum cones (those formed in MFF materials) will only form close to the lava-MFF contacts.

Conclusion: The Aeolis Planum cones differ from pure pseudocraters fields on Mars. While some of the cone clusters in the study area could still be interpreted as pseudocraters, we believe that our combined model of pseudocratering and hydrothermal venting can best explain the observations. Our interpretation is based on the assumption that the Aeolis Planum-MFF materials have a high volatile content, which is supported by radar observations [8]. The cones are found exclusively in close proximity to Aeolis Planum or outcrops of MFF, and a high volatile content seems the most likely mechanism to drive cone-forming processes. Fluvial processes or groundwater discharges in association with the lava eruptions along Cerberus Fossae (see e.g. [9], [10]) could have led to a partial enrichment of Aolis Planum material in volatiles. The emptying of a proposed large lava-basin in Cerberus Palum [7] has rapidly filled the study area, covering parts of the Aeolis Planum complex and surrounding regions with a thick lava body. Along the southern margin of the valley, the gently sloping morphology of Aeolis Planum material created a broad contact zone between the lava flows and the MFF materials they embay. Finally, the heat of the lava caused the mobilization of volatiles in the fine-grained materials and the formation of the described cones.

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