

**SMALL MARTIAN NORTH POLAR VOLCANOES: TOPOGRAPHIC IMPLICATIONS FOR ERUPTION STYLES.** S. E. H. Sakimoto<sup>1</sup>, J. B. Garvin<sup>2</sup>, B. A. Bradley<sup>3</sup>, M. Wong<sup>4</sup>, J. J. Frawley<sup>5</sup>, <sup>1</sup>UMBC at NASA's GSFC, Geodynamics Branch, Code 921, Greenbelt, MD 20771; sakimoto@core2.gsfc.nasa.gov, <sup>2</sup>NASA HQ, Office of Space Science, Code SR, Washington DC 20546-0001; garvin@core2.gsfc.nasa.gov, <sup>3</sup>Caelum at NASA's GSFC, Geodynamics Branch, Code 921, Greenbelt, MD 20771; beth@core2.gsfc.nasa.gov, <sup>4</sup>Department of Geological Sciences, University of California, Santa Barbara, CA, 93106; wong@geol.ucsb.edu, <sup>5</sup>Herring Bay Geophysics, Raytheon-STX, at NASA's GSFC, Code 921, Greenbelt, Maryland 20771; hbgjff@avalon.gsfc.nasa.gov.

**Introduction:** The Mars Orbiter Laser Altimeter [1] has revealed numerous small (<50 km diameter) volcanoes in the polar and mid-latitude regions of Mars that are not documented in Viking Image data [2,3,4,5]. For the northern polar regions, the actual number of volcanoes may be 1-2 orders of magnitude greater than the Viking number [3]. Recent work suggests that at least a few of the Mars polar edifices may be geologically recent (tens of millions of years) [2]. This plus the proximity to the current polar cap makes these newly discovered edifices interesting prospects for possible volcano-water or volcano-ice interactions. This study has two goals: 1) To help characterize the geometric parameters of the newly discovered edifices, and 2) to compare those parameters to those predicted by both effusive and explosive volcanic models in order to constrain their eruption styles. Preliminary results indicate that the polar edifices significantly differ from mid-latitude edifices in flank slope, summit crater size, and other parameters.

**Methods: Geometric Measurements:** High resolution Viking images, MOLA profile data, and MOLA gridded topography data are simultaneously used to identify and map the prospective volcanic features [e.g. 3-6], and identify center MOLA passes for geometry measurements (after [2]), which include average flank slope, crater size, surface area, volume, basal diameter, and other parameters. Additionally, basal diameters and crater sizes were also measured from high resolution Viking images and MOLA gridded topography.

**Modeling:** We compare geometry measurements to several model results. These include the Wilson and Head [7] predictions for extrusive volcano aspect ratios on Mars (a simple gravity scaling), and a percolation model predicting volcano shapes (also scaled for gravity) after Lacey et al. [8], that fits a similarity solution to edifice flank slopes to yield a volcano reference height of combined flow rate, flow viscosity,  $g$ , permeability, and density ( $hr = 0.673(\mu Q_0/k\rho g)^{1/2}$ ).

**Results: Geometric Measurements:** Many of the geometric measurements show clear differences between martian mid-latitude and polar volcanoes, as well as between martian and terrestrial volcanoes. In some cases, the polar volcanoes have a possible latitude-dependent trend as well. Fig. 1 shows a relatively

simple parameter—the ratio of summit crater diameter to basal diameter—that Pike [9] measured for numerous martian and terrestrial volcanoes. Unlike Pike, we find that this simple ratio is *not* the same for terrestrial and martian volcanoes [5], as the new topography data shows that Pike' basal diameter measurements likely included only the steep summit regions [5]. However, it is interesting to note that there is an apparent latitude dependence of this ratio for polar edifices. Since this ratio is not always a good indicator for terrestrial volcano eruption styles, we turn to other parameters for eruption style constraints.

Fig. 2 shows the volume to basal diameter ratio (volcano productivity [2]), vs mean flank slope. As is described in the caption, martian impact craters, terrestrial volcanoes, and martian volcanoes are plotted here. While we do not have this parameter measured for as many edifices as shown in Fig. 1, Fig. 2 suggests that this parameter is useful in separating the terrestrial explosive features from the effusive ones, and that the few points we have for known martian effusive or explosive features in the well-imaged mid-latitudes are widely separated on this plot.

**Modeling:** Figures 2 and 3 show some of the modeling results. Fig. 2 shows range of flank slopes for terrestrial shields (blue hashed region) and predicted martian (red hashed region) shield volcanoes based on [7]. For this model, the predicted flank slopes match only for the mid-latitude martian shields, and not the majority of the polar features. Fig. 3 shows centerline MOLA topography profiles and percolation model flank slope fits for seven martian volcanic edifice examples. Features F and G are mid-latitude shield and explosive edifices, respectively, and features A to E are polar volcanic edifices shown from highest latitude to lowest. In general, the model fits are good matches for the flank slopes. This model has a weak singularity at the center, and the fit deteriorates there. However, while the shapes are well fit, suggesting that these are indeed volcanoes, the prediction that these edifices should be, on average a factor of 1.6 [7,8] (the scaled gravity) shorter for the same given diameter than their terrestrial extrusive and explosive counterparts is not the case except for some of the mid-latitude shields.

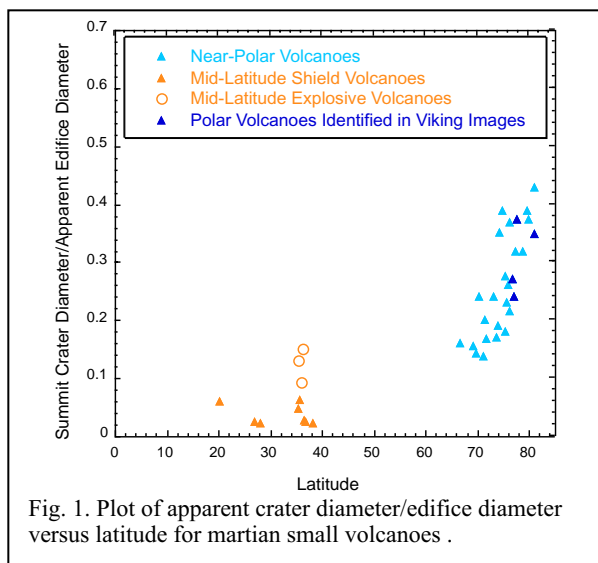


Fig. 1. Plot of apparent crater diameter/edifice diameter versus latitude for martian small volcanoes .

**Discussion:** Both models suggest that martian mid-latitude shields are closer to our predicted geometry and shapes than the polar edifices are. This, plus the possible latitude-dependent trend in Fig. 1 raise the interesting possibility that the polar features are systematically affected by ambient volatiles, and that this effect increases towards the pole. It is not clear, given the polar features' location in Fig. 2, if this possible greater involvement of volatiles in edifice formation has completely changed the eruption style or simply modified it. It is interesting to note that work by Wilson and Head ([7], and others) so far predicts that explosive martian volcanic features should have slopes  $>10^\circ$ , which is not the case for those martian features in figures 1-3, even for the best-known explosive candidate in Tempe. Further work will add observations and model fits in the 40N-65N data gap, to see if there is a data continuum or simply two intersecting trends in parameter versus latitude plots like that of Fig. 1, and to explore alternate explosive, or mixed explosive/effusive models, which we have started to do.

**Conclusions:** while our model fits do suggest that the newly detected features in the mid-latitude and Borealis fields are very likely volcanoes, it is not yet clear where the polar volcanoes fit along the spectrum

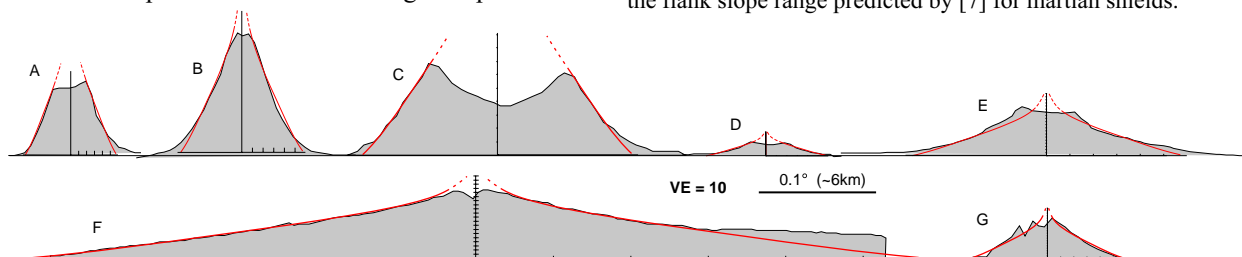


Figure 3. MOLA Topographic profiles (black lines with shading underneath) with model fits (red lines) for 7 examples of small martian volcanoes. Features A-E are polar edifices in order of decreasing N. Latitude, features F and G are mid-latitude volcano examples. Feature F is a Tempe Mareotis shield volcano, and feature G is Tempe volcano, a probable explosive volcanic feature. All features are shown at the same scale (6 km scale bar at center), and at a vertical exaggeration of 10.

of eruption styles, or why both mid-latitude and polar volcanoes do not follow the simpler gravity scaling arguments and models. However, suggestions of a possible latitude-dependent trend in the geometry parameters hints that martian volatile distribution in the subsurface may play a significant role.

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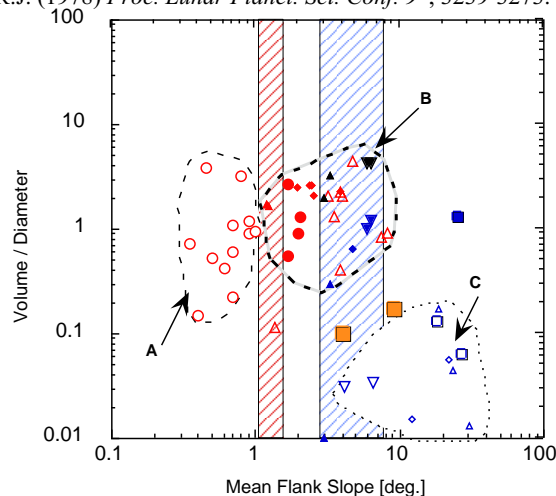


Figure 2. Volcanic productivity (edifice volume/diameter) versus mean flank slope for polar impact craters (group A), terrestrial explosive volcanic features (group C), and martian and terrestrial shield volcanoes (group B). Group B includes terrestrial shields (blue solid symbols), martian mid-latitude shields (red triangles), martian volcanic domes (solid red circles), terrestrial shields scaled to mars (black filled symbols) and martian polar cratered cones (red open symbols). The blue square is a Icelandic tuya (table mountain), and the filled orange symbols are mid-latitude martian explosive edifices. The cratered cone to the lower left of the cluster is a very small one, and may not have enough laser shots to measure correctly. Blue hashes indicate the flank slope range common for terrestrial shields, and the red hashes indicate the flank slope range predicted by [7] for martian shields.