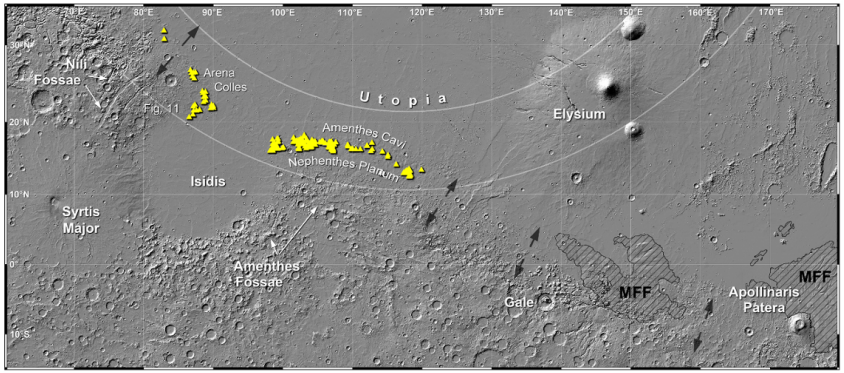
Amenthes Cones, Mars: Hydrovolcanic (Tuff) Rings and Cones from Phreatomagmatic Explosive Eruptions on Mars

P. Brož[1,2] and **E. Hauber**[3]

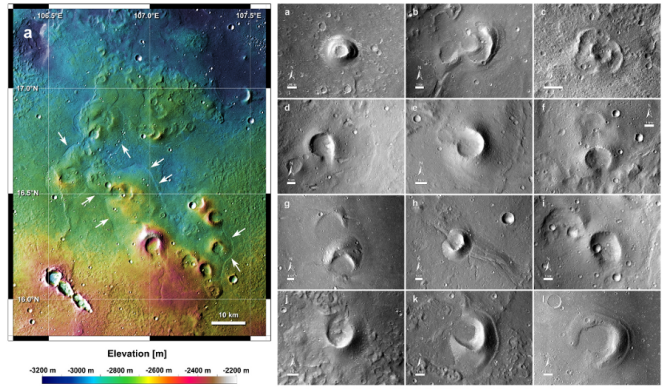
[1)]Institute of Geophysics ASCR, v.v.i., Prague, Czech Republic, **Petr.broz@ig.cas.cz,** [2)]Institute of Petrology and Structural Geology, Charles University, Czech Republic, [3)]Institute of Planetary Research, DLR, Berlin, Germany, **Ernst.Hauber@dlr.de**

Introduction



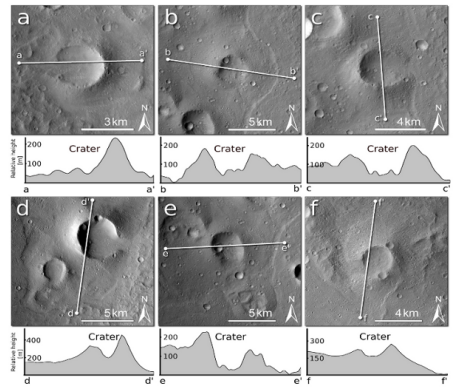
Hydrovolcanism refers to the interaction of magma or magmatic heat with an external water source [1], producing tuff rings, tuff cones and maars. Hydrovolcanism is a common natural phenomenon on Earth and should be common on Mars, too, since the Martian surface displays widespread evidence for volcanism [2] and near-surface water [3]. We investigate fields of pitted cones (yellow symbols in the figure above) in the Nephentes/Amenthes region (NAC) at the southern margin of the ancient impact basin, Utopia (large circles mark Utopia ring perimeters), which were previously interpreted as mud volcanoes [4], and another cone field north of Isidis Planitia in the Arena Colles region, which was previously unknown. Black arrows mark possible extension along the dichotomy boundary. The aim of our study is to test the hypothesis of a (hydro)volcanic origin of these cones.

Morphology



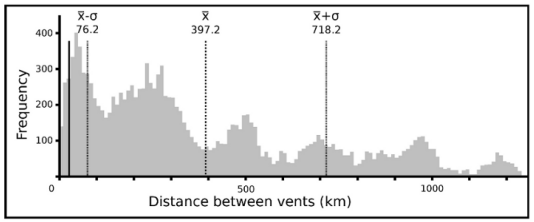
The study area displays >210 cones with texturally smooth flanks and typically wide central craters. Cones are often overlapping each other and forming chaotic clusters. In many cases, the rims of the central craters are breached, and only segments of a full cone are observed. Based on detailed morphological measurements, the investigated cones are ~3 to 15 km wide (mean 7.8 km) and ~30 to ~370 m high (mean ~120 m). The morphology of the cones shown above resembles that of terrestrial tuff cones and tuff rings, although some of them may also be scoria cones.

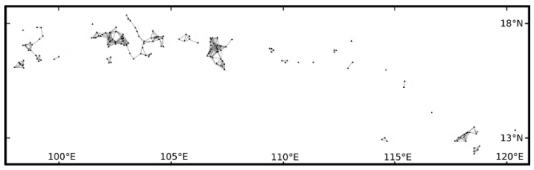
Morphometry

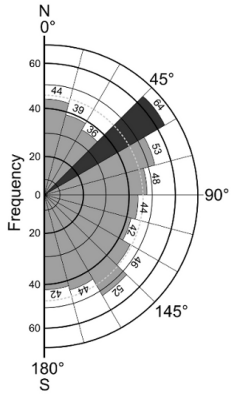


Details of several investigated cones in the NAC field (CTX images). Cones often have well-developed central deep and wide craters (resulting in a large W_{CR}/W_{CO} ratio: median 0.42). The crater floors have elevations that are at the same level or even below the surrounding plains. This is a common characteristics of tuff cone or maar topography, and rarely observed at scoria cones.

Structural control

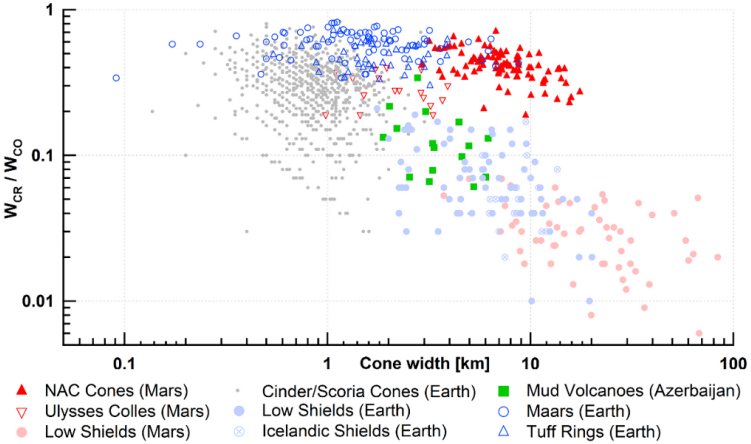






The two-point azimuth technique developed by [5] can be used to identify possible structural trends within a volcanic field. It tests if there is a preferential alignment of points (i.e. vents) along certain orientations [6] and has been previously applied to Mars [7]. The application of the two-point azimuth technique (figure above) did not reveal any dominant trend (see the rose diagram for details), which would indicate significant structural control. However, a weak peak in orientation is visible between 45°N to 60°N. This is quite different from the trend of the Amenthes Fossae, which are oriented between 15°N and 30°N. Therefore, we discard the possibility that the cone orientation would be controlled by a now hidden fracture set with the same orientation as the Amenthes Fossae. We were also not able to detect any link to the formation of Elysium Planitia plains and associated fractures, e.g., Cerberus Fossae).

Comparison with other edifices



The morphology of pitted cones in the NAC region in comparison with several other types of terrestrial and martian volcanic cones, displayed as plot of the ratio W_{CR}/W_{CO} versus the basal width (WCO). Data are shown for the investigated NAC cones and for terrestrial mud volcanoes in Azerbaijan, martian low shield volcanoes [8], martian scoria cones (Ulysses Colles) [9], tuff rings and maars [10] and terrestrial scoria cones [11-12]. In general, the observed morphology, shape and size of the pitted cones in our study area are similar to those of terrestrial tuff cones or rings, except a larger absolute basal diameter. A larger basal diameter of volcanic edifices on Mars as compared to Earth appears to be typical, whatever the edifice type: While the W_{CR}/W_{CO} ratio is comparable for cinder cones, tuff rings/maars, and low shields, the basal diameter is always larger on Mars. Note the difference of the W_{CR}/W_{CO} ratio between pitted cones in the NAC area and terrestrial mud volcanoes.

Results

- Pitted cones along the southern margin of Utopia Planitia share morphological similarities to terrestrial tuff cones and tuff rings.
- Another field with identical landforms was newly detected north of Isidis Planitia in the Arena Colles region, also along the margin of Utopia Planitia.
- Several cones in the impact crater Lederberg in Xanthe Terra (not shown here) share the same morphological characteristics and may suggest that such cones are neither unique nor require unique conditions for their formation.
- A hydrovolcanic origin of these cones appears consistent with the observed morphology and the regional geologic setting (many rampart craters indicate subsurface water/ice). Nonetheless, a formation as mud volcanoes [4] can not be ruled out.

References

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