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Hydrovolcanic (Tuff?) Rings and Cones on Mars: Evidence for Phreatomagmatic Explosive Eruptions?

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Abstract

We present observations of two fields of small pitted and mostly breached cones; one located along the dichotomy boundary in the Amenthes region (southern Utopia); the second located in an unnamed impact crater in the Xanthe Terra region. The aim of our study is to test the hypothesis of a (hydro)volcanic origin of these cones, which would be an alternative to the mud volcano scenario put forward by [1] for cones in Amenthes region. To aid our analysis, we also examine morphological and morphometrical data of possible terrestrial analogues (tuff rings and cones, mud volcanoes in Azerbaijan).

1. Introduction

Most Martian volcanoes studied so far have been formed predominantly by effusive eruptions [2], although the environmental conditions on Mars (i.e. low atmospheric pressure) should theoretically favor explosive eruptions (e.g. [3]). Despite the predicted abundance of explosive eruptions, only limited observational evidence is available [e.g. 4-6]. In a previous study [7], we suggested that a volcanic field in the Ulysses Fossae region (Tharsis province, Mars) exhibits pyroclastic cones probably formed by "dry" explosive eruptions driven by magma degassing. Since the shallow Martian subsurface contains water ice in varying amounts in wide areas [e.g., 8], and very likely contained even more water and/or water ice in the past, it is reasonable to expect that phreatomagmatic explosions left some evidence of "wet" explosive eruptions in the observable geologic record. Therefore we searched and investigated several promising structures in different areas.

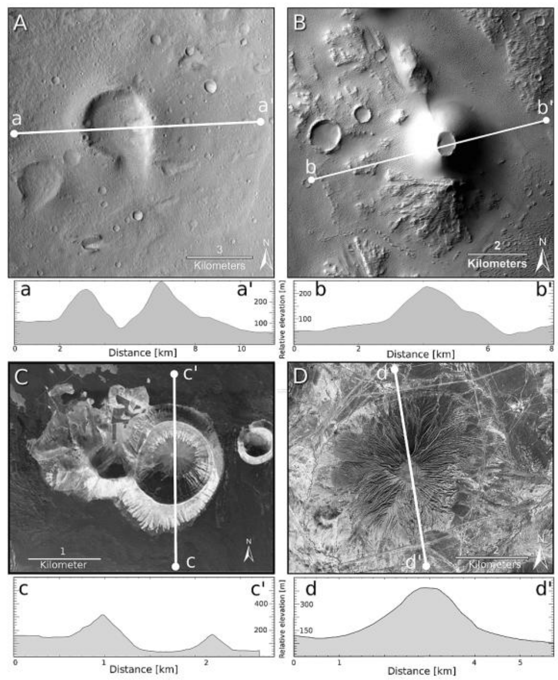

Figure 1: Different types of cones with topographic profiles. A. Investigated cone in Amenthes cone (CTX), B. cinder cone in Ulysses Fossae (from [7]), C. Tuff ring Caldera Blanca, Tenerife and D. mud volcano in Azerbaijan (image from Google Earth).

2. Methology

We used images from CTX, HRSC, and HiRISE;. Topographic information was derived from single MOLA shots and a derived gridded digital elevation model (DEM), and from HRSC DEM. Terrestrial data for comparative analyses were obtained from Google Earth software. Google Earth is using DEM data collected almost world-wide by NASA's SRTM with a horizontal resolution of ~90 m per pixel with a vertical error of less than 16 m.

3. Morphology

The study area in the Amenthes region displays >170 cones, often overlapping each other and forming chaotic clusters widely spread throughout the region. Individual cones are ~5 to 10 km wide and in average 120 m high. Cones often have well-developed, deep and wide central craters (resulting in a large Wcr/Wco ratio: median 0.42). The crater floors have elevations that are at the same level or below the surrounding plains. Cones are often breached, and in several cases lobate flows seem to have emanated from the breached cones and moved gravitationally downslope. High-resolution HRSC DEMs show that flank slopes are typically below 10°, but can reach up to about 20° in the steepest parts.

Another field is represented by cones located along the inner wall of an impact crater in Xanthe Terra. The total amount of cones is lower than in Amenthes cones (we detected 9 cones), however with similar morphology (low relief, height Wcr/Wco ratio and deep central crater). Most of the cones are also breached.

In an attempt to compare the Martian cones with terrestrial analogues, we investigated mud volcanoes in Azerbaijan [1]. We measured 17 cones, and the median for Wcr/Wco ratio is 0.13 (significantly lower than that of the Martian cones of our study areas) and only one edifice has a crater which is 19 m deep. This is distinctly different from the observations of the studied Martian cones (Fig. 1), which often have deep craters reaching down to the level of the surroundings.

4. Summary and Conclusions

While the consistent scenario of [1] can not be ruled out (at least for the Amenthes cones), we note the existence of regional-scale volcanism around the Amenthes field [e.g. 9-11] and morphological inconsistencies between the proposed terrestrial analogues (mud volcanoes) and their Martian equivalents. Therefore, we tentatively propose another scenario: hydrovolcanic cones are consistent with the observed morphology and the regional geologic setting. A contribution of phreatomagmatic explosions to the observed landscape morphology seems possible, which would further contribute to the notion that volcanism on Mars was widespread and morphologically diverse.

Acknowledgements

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