A UNIQUE VOLCANIC FIELD IN THARSIS, MARS: MONOGENETIC CINDER CONES AND LAVA FLOWS AS EVIDENCE FOR HAWAIIAN ERUPTIONS.

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Introduction: Most volcanoes on Mars that have been studied so far seem to be basaltic shield volcanoes, which can be very large with diameters of hundreds of kilometers [e.g., 1] or much smaller with diameters of several kilometers only [2]. Few Viking Orbiter-based studies reported the possible existence of cinder cones [3,4] or stratovolcanoes [5-7], and only the advent of higher-resolution data led to the tentative interpretation of previously unknown edifices as cinder cones [8] or rootless cones [9]. The identification of cinder cones can constrain the nature of eruption processes and, indirectly, our understanding of the nature of parent magmas (e.g., volatile content). Here we report on our observation of a unique cluster of possible volcanic cones situated north of Biblis Patera in Tharsis (Fig. 1). To our knowledge, this is the first ever study of this unique volcanic field. We determine morphometric properties and compare them to terrestrial analogues, and we describe the morphology of the landforms in the volcanic field. Our results suggest that it was formed by Hawaiian-style eruptions.

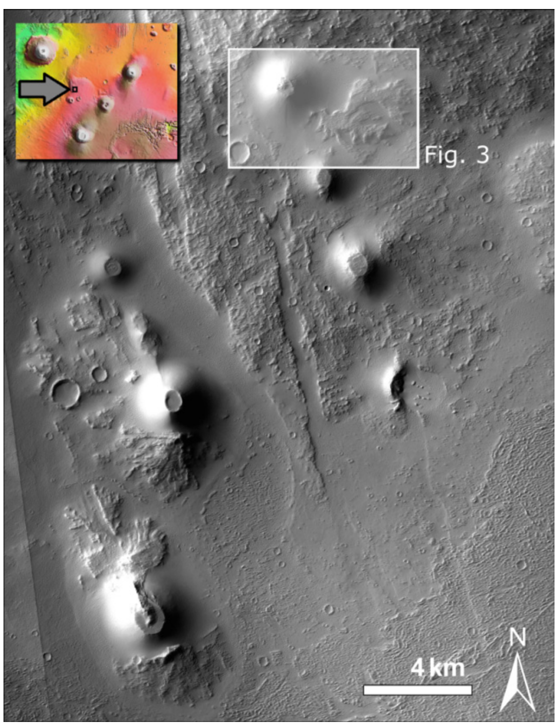

Fig. 1: Several volcanic cones and associated lava flows emanating from these cones (north of Biblis Patera). The distribution of cones is controlled by NW-trending older extensional fault systems (CTX image P19_008262_1862, image center at 5.75°N and 237.1°E).

Data: We use images from several cameras, i.e. Context Camera (CTX), High Resolution Stereo Camera (HRSC), and High Resolution Imaging Science Experiment (HiRISE) for morphological analyses. Topographic information (e.g., heights and slope angles) were determined from single shots of the Mars Orbiter Laser Altimeter (MOLA) in a GIS environment, and from stereo images (HRSC, CTX) and derived gridded digital elevation models (DEM).

Morphometry: For comparison between the cones and terrestrial morphological analogues (i.e. cinder cones [10]) we determined some basic morphometric properties and their ratios (e.g., crater diameter [W_{CR}] vs. basal diameter [W_{CO}]) and their spatial distribution. The morphometry of terrestrial monogenetic volcanic landforms was previously determined [e.g., 3]. In particular, Wood [11] reports the morphometry of 910 cinder cones. Cinder cones on Earth have a mean basal diameter (W_{CO}) of 0.9 km, but can range from 0.25 to 2.5 km. The ratio between crater diameter (W_{CR}) and basal diameter has an average value of 0.4 [11,12], but other studies including cinder cones in different stage of erosion show a lower value for this ratio (see Fig. 2, black line). The height of fresh cinder cones on Earth (H_{CO}) is equivalent to $0.18 \times W_{CO}$ [11,12], however it also has a wide range towards lower values.

We identified 29 cones in different stages of degradation, and we were able to measure the morphometric properties for almost half of them. Differences in cone shape suggest erosional modification.

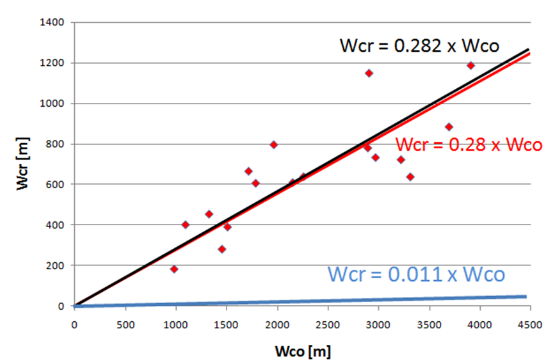

Fig. 2: W_{CR} vs. W_{CO}. Red dots are investigated cones on Mars, red line is best fit of W_{CR}/W_{CO}. The black line is the best fit to measurements of 692 terrestrial cinder cones from several volcanic regions, data from [13-15]. For comparison, the blue line shows terrestrial stratovolcanoes with summit craters after [13].

Our measurements suggest that the cones in our study area have a mean basal diameter of 2,300 m, about ~2.6 times larger than that of terrestrial cinder cones. The W_{CR}/W_{CO} ratio has mean value 0.28. The edifices are also higher (from 64 to 651 m) than terrestrial cinder cones. The H_{CO}/W_{CO} ratio of 0.12, which is less than that of pristine terrestrial cinder cones with a ratio of 0.18. The slope distribution of cone flanks is between 12° and 27.5° (the steepest sections reach >30°), with higher values for well-preserved cones and lower values corresponding to more degraded edifices.

Morphology: In plan view, the cone morphology is characterized by circular to elongated outlines, relatively steep-appearing flanks, and summit craters or plateaus. Some cones are associated with lobate and sometimes branching deposits, which emanate from the summit craters or from some points at or very near the flanks (Fig. 3). We interpret the lobate deposits as lava flows. The association of cones with lava flows distinguishes these cones from other cone fields on Mars, which were mostly interpreted as pseudocraters [9]. The cones and flows are much better preserved than recently detected cones and flows in Utopia [8]. The study area is thickly covered by dust, which hinders a reliable age determination of these small-scale landforms by crater statistics.

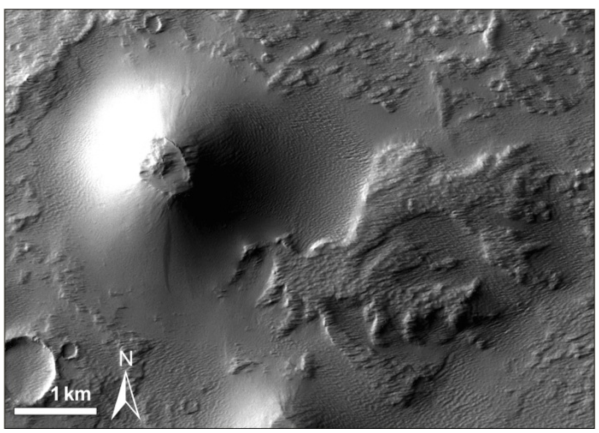

Fig. 3: Cone and associated lava flow originating on the lower flank of the cone, suggesting that it was fed by a parasitic vent (CTX P19_008262_1862; see Fig. 1 for location).

Discussion: Some morphometric characteristics of the cones in our study area suggest an origin as cinder cones. The most striking similarity of the Martian cones and terrestrial cinder cones is the W_{CR}/W_{CO} ratio (Fig. 2). It is clearly distinguished from that of terrestrial stratovolcanoes. Other morphometric parameters, however, are different from terrestrial cinder cones, e.g., the basal diameter and the height. Theoretical considerations predict considerable differences between cinder cones on Earth and Mars (for a given magma volume and volatile content) due to the specific surface environment on both planets, in particular the gravity and atmospheric pressure [16]. Cinder cones on Mars should have larger basal diameters and lesser heights [16,17], and the W_{CR}/W_{CO} ratio should be larger [16]. The larger basal diameters and heights of the cones in our study area could be accounted for by a larger erupted magma volume than for most cinder cones on Earth. The basically identical W_{CR}/W_{CO} ratio is not in agreement with theoretical predictions [16]. Possible explanations are an old age (with a correspondingly thicker atmosphere) or a different volatile content of the magma. The morphology of the cones and associated lava flows is analogous to terrestrial cinder cone fields, and is a typical morphological result of Hawaiian-style eruptions [18]. It is not possible to distinguish between lava flows originating directly from a vent and rootless flows (Fig. 3). Interestingly, however, none of the cone craters is breached by a lava flow, a common situation on Earth [18].

Conclusions: Based on morphological and morphometrical analyses, we interpret an assemblage of landforms in Tharsis as a basaltic cinder cone field. It is surprising that this is the only well-preserved field of this kind seen so far on Mars, given the fact that cinder cones are the most common volcanoes on Earth [11,19]. The evidence for physiological diversity of Martian volcanism is still growing (see also [8]).

References: [1] Plescia J. (2004) *JGR*, *109*, E03003, doi: 10.1029/2002JE002031. [2] Hauber E. et al. (2009) *J. Volcanol. Geotherm. Res.*, *185*, 69–95. [3] Wood C.A. (1979) *Proc. Lunar Planet. Sci. Conf.*, *X*, 2815–2840. [4] Edgett K.S. (1990) *LPS*, *XXI*, 311–312. [5] Greeley R. and Spudis P.D. (1978) *GRL*, *5*, 453–455. [6] Hodges C.A. and Moore H.J. (1994) *Atlas of Volcanic Landforms on Mars*, U.S. Geological Survey Professional Paper 1534. [7] Stewart E. and Head J.W. (2001) *JGR*, *106*, 17,505–17,513. [8] Lanz J. et al. (2010) *JGR*, *115*, E12019, doi: 10.1029/2010JE003578. [9] Fagents S.A. and Thordarson T. (2007) *in:* Chapman M. (ed.) *The Geology of Mars*, pp. 151_177, Cambridge University Press, Cambridge. [10] Settle M. (1979) *Amer. J. Sci.*, *279*, 1089–1107. [11] Wood C.A. (1980) *JVGR*, *7*, 387–413. [12] Porter S.C. (1972) *Geol. Soc. Amer. Bull.*, *83*, 3607–3612. [13] Pike R.J. (1978) *Proc. Lunar Planet. Sci. Conf.*, *IX*, 3239–3273. [14] Hasenaka T. and Carmichael I. (1985) *Geofisica Int.*, *24-4*, 577–607. [15] Inbar M. and Risso C. (2001) *Zeitschr. Geomorph.*, *45*, 321–343. [16] Wilson L. and Head J.W. (1994) *Rev. Geophys.*, *32*, 221–263. [17] Parfitt E.A. and Wilson L. (2008) *Fundamentals of Physical Volcanology*, Blackwell, Oxford. [18] Head J.W. and Wilson L. (1989) *JVGR*, *37*, 261–271. [19] Valentine G.A. and Gregg T.K.P. (2008) *JVGR*, *177*, 857–873.