TOPOGRAPHY OF SMALL VOLCANOES AT THE MARGIN OF THE MARS NORTH POLAR CAP

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Introduction: Putative volcanic craterforms have been observed in the north polar region of Mars since Mariner 9. Hodges and Moore [1,2] described some of these features for the region they called the "Borealis Volcanic Field", and suggested that several were formed as a consequence of magma-ice or magma-water interactions. Mars Orbiter Laser Altimeter (MOLA) [1,2] topographic measurements confirm suggest that the features are unlikely to be of impact origin, and that there are many more of them present around the north polar cap than suspected from images alone. Analysis of one of the larger features—suggested by Hodges and Moore [3, 4] to represent a hydromagmatic explosion crater or maar—showed topographic characteristics more similar to a terrestrial small basaltic shield volcano [5, 6], possibly of recent origins. Recent work with the MOLA topography has also suggested that the possible volcanic extent of the Borealis Field is substantially larger in both number and range than previously mapped [5, 6, 7, 8]. Since the majority of these features are within 100 km of the present edge of the northern residual polar cap, and several extend into the Chasma Boreale cap re-entrant, they are some of the best Mars candidates for possible magma-water or magma-ice interactions. However, so far, these features have not displayed the expected average slope or other characteristics predicted for martian hydrovolcanic features, or even martian explosive volcanic features. Here, we show some of the range of feature types observed in the topography, along with their characteristic topographic measurements, and compare them to terrestrial and martian volcanic features.

MOLA Observations: Figure 1 shows a few of the volcanic features identified by Hodges and Moore [1, 2], as well as the many more revealed in the topography (and difficult if not impossible to see in the Viking Imagery). In Figure 1, the feature labeled "B1 MCC" is the cratered cone suggested on the basis of MOLA topography by Garvin et al., [5, 6] to be evidence of possible recent shield volcanism, rather than then maar or tuff cone suggested earlier [1,2]. The features in this Figure are all in the Vastitas Borealis Formation [8], and range from 1.5 to over 20 km in diameter, and from tens of meters to about a km in height. Average flank slopes range from ~1 to 7 degrees, and most of the features display a summit depression.

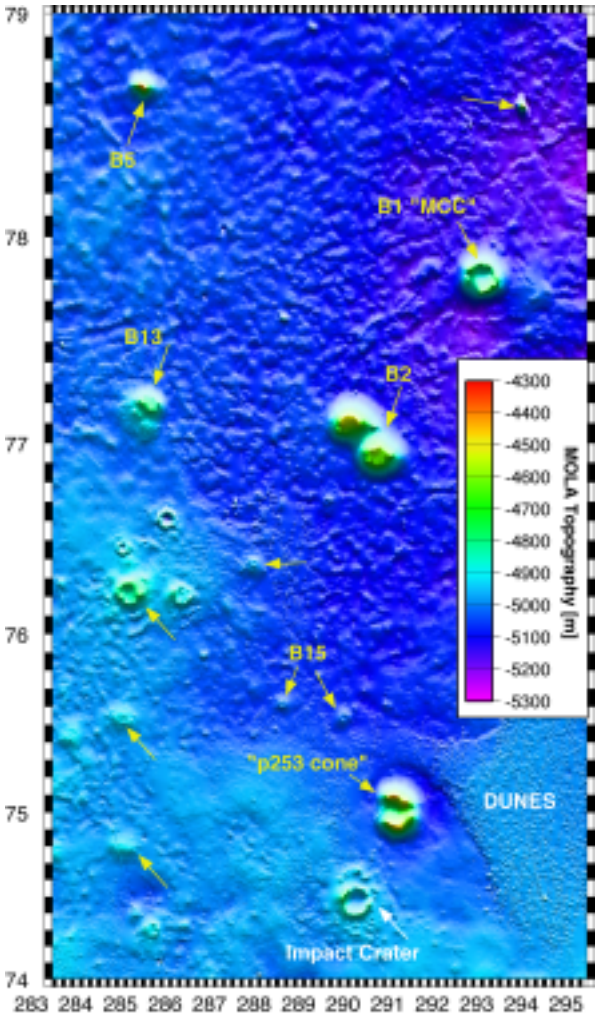

Figure 1. MOLA High-resolution digital elevation model of a portion of the Borealis Volcanic Field. Features marked B1, B2 were previously identified in Viking images as possible volcanic features [1,2]. Yellow arrows indicate many of the probable volcanic features apparent in the topography [5]. The pair indicated as "B15" is shown in profile in Figure 3. (For scale, grid is ~300 km top to bottom)

For all of the features so far examined closely in Figure 1, the slope break is gradual between the edifice and the surrounding plains, suggesting a lack of burial of the edifice base. Impact craters (one indicated at the bottom of figure 1) are noticeably lacking in comparison with the remainder of the Vastitas Borealis Formation.

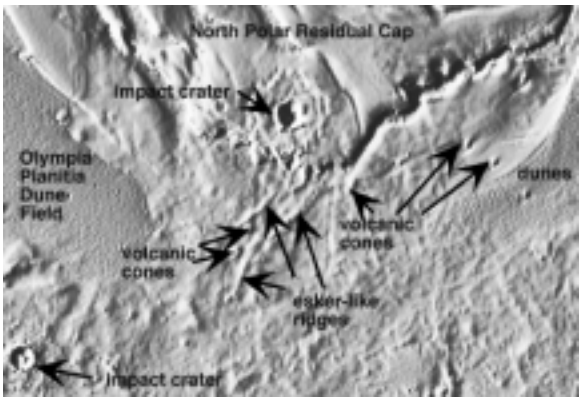

Figure 2. MOLA High-resolution digital elevation model (shown as shaded relief) of a portion of polar cap margin near the Olympia Planitia Dune Field.

Figure 2 shows another portion of the residual cap margin, this time outside the regions with previously mapped volcanics. Here, several cratered cones are apparent amongst several esker-like ridges similar to those suggested by Head [10] to be Eskers near the south polar cap. On the basis of their topographic morphology, we suggest that these cones are also volcanic [7], with flank slopes of a few degrees. To the West of these in the Olympia Planitia dune field, there are nearly a dozen more small cones and cratered cones partially buried by the dunes. It seems plausible that these may be of volcanic origins also.

Conclusions: We can now observe dozens of cones, cratered cones, and apparent breached or collapsed cones within 100 km of the Martian northern residual polar cap. Our topographic measurements suggest that these are very unlikely to be impact craters. With slopes ranging from 1–7 degrees, they are also less steep than predicted for explosive martian volcanic constructs (e.g. [9]), and do not display the characteristic slope breaks expected for table mountains or tuyas[11]. Summit craters for all examined so far have bases well above the surrounding terrain. Morphologically, they are similar, but not identical with the mid-latitude martian shield volcanoes cited as textbook examples of extrusive volcanism [4, 5, 6, 7 based on our current knowledge of eruption mechanics on Mars and the morphology of resulting edifices,], we suggest that that the majority of these features are extrusive basaltic edifices. Alternatively, and equally plausible, is the possibility that we are seeing the effects of water or ice on basaltic volcanism in ways we do not yet understand for Mars. Possibly slow extrusion into a northern ocean such as that suggested by [12], or some more subtle effect that perhaps modifies the resulting edifices but leaves them more similar to basaltic and martian mid-latitude extrusive shields than to terrestrial explosive eruptive products or predicted martian ones. We have undertaken preliminary models, but cannot yet explain the topography observed.

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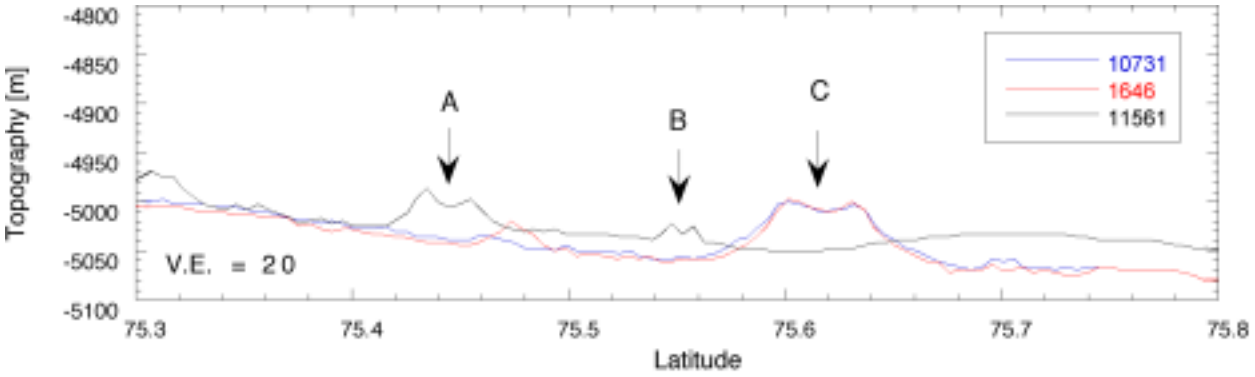

Figure 3. MOLA topographic profiles for several of the smallest cratered cones in the northern near-polar regions. Feature A has a diameter of 3.6 km, and a height of 45 m, Feature B has a diameter of 1.5 km, and a height of 20 m, Feature C has a diameter of 7.2 km, and a height of 65 m. MOLA pass numbers are indicated in the upper right. For scale, one degree of Latitiude is about 60 km. Vertical Exaggeration is 20.