MARTIAN NORTH POLAR CONICAL MOUNDS: A REASSESSMENT OF THE VOLCANIC ORIGIN HYPOTHESIS. N. H. Warner[1] and J. D. Farmer[1], [1]School of Earth and Space Exploration, Arizona State University, P.O. Box 871404, Tempe, AZ 85276-1404

Introduction: Modification of the surface terrain within the northern plains and north polar cap of Mars is currently dominated by aeolian processes [1,2,3,4]. Other surface modification mechanisms, including fluvial, glacial and volcanic processes may have further contributed to near-polar morphology. [5] first suggested a volcanic origin for the large polar chasmata, including Chasma Boreale, a large re-entrant in the Martian north polar cap. In this model, melting of the base of the ice cap from volcanism or cap overburden pressure may have undermined the layered material causing collapse, catastrophic outflow, and erosion.

While obvious volcanic landforms are absent at the heads of the polar chasmata, volcanic-like conical features do occur near the mouth of Chasma Boreale and within two smaller chasmata located west of Chasma Boreale (Fig. 1) [6,7].

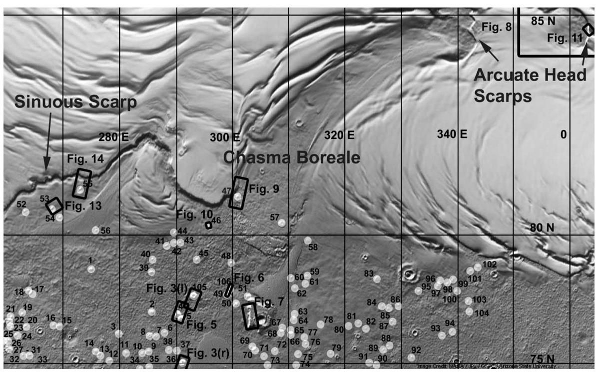

Fig. 1: MOLA shaded relief map (64 pixels/degree) of the Mars north polar region showing locations for near polar conical mounds identified in this analysis.

Although a genetic relationship between the volcanic-like conical mounds and the north polar chasmata has never been directly suggested, the proximity of possible youthful volcanic landforms to the water ice-rich polar cap has important implications for the polar cap basal melting hypothesis.

In this study we combine MOLA topographic data with the most recent high resolution imagery from the Thermal Emission Imaging System (THEMIS) (20 – 40 m/pixel), the Mars Orbiter Camera (MOC) (1.5 – 6 m/pixel), and the High Resolution Imaging Science Experiment (HiRISE) (~30 cm/pixel). The region centered at the mouth of Chasma Boreale (80° N, 310° E) was chosen because of the presence of putative volcanic landforms identified by previous workers [6, 7]. In addition, in this area we have identified many previously undescribed conical mounds that have broadened the basis for our investigation (Fig. 1). The primary question we ask is: What is the origin of these conical mounds and what is their relationship to the morphologic evolution of the region?

Methods: Mound forms were identified and mapped using THEMIS, MOC, and HiRISE imaging data. Once the mounds were identified, MOLA topographic profiles were constructed in four directions across each object, E-W, N-S, NE-SW, NW-SE. The java-based GIS program JMARS [8] was used to create MOLA data profiles with spatial resolution of 64 pixels/degree. The values from each of the four profiles were averaged and used to compare the mounds to terrestrial volcanic forms, sediment extrusion features, and Martian impact craters based on the morphologic metrics presented by [6]. Imaging data was analyzed further to understand the relationship of these features to the local polar geomorphology.

Results: Within this region, 106 mounds, were identified and measured, most located within the northern plains unit mapped as Hesperian-aged Vastitas Borealis (Hvg) formation [3]. A handful of mound-shaped features were mapped within Chasma Boreale proper and within two adjacent smaller polar chasmata. Mound heights range from 10 – 610 (+/- 1) m, basal diameters from 2.7 – 20 (+/- 0.73) km, and flank slopes from 0.4 – 12.8°. Steep sided silicic domes, composite cones, and scoria cones whose flank slopes typically approach 30° [9] can easily be excluded as an analog for the Martian mounds.

A majority of the Martian mounds are < 100 m in height and have flank slopes < 2.0°. Important outliers exist beyond this range including mound 36 and mound 105, which have relatively large diameter (7 - 10 km) summit craters. A reconstruction of the [6] plot of flank slope vs. volume/diameter is presented in Fig. 2.

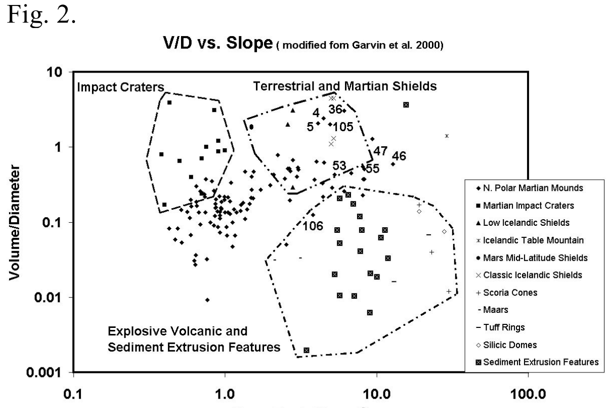

Fig 2: Volume/diameter vs. flank slope plot after [6] displaying morphologic data for a wide variety of Martian and terrestrial features including the 106 mounds and terrestrial sediment extrusion features.

This plot isolates impact crater morphologies from terrestrial volcanic forms, including small shields, cones, and domes. Data from the 106 Martian mounds and terrestrial sediment extrusion features were added for this analysis. A majority of the Martian mounds plot between the fields identified by [6]. Only four objects, including mound 106, are within the field for explosive volcanic features and sediment extrusion features. The remaining mounds fall within either the small shield volcano class, or the impact crater class even in most cases despite the lack of summit craters.

Discussion and Conclusions: Mounds 4, 5, 36 and 105 fall within the morphologic range of small Icelandic terrestrial shield volcanoes (Fig. 2). Mounds 4 and 5, located proximal to mounds 36 and 105, were not initially identified by [6]. A THEMIS image taken across mounds 4 and 5 shows that they are non-circular, relatively flat topped, and are comprised of obvious horizontally layered units, including a resistant cap layer (Fig 3). The capping unit exhibits a polygonal form suggestive of fracture controlled mass wasting consistent with the polygonal fracture pattern of the underlying Hvg formation. Closer examination of mound 36 also reveals the presence of meter scale horizontal layering on its flanks.

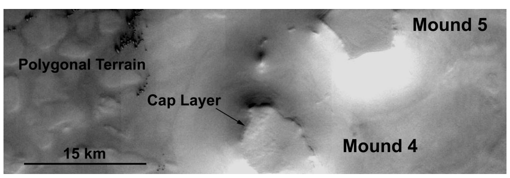

Fig. 3: THEMIS image V11262001 of mounds 4 and 5. These features fall within the shield volcano field on the Garvin et al. (2000) morphologic plot.

Despite the morphologic similarities of mounds 4, 5, and 36 to terrestrial volcanic landforms the visual observations of horizontal layering, capping units, and non-circular polygonal forms are inconsistent with a volcanic origin. Rather, these features share a layered appearance consistent with the northern plains layered materials and may therefore be remnants of a once much thicker and laterally continuous sequence. Further, given the placement of these non-volcanic features within the shield volcano field of the [6] plot, our analysis indicates that the morphologic metric of flank slope vs. volume/diameter is unable to distinguish volcanic landforms from erosional remnant conical forms.

The origin of conical forms identified in this analysis within the explosive volcanic field on the [6] plot is also suspect. Terrestrial sediment extrusion features, such as mud and sand volcanoes, share similar morphologic characteristics to terrestrial scoria cones, maar craters, and tuff rings [10, 11] and plot within the same field as explosive volcanic forms (Fig. 2).

Exposures of layered material are ubiquitous throughout the northern plains [3] and are obvious along the flanks of the majority of conical mounds. We suggest that the mounds located in this region of the northern plains are erosional remnants of north polar layered material and not volcanic landforms. Specifically, mounds located proximal to the PLD and the mouth of Chasma Boreale are more likely remnants of the PLD that have been isolated by northward retreat of polar scarps. Long-term polar scarp retreat by wind erosion was suggested by [2, 4] to explain the mechanism of chasma formation and may have also facilitated the stranding of isolated conical mounds on the plains surrounding the polar cap. At several locations along the margins of the cap, including along the steep sinuous scarp associated with Chasma Boreale, irregular scarp retreat has resulted in the formation of conical promontories along the scarp rims that under continual retreat become isolated from the PLD.

Retreat of the PLD and isolation of mound forms appears to be a process that has operated pervasively in the past and is likely currently operating at several locations throughout the cap. Figure 4 is a HiRISE image at 31.8 cm/pixel displaying a small conical mound located at 84.4° N, 142.9° E in the basal sequences of the PLD. In this instance, the mound has not detached from the polar scarp layered sequences. Continuation of aeolian erosion and retreat along the front will isolate the mound leaving behind a volcanic-like conical landform.

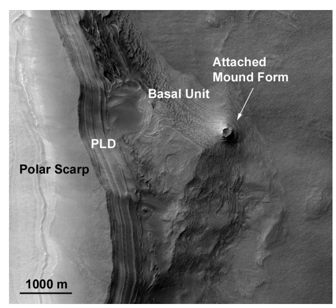

Fig 4: HiRISE image PSP_001548_2755_RED (NASA /JPL/University of Arizona) displaying retreat of layered material and formation of a near polar conical mound.

References: [1] Greeley, R., N. Lancaster, S. Lee, P. Th mas (1992), in *Mars*, 730 – 766. [2] Howard, A. (1980), *NASA Tech. Memo*., 82385, 333 – 335. [3] Tanaka, K.L. J.A. Skinner, T.M. Hare (2005), Map 2888, *U.S. Geol. Surv. Sci. Invest. Map.* [4] Warner, N. H., Farmer, J.D., (2007), *Icarus,* doi:10.1016. [5] Clifford, S. (1987), *J. Geophys. Res.*, 92, 9135 – 9152. [6] Garvin, J.B., S.E.H. Sakimoto, J.J. Frawley, C.C. Schnetzler, H.M. Wright (2000), *Icarus*, 145, 648-652. [7] Neukum, G., S. van Gasselt (2006), *Geophys. Res. Abstracts*, 8, 11103. [8] Gorelick, N. S., M. Weiss-Malik, B. Steinberg, S. Anwar (2003), *34th LPSC,* 2057. [9] Garvin, J. B., R. S. J. Williams (1990), *Geophys. Res. Lett.,* 17, 1381–1384. [10] Zimanowski, B. (2001), in *From Magma to Tephra*, pp. 25-50. [11] Krastel, S., V. Spiess, M. Ivanov, W. Weinrebe, G. Bohrmann, P. Shashkin, F. Heidersdorf (2003), *Geo-Mar Letters*, 23, 230 – 238.