# FORMATION CONSTRAINTS ON MARTIAN NORTH POLAR VOLCANIC EDIFICES.

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**Terrestrial Subglacial Volcanism:** Many terrestrial subglacial volcanic features have been identified in Iceland [1-3], British Columbia, Canada [4], the Tuva Republic, Russia [5], Alaska [6], and Antarctica [7]. These features are though to follow a typical sequence of events although interpretations and details may differ by author and/or location: a single volcanic vent or short fissure opens under an ice sheet [8] releasing hot, magmatic gas which begins to melt the overlying ice, creating a subsurface lake of meltwater [8,9]. If the hydrostatic pressure is sufficiently higher than the gas pressure, pillow lavas form beneath the ice [10,11]; if the hydrostatic pressure is low relative to the magmatic gas pressure, then the erupting magma fragments into hyaloclastite due to the rapid heat transfer between the magma and ice [12]. Hyaloclastite layers build on top of the pillow lavas causing the edifice to near the surface of the ice, which drastically reduces the hydrostatic pressure from the overburden of lake water and ice; the gas in the magma expands, meltwater seeps into the vent causing steam explosions, and the eruption enters into an explosive phase producing greater amounts of hyaloclastites [8,11 and forming moberg subglacial cones or ridges [3]. When the edifice emerges from the lake and ice, further effusive activity produces flat, cap-rock lavas and effectively forms a tuya (stapi in Icelandic) [3,8,11].

**Martian Subglacial Volcanism:** Identification of subglacial volcanism on Mars is more difficult than on earth due to resolution of satellite data as well as the lack of a stratigraphic column necessary for unequivolcal confirmation. However, despite the obvious obstacles, many possible subglacial features have been noted in various regions of Mars including Acidalia Planitia [8], Utopia Planitia [11,13], Valles Marineris [14,15], the south polar region [9,16,17] and the north polar region [16,18].

**Motivation and Data:** This study focuses on possible volcanic features in the north polar region of Mars in an effort to constrain their formation mechanisms and to estimate the thickness of a former possible ice-sheet. NASA works on the assumption that both water and energy sources, such as heat, are necessary for life [19], and this study considers both as the interaction between volcanoes and ice. Using MOLA, THEMIS, and HiRISE data, we conduct topographic characheristic analyses of 109 putatitve volcanic edifices in the Borealis Volcanic Field (Fig. 1) within 69º-81ºN and 197º-330ºE. As it is rarely possible to identify rock types on Mars such as palagonite or hyaloclastite, we are limited to the use of topography data and images alone in our study, thus we use similar available data for Iceland. We examine 21 Icelandic volcanoes of subglacial and postglacial origin using Digital Elevation Models (DEMs) as well as limited differential GPS data. Using the Icelandic data for comparison, we suggest by analogy that many of the features in the Borealis Volcanic Field were likely formed subglacially; we use these data to estimate an ice-sheet thickness for the area. In addition, we took a small sampling of martian volcanoes in Tempe Terra and the equatorial region, as well as re-examining the south polar edifices analyzed by Ghatan and Head, 2002 [9] to use as further comparison.

**Preliminary Results:** There are significant latitude dependencies for the Martian edifices. First, we find that the average flank slope increases with distance from the equator (Fig. 2a); however, it should be noted that those edifices sampled nearer the equator are very low-slope shields and it is possible that there are higher-slope edifices in the area. We also find that the normalized summit crater diameter ($D_{crater}/D_{basal}$) increases with distance from the equator (Fig. 2b); this is especially true with the north polar edifices, which tend to have a higher ratio than those from the South Pole. However, we also find that within the north polar region itself, the data shows a decreasing ratio trend with increasing latitude (Fig. 2c). Finally, we find that the Volcanic Productivity Index ("VPI", $V_{edifice}/D_{basal}$) decreases with distance from the south pole (Fig. 2d); this may be due to differences in basal elevation, so such a data set should be examined in the future.

Using the topographic profiles of the Icelandic volcanoes as a guide, we separated the edifices into six groups: flat-topped, steep-sided cones, shields/rings, shields without a summit crater, low shields with a summit crater, and "other," where the final category contained edifices that did not fit into any of the specified categories. Those edifices within the "flat-topped" and "steep-sided cone" groups are considered to be possible subglacial features; the "flat-topped" have likely emerged from the subglacial lake while the "steep-sided cones" formed entirely beneath the subglacial lake. The other categories are less likely to have formed in a subglacial environment. We find that, when plotting the VPI against the average flank slope for north polar edifices (Fig. 2e), the data splits into two branches with the "steep-sided cones" forming the lower branch suggesting a different process such as forming subglacially or simply being a more explosive feature.

We can assume that the level of the subglacial lake reached 75-90% of the original ice thickness [12]. Using this assumption and the heights of the steep-sided cones and the tuya-like edifices, we can estimate a preliminary minimum ice sheet thickness of 80-550m in the Borealis Volcanic Field.

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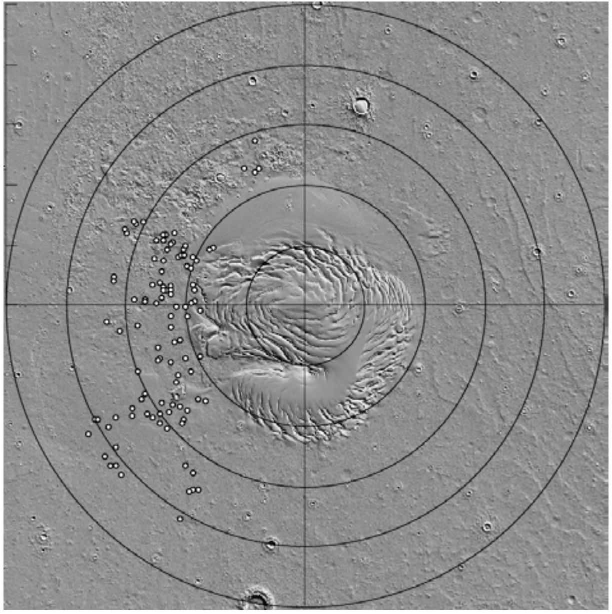

***Fig. 1:*** Location map of putative volcanic edifices in the Borealis Volcanic Field, north polar region of Mars over MOLA shaded relief.

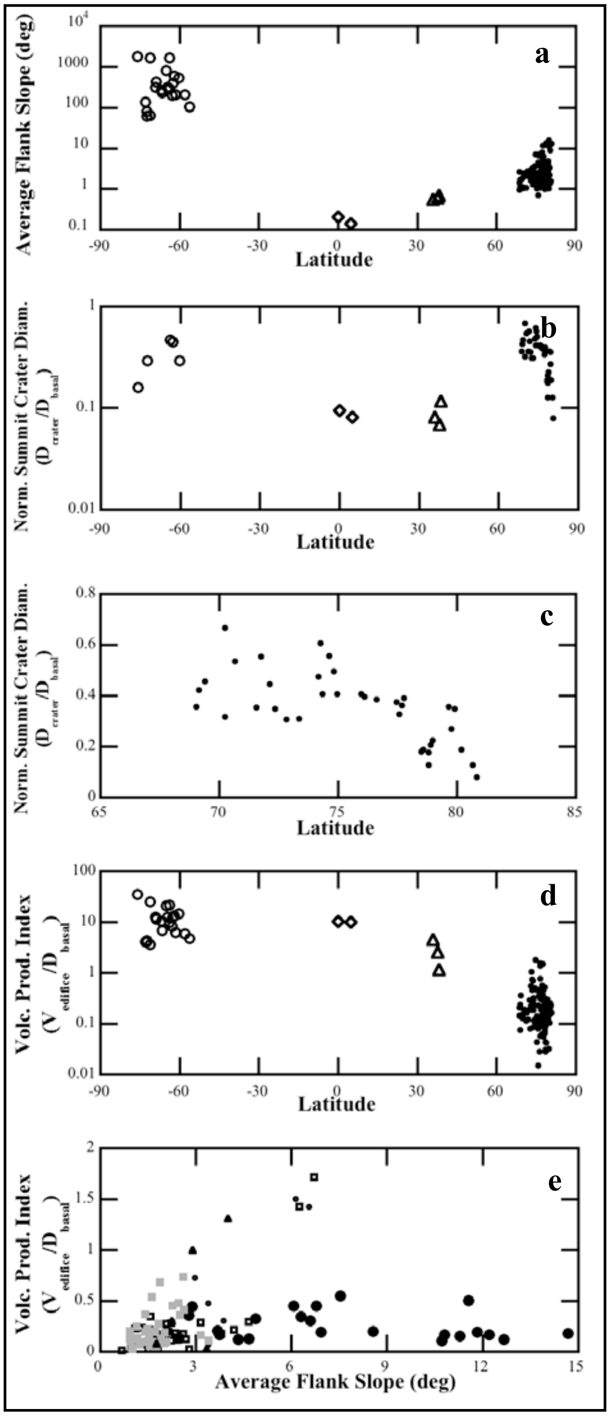

***Fig. 2:*** Latitude dependencies of Martian volcanic edifice characteristics where (a-d) small black circles are north polar, open circles are south polar, open triangles are Tempe Terra, and open diamonds are equatorial edifices. For 2e, open circles are "flat-topped," black circles are "steep-sided cones," open squares are "shields/rings," grey squares are "shields without summit craters," and open triangles are "other" edifices that do not fall into any former category.