SMALL-SCALE POST-NOACHIAN VOLCANISM IN THE MARTIAN HIGHLANDS? INSIGHTS FROM TERRA SIRENUM 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: Volcanism was globally widespread on Mars in the early history of the planet, but focused with ongoing evolution on two main provinces in Tharsis and Elysium [1]. On the other hand, evidence for post-Noachian volcanism in the Martian highlands is rare outside some isolated regions (e.g., Tyrrhena and Hadriaca Montes) and, to our knowledge, few, if any, such volcanic edifices have been reported so far. It is generally thought that highland volcanism occurred early in Mars` history and stopped not later than ~1 Ga after planet formation [2, 3]. Several candidate locations were suggested as volcanic centers in western Gorgonum and south-eastern Atlantis basins [4], where extensive accumulations of possible volcanic deposits exist, however, these volcanic centers were not confirmed by later studies [5, 6].

Based on our observations we report several promising edifices in Terra Sirenum that might change this view. The study area is situated south of Gorgonum basin and is about 150x50 km wide. It contains two spectacular cones with outgoing flow-like features and 3 dome-like structures (Fig. 1a).

Data: Images from CTX, HRSC, HiRISE and THEMIS-IR (day and night) were used for this study. Topographic information (e.g., heights and slope angles) was determined from single shots of the Mars Orbiter Laser Altimeter (MOLA) in a GIS environment, and from stereo images (HRSC) and derived gridded digital elevation models (DEM). Absolute model ages were determined from the crater size–frequency distributions, utilizing the software tool ‘cratertools’ [7] and ‘craterstats’ [8] applying the production function coefficients of [9] and the impact-cratering chronology model coefficients of [10].

Geologic setting: The study area is located in Terra Sirenum, where the crust is fractured by ~E-W-trending Tharsis-radial graben systems propagating from Arsia Mons [11] and a series of older, ~N-S-trending faults interpreted as wrinkle ridges [12]. The area was included by [13] as part of the large Eridania paleolake, a possible source for the formation of the Ma’adim Vallis outflow channel during the Hesperian/Noachian period [13, 14]. Based on the spectroscopic detection of phyllosilicates and morphological evidence, Wendt and co-workers [14] concluded that liquid water may have persisted in this area longer than elsewhere on Mars, perhaps far into the Hesperian or even Amazonian period. Hence, our area of interest

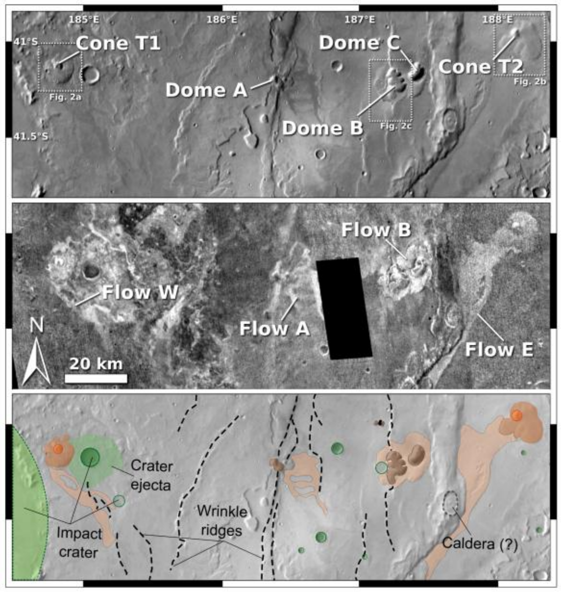

Fig. 1: Themis-IR day-time (upper image), night-time (middle), and interpretational map of the study area. The thermal contrast between the two upper images suggests the presence of flow-like structures associated with cones and domes.

was probably part of the former lake bottom and the observed surface may be relatively young.

Morphology: In the day and night THEMIS images (Fig. 1a, b), several centers of higher thermal inertia are visible. They correspond to two well-developed breached cones (Fig. 2a, b) with outgoing flows partly covering the cones themselves, and three domical structures also associated with flow-like units (Fig. 2c). The cones are situated at the western and eastern margin of the investigated area. Overlapping flow margins suggest a repetitive process of their formation. The edges of the flows seem to be relatively steep, based on MOLA measurements, reaching values between 4° (for eastern cone T_2) up to 20° (for western cone T_1). The flows occurred from the breached cone’s centers. In the central part, three dome-like structures are associated with flows. Two of them are covered by CTX and HiRISE images (Dome B and C), enabling observations of small details. Those two domes stand from 390 m to 530 m above the surrounding plains and have steep flanks with slopes between 17° and 23.5°. The topography also reveals that they do not have a uniform height, which decreases in southern direction. Dome B is superposed on a wrinkle ridge and the south-western edge seems to flow over a short distance in southern direction. HiRISE images reveal that the

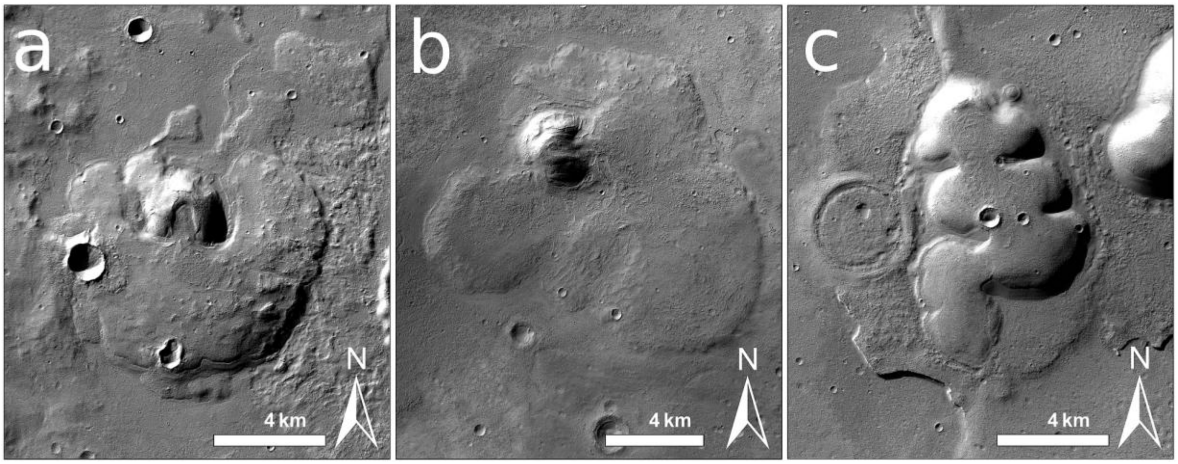

Fig. 2: Two cones (a - Cone T_1, b – Cone T_2) with associated flows and one dome (c – Dome B). See the Fig. 1 for position. Note the significant shadow length on the edges of Cone T_1. CTX images (a - B18_016835_1386_XI_41S175W; b – mosaic of P16_007117_1362_XI_43S171 and B19_016914_1399_XI_40S172W; c - G19_025696_1389_XN_41S172W).

investigated edifices together with their associated flows are composed of boulders up to several meters large and are partly covered by eolian deposits forming small dunes. The Cone T_2 displays a small central elongated plug from where the flows originated. There is a significant scarp with vertical offset around 80 m situated at the southern margin of Dome B. A similar scarp, however with lower vertical offset, is also seen at the southern edge of Dome C. There is no visible talus composed of large boulders at the foot of these scarps. The exposed material is layered and shows signs of ongoing erosion. Preliminary age determinations based on crater counting suggest that the cones (Fig. 2a, b) were formed at 0.5 to 1 Ga.

Discussion: Based on our observations and the similarities to terrestrial obsidian flows, we interpret these features as probably volcanic in origin and post-Noachian in age. The observed cones may represent Martian small-scale volcanic cones with outgoing lava flows, but they are different in morphology to previously observed Martian cinder cones [15, 16] or tuff rings/cones [17]. The flows associated with cones have steep edges; in strong contrast to basaltic flows in Tharsis that typically display low relief and very gentle slopes. The observed domes seem to be unique; both with respect to this region as to global Mars. They do not share similarities with other observed edifices in the former area of the Eridania lake, where several processes modified the surface over time (e.g., aqueous erosion and/or deposition, aeolian, periglacial and glacial). However, these domes partly share some similarities with domical structures in Arcadia Planitia, interpreted by [18] as magmatic cryptodomes or extrusive lava domes formed by felsic lava. Spectroscopic investigations of Arcadia's cryptodomes support their volcanic origin. Several domes in Arcadia display spectral absorptions consistent with the presence of olivine and high-Ca pyroxene, nominally augite [19], suggesting a basaltic composition.

Conclusions: We identify small-scale volcanic edifices in the southern highlands of Mars with a relatively young age. The steep-sided morphology suggests that highly viscous lava formed them. If so, volcanic edifices composed of evolved magmas may not only be present in the northern lowlands [16], but also in the 'middle of nowhere': in the southern highlands far away from any known volcanic centers. We currently have no explanation why such evolved volcanism might have occurred in those regions and such magmas were generated. But our finding may expand our knowledge about evolved magmas on Mars, which seem to be more widespread than previously thought [20, 21, 22]. Therefore, the explanation for cryptodomes in Arcadia Planitia as proposed by [19] may also be valid here, i.e. magma viscosity might have been increased by magma degassing and/or a high degree of crystallization in the magma. Further investigations are needed in this field, and the cones and flows in Terra Sirenum might represent ideal candidates for spectroscopic observations.

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