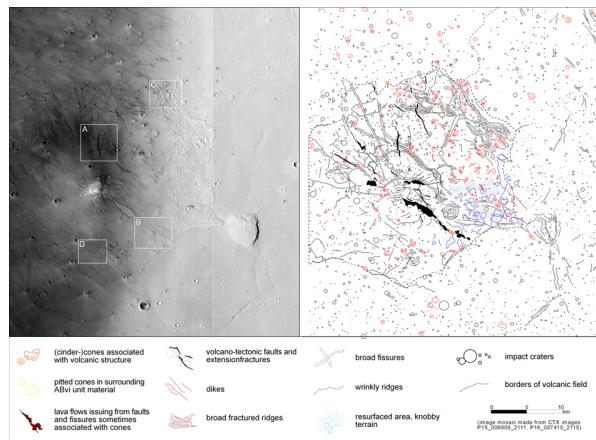


## VOLCANIC RIFT ZONE AND ASSOCIATED CINDER CONE FIELD IN UTOPIA PLANITIA, MARS.

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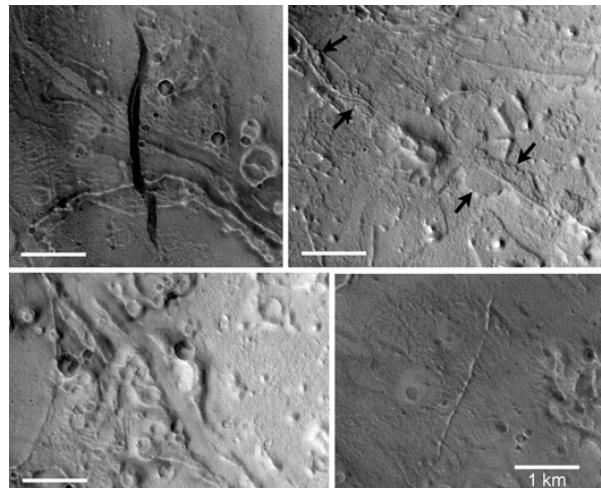
**Introduction:** We have analyzed a small area in SW Utopia Planitia that shows striking similarities to rift zone volcanoes on Earth. The position of the study area is particularly interesting as it lies off any of the volcanic centers of Mars in the northern hemisphere lowlands embedded in Vastitas Borealis Formation (VBF) material. It shows evidence for volcanic activity in the Late Noachian to Early Hesperian that was accompanied, or caused, by localized rifting processes and the formation of an extended cinder cone field. We propose that the area represents part of older lowland surfaces pre-dating the resurfacing by the Vastitas Borealis Formation and that it could be an indicator of volcanic processes and of the type of volcanic activity in the Late Noachian to Late Hesperian in the northern lowlands of Mars.



**Figure 1:** CTX-Image mosaic and map of the study area in Utopia Planitia.

**Geology and morphology of the study area:** The study area lies outside any of the large volcanic centers on Mars over 2.500 km west of the Elysium rise and approximately 2.000 km NE of the Syrtis Major volcanic province. It consists of a heavily eroded central cone with a basis diameter of 4.5 to 5.0 km that is surrounded by numerous considerably smaller pitted cones. The smaller cones are mostly randomly distributed though some cones can be seen to be aligned in chains along prominent fissures (Figure 1). A dense pattern of radial and concentric faults, fissures and narrow ridges surrounds the central cone (Figure 1) with a dominant NW-SE direction. Particularly in the north-northeastern parts of the study area fissures can be seen to cut through older cones and ridged surfaces.

Several flow features issue from discrete sources along the faults and fissures and in some cases they seem to be directly associated to cones aligned along the fissures (Figure 2). Some of these flows are restricted by lateral levees. The observed features end abruptly towards the north approximately 12 to 16 km away from the central cone and more gradually in the southern regions indicating the borders of the study area to the surrounding VBF material. It appears that VBF material covers and surrounds parts of the observed structures and is thus younger than the surfaces and features observed in the study area.

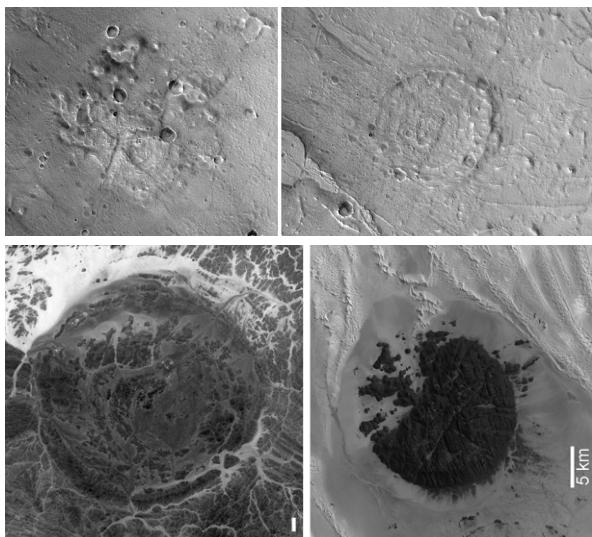


**Figure 2:** Extension fracture crosscutting older fissures (top left); pitted cones aligned along fissure, note lava flows issuing from cones and fissure (top right); small cone cluster cut by younger fissure (bottom left); small dyke oriented radial to the central cone (bottom right).

**Rifting and volcanic activity:** The most striking features are the elongated fissures surrounding and cross-cutting the central cone and the adjacent areas. The fissures are developed as either long and broad features crossing the full length of the study area or as short and narrow linear structures that show lava flows emanating from them. We interpret these structures to be eruptive volcanic fissures that furthermore give testimony of the proposed rifting processes in the study area. The best examples of ongoing extension can be found along the broad fissures as small cones and cone clusters can be seen to have been rifted apart by the fissuring process in several places (see Figure 2).

We interpret most of the pitted cones in the study area to be cinder cones based on the following characteristics. As already mentioned, cones are often associated with fissures either sitting on top of them, being aligned along them, or being rifted apart, indicating that the fissure and cone formation processes were interconnected. Several cones are situated on the slopes of the large central cone (see Figure 1) and there are even several examples where lava flows can be seen to have issued from the cones (Figure 2).

Narrow elongated ridges are oriented roughly radial around the central cone (Figures 1 and 2) though a prominent NW-SE direction is visible. Some of these ridges appear to be the extension of the small narrow fissures described earlier and many ridges lie close and directly parallel to these fissures. Cones are in places associated with the ridges and form cone chains or small clusters along their paths. Their orientation both in radial and in parallel swarms often close to the fissures is typical for dyke intrusions on Earth (e.g. [1]) as well as their resistance against erosion.



**Figure 3:** Multi-ring structures in the study area (top) resembling magmatic intrusions on Earth (bottom left: Jabal Karamaretri, Sudan; bottom right: Air Plateau, Niger).

Particularly interesting in the context of magmatic intrusions are several (multi-)ring structures identified in the study area (Figure 3). They show characteristics of magmatic intrusions on Earth. All identified ring-structures in the study area are small, less than 2-3 km in diameter and lie far below the crater diameters of complex craters on Mars (e.g. [2]). Furthermore, the left ring structure in figure 3 shows radial fractures that are untypical for eroded impact craters. Instead, they are similar to joints formed by cooling processes in terrestrial magmatic intrusions. That they are younger tectonic features superimposed on the older

structures can be ruled out as they show no continuation into the surrounding terrain. The right image in figure 3 shows an irregular, slightly elongated central depression situated a little off the actual center of the structure. Impact craters on Mars sometimes contain a central depression or central pit possibly caused by the presence of ground ice ([3]). However, central pits are usually found in larger complex craters with diameters of a few tens of kilometres (e.g. [3], [4]). The slight offset from the structures centre and the irregular shape of the depression is also unusual for central pit craters on Mars.

**Cratering Ages:** To better constrain the age of activity in the study area we performed crater counts on several geologic units. Stratigraphic correlations already indicate that the study area is older than the surrounding VBF material. Crater statistics of the study area gave ages between Late Noachian and Late Hesperian. That means that the volcanic activity in the study area falls in the same time period during which the highland paterae and the Syrtis Major volcanoes were forming (e.g. [5], [6]). Volcanism in the Elysium volcanic province started in the same time period and continued throughout most of Mars history (e.g. [7], [8], [9]). In combination with stratigraphic correlations that confirms the assumption that the study area represents part of the northern lowland surfaces predating the resurfacing processes that covered the lowland plains.

**Conclusions:** We interpret the combination of features in the study area to be the result of localized volcanic activity caused by rifting processes. Upwelling magma along the rift zone formed magmatic intrusions, dykes and led to localized volcanic activity and the formation of cinder cone fields. Possibly the area is a remnant of more widespread volcanic activity in the northern hemisphere during that period indicating that volcanic activity occurred more globally and was not restricted to the large volcanic centers on Mars.

- References:** [1] Walker, G. P. L. (1999) *Journal of Volcanology and Geothermal Research*, 94, 21-34. [2] Carr, M. H. (2007) *Cambridge University Press*, New York, pp. 322. [3] Barlow, N. G. (2006) *Meteoritics and Planetary Science*, 41, 1425-1436. [4] Barlow, N. G. (2008) *11<sup>th</sup> Mars Crater Consortium Meeting*, abstract #1104. [5] Hiesinger, H., and J. W. Head (2004) *J. Geophys. Res.*, 109, doi:10.1029/2003JE002143. [6] Werner, S. C. (2009) *Icarus*, 201, 44-68. [7] Hartmann, W. K. and D. C. Berman (2000) *J. Geophys. Res.*, 105, 15,011–15,026. [8] Berman, D. and Hartmann, W. (2002) *Icarus*, 159, doi:10.1006/icar.2002.6920. [9] Vaucher, J., et al. (2009) *Icarus*, doi: 10.1016/j.icarus.2009.06.032.