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Rift-zone volcanism and associated cinder cone field in Utopia Planitia, Mars

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Abstract

We have analyzed a small cone field in SW Utopia Planitia that shows striking similarities to volcanic rift zones on Earth. This is of particular interest as the study area lies off any of the volcanic centers of Mars in the northern hemisphere lowlands and is embedded in Amazonian-aged Vastitas Borealis Formation material. The most striking characteristics are (1) a set of broad eruptive fissures showing signs of ongoing extension during cone formation, (2) parallel dike swarms, (3) magmatic intrusions, and (4) a number of lava flows that can be seen to have erupted from the fissures and pitted cones aligned along fissures and dikes. Based on stratigraphic analyses and cratering statistics we believe that our study area might represent a "geologic window" to volcanic activity in the northern lowlands pre-dating the extensive resurfacing by VBF units.

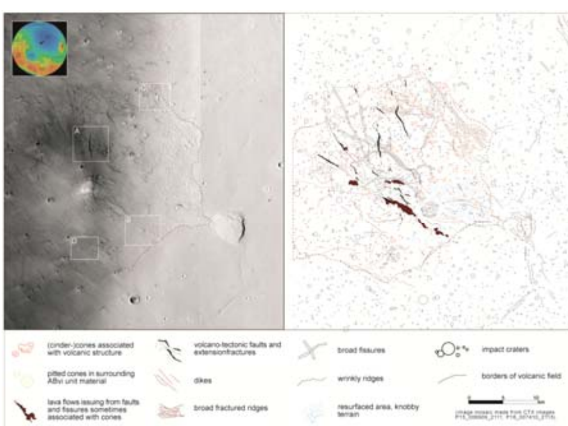

Figure 1: Map of the study area; rectangles A-D indicate positions of close-ups in figure 2

1. Introduction

Our study area lies in southwestern Utopia Planitia at 30.5°N and 262°W (see figure 1) 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 are aligned in chains along prominent fissures (figure 1, 2). A dense pattern of radial and concentric faults, fissures and narrow ridges surrounds the central cone with a dominant NW-SE direction. 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. The observed features end abruptly towards the north approximately 12 to 16 km away from the central cone and more gradual in the southern regions indicating the borders of the study area to the surrounding VBF material.

2. Special characteristics of the study area

2.1 Volcano-tectonic structures

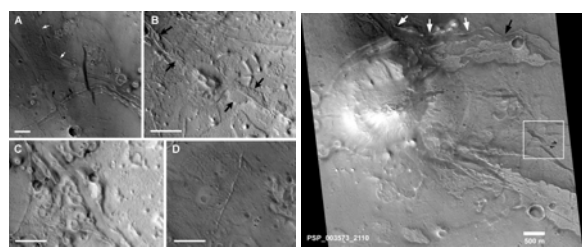

Figure 2: Extension fractures (A), fissures (A-C, right image), aligned cones (B), lava flows emanating from cones and fissures (B, right image), and dikes (D)

The study area shows a dense pattern of cross-cutting volcano-tectonic features indicating ongoing tectonic processes during the volcanic activity. The oldest volcano-tectonic structures are large fissures in the NE and central part of the study area which are cut by younger ridges, fractures and faults (see figure 1, 2). In the NE the fissures cut through fields and clusters of pitted cones. Some of these cones are aligned along the fissures; others can be seen to be rifted apart by the fissuring process (figure 2C).

Several smaller, narrower fissures oriented NW-SE to W-E have short flows issuing from them. We interpret these structures to be eruptive volcanic fissures. Cones superposed on the fissures or being aligned along them are interpreted to be cinder cones. Narrow elongated ridges are oriented roughly radial around the central cone though a prominent NW-SE direction is visible. Cones are in places associated with the ridges and form cone chains or small clusters along there paths. The orientation of the ridges both radial and in parallel swarms often close to the fissures is typical for dike intrusions on Earth (e.g. [1]) as well as their resistance against erosion.

2.2 Magmatic intrusions

Particularly interesting are several (multi-)ring structures identified in the study area (figure 3). They show characteristics of magmatic intrusions on Earth.

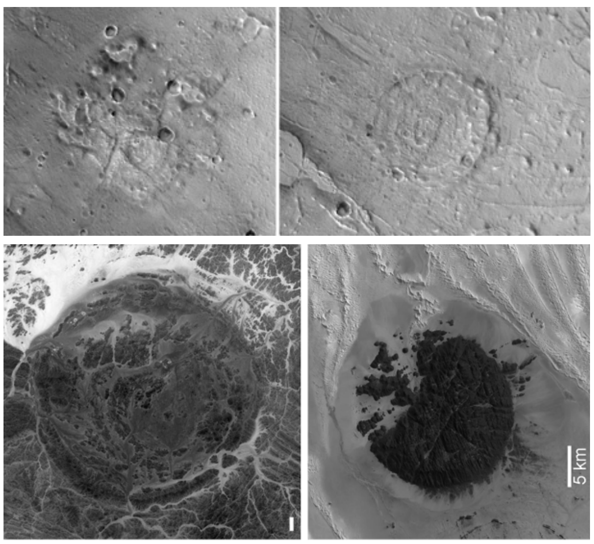

Figure 3: Multi-ring structures in the study area (top) resembling magmatic intrusions on Earth (bottom left: Jabal Karamareitri, Sudan; bottom right: Air Plateau, Niger).

All ring-structures in the study area lie far below the crater diameters of complex craters on Mars (e.g. [2]). There is no indication that the ring-patterns in the study area are due to sedimentary processes as the morphology of the eroded surfaces and the lack of layering speaks against it. The left ring structure in figure 3 (top) shows radial fractures that are similar to joints formed by cooling processes in terrestrial magmatic intrusions. The right image in figure 3 (top) 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 kilometers (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. Based on our observation we therefore believe that the structures could be magmatic intrusions that formed in connection with the rifting processes.

3. Conclusion

The study area shows an assemblage of volcano-tectonic features that is quite unique particularly for the northern hemisphere lowlands of Mars. Large eruptive fissures, dike swarms, cinder cones with erupted lava flows, and possible magmatic intrusions paint a picture typical for volcanic rift zones on Earth. Volcanic rifting is a common trait of terrestrial volcanoes, in fact most volcanoes on Earth have rift zones, characterized by eruptive fissures and underlain by swarms of dikes and other minor intrusions. On Mars, however, rift zones have so far only been described in a much larger scale usually in association with the tectonic centers of the Tharsis region (e.g. [5], [6], [7]). Small scale volcanic rifting in an area far off any of the volcanic centers of Mars could therefore indicate that volcanic processes acted more extensively if not globally giving further constraints for thermal evolution models of Mars.

References

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