GEOMORPHOLOGIC MAPPING OF A POSSIBLE HESPERIAN SUBGLACIAL VOLCANIC ENVIRONMENT IN THE SISYPHI MONTES, MARS.
S. Ackiss[1], B. Horgan[1], M. Suda[1], D. Minton[1], A. Campbell[1], [1]Purdue University, Department of Earth, Atmospheric, and Planetary Sciences, West Lafayette, IN 47907 (sackiss@purdue.edu)

Introduction: Sisyphi Planum (55-75°S, 335-40°E) is located in the southern highlands between the Argyre and Hellas basins. It is composed of isolated domical features [1, 2] known as the Sisyphi Montes and a unit interpreted to be portions of the ancient Dorsa Argentea ice sheet [3, 4]. While the domes are thought to be volcanic in nature, it is still unclear whether they were formed subglacially or subaerially. To constrain their origin, [5] used mineralogy assemblages to show that the formation environment is most consistent with a subglacial origin. Here we construct a geomorphic map of the area in order to decipher the relationship between the edifices and features on the surrounding plains. From this, we can determine whether or not there was ice in the region and subsequently constrain the extent of the proposed ice sheet. We can also evaluate the history of the ice, by determining where the melted ice might have drained and how significant melting was across the region. Overall, geomorphic analysis of the region can help to determine the relationship between the Dorsa Argentea Formation and the edifices.

Methods: The geomorphic and mineralogic properties of the Sisyphi Montes are most consistent with volcanism, but the nature of the volcanism is poorly constrained. Here, we consider two hypotheses for the origin of the high latitude edifices:

(1) Subglacial volcanism: In volcanic eruptions beneath ice sheets and glaciers on Earth, the combination of heat and large quantities of melt water lead to the production of unique morphologies. Subglacial volcanoes that breach their ice sheet form “tuyas” or table mountains that are steep sided and flat topped edifices as well as “tindars” or ridges that are flat-topped and linear [6], while those that don’t breach the ice sheet form rounded or sharp peaked summits. A possible smectite-zeolite-iron oxide mixture, consistent with terrestrial palagonite, has been recently identified on the edifices using CRISM spectra [5], also supporting a subglacial volcanic origin.

(2) Subaerial volcanism: Subaerial volcanism includes stratovolcanoes, complex volcanoes, compound volcanoes, somma volcanoes, shield volcanoes, pyroclastic shields, lava cones, and lava domes [7]. The morphologies of these edifices are typically cone-, dome-, or shield-shaped and generally have flank slopes that are less steep than glaciovolcanic edifices (<30 degrees) [8].

To evaluate these two hypotheses, we have identified and classified all of the edifices in the Sisyphi Planum based on their topographic profiles. Additionally, we constructed a geomorphologic map to characterize the relationship of the Montes and the surrounding plains units of the region. The goal of geomorphologic maps is to show the spatial distribution of landforms and surface deposits in order to constrain the processes that act on those landforms and better understand how a landscape has developed over time. This is in contrast to geologic maps, which focus on characterizing rock units and/or geologic strata, and may not differentiate between surficial landforms.

Results: Eleven units were observed and mapped based on their geomorphology (Figure 1). There are four units that we interpret to be associated with older (possibly Noachian in age) and/or cratering events including the Crater Unit, the Ejecta Unit, the High Elevation Plateau Unit (HEP), and the Patera Unit. Four units including the Polygonal Patterned Unit, the Braided Feature Unit, the Mantled Unit, and the Cavi Unit, are interpreted to be ice- or melt-related. Two edifice-related units were mapped including the Montes Unit and the Circular Depression Unit. The final unit that was mapped is the Surficial Sediments Unit.

We have identified and analyzed 106 edifices in the Sisyphi Planum. Of those, 8% (9/106) have flat peaks, 8% (9/106) are topped by crater-like depressions, 10% (11/106) have rounded peaks, 31% (33/106) have sharp peaks, and 42% (45/106) have heights less than 300 meters (Figure 2).

Discussion: Crater counts over the edifices and immediately surrounding units provide a surface exposure age of ~3.6-3.7 Gy, corresponding to the Hesperian [9]. However, the relationship between the Montes and other units is not always clear. Based on superposition relationships, we suggest that the oldest units (in no particular order) are the HEP, Patera, Crater, and Ejecta Units, followed by the Mantled Unit, the Cavi Unit, the Circular Depressions Unit, and the Surficial Sediments Unit. The relative age of the Polygonal Patterned Unit, the Braided Feature Unit, and the Montes Unit is still unclear.

One of the distinctive characteristics of the Sisyphi Montes is their variable top shape, which has been attributed to subglacial processes in previous studies [1]. However, this characteristic alone is insufficient to determine whether the edifices are subglacially or subaerially formed structures. Sharp, cratered, and rounded peaks on volcanoes could be interpreted to be either subglacial or subaerial in origin, while flat topped edifices are most likely subglacial in origin. Therefore, of the edifice classifications within this study, the most important category for constraining the history of ice in the region is the flat topped category, as they are the only class that has a uniquely subglacial morphology. The sharp peaked edifices are more common and scattered throughout the study region with a similar distribution as the smaller edifices. The flat-topped edifices are concentrated in the center of Sisyphi Planum. From this information, it is plausible that the flat topped edifices were formed under ice while the sharp peaked edifices could have been formed at any time before, during, or after the ice was present.

Combining the edifice top classifications with the results from the geomorphologic map, we have interpreted that the Mantled Unit was previously more extensive in Mars' history. Here we have interpreted the Mantled Unit to be a remnant of an ancient ice sheet, a subset of which has been mapped as the Dorsa Argentea Formation. We also observe that the flat topped edifices, which have morphologies consistent with subglacial volcanism, are present outside of the Mantled Unit. This implies that the ancient ice sheet once extended much further north. Our crater count age for these edifices of ~Hesperian is consistent with climate models suggesting that large ice sheets could have formed at these high latitudes in the early Hesperian [ref].

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References: [1] Ghatan and Head (2002), *J. Geophys. Res. Planets*, vol. 107, p. 5048. [2] Farrand et al., (2008), 39th LPSC, Abstract # 1761. [3] Ghatan and Head (2004), *J. Geophys. Res. Planets*, vol. 109, no. E7, p. E07006. [4] Scanlon and Head (2015), 46th LPSC, Abstract # 2247. [5] Ackiss et al., (2018), *Icarus*, vol. 311, p357. [6] Russell et al., 2014 [7] Grosse et al., 2014 [8] Pedersen and Grosse, 2014 [9] Suda (2018), this conference.

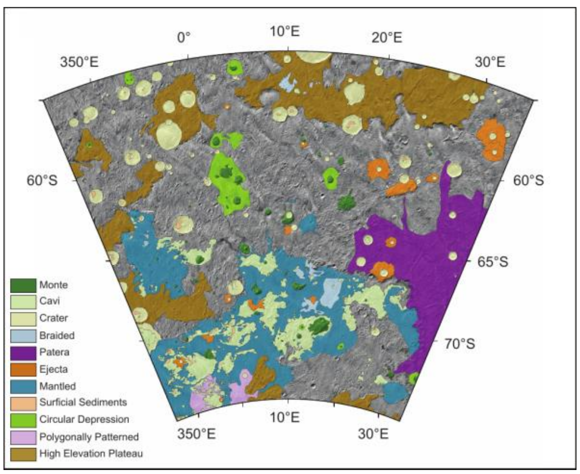

Figure 1. Geomorphologic map.

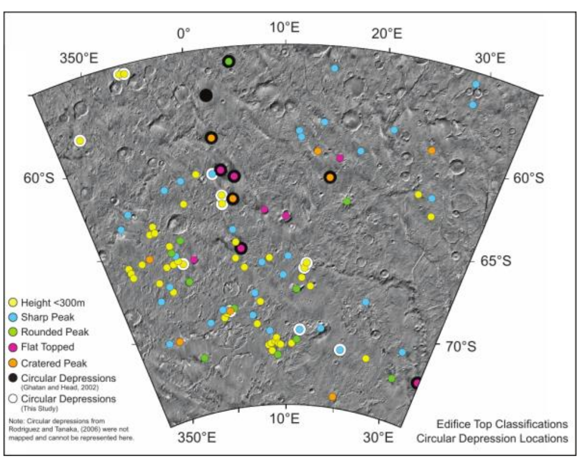

Figure 2. Locations of edifices and circular depressions.