CAVI ANGUSTI, MARS: EVIDENCE FOR VOLCANIC ACTIVITY, ICE SHEET MELTING, AND BASAL DRAINAGE OF WATER.

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Introduction and Background: The south polar region of Mars contains areas characterized by irregularly shaped pits, generally located between 65 and 80°S, incised into a smooth upland surface. These regions are formally named the "pitted plains" or "pitted terrain". From Mariner data, the pits were observed to be well-outlined features with sharp, steep walls, some elongate and others more rounded, approximately 0.5 – several tens of km in diameter. Their floors came in both smooth and rough varieties, rounded or flat-bottomed, with some exposing the underlying "cratered terrain" [1-3]. Based upon inferred local wind direction from albedo markings, and nearby features interpreted to be due to eolian processes, the origin of the pits was attributed to eolian deflation [3-5]. Using Viking data, *Howard* [6] reexamined the pitted terrain, and proposed basal melting of ground ice as an alternative origin for the pits, implying that ice is a significant component of the pitted plains unit.

The pitted plains unit was largely incorporated into the units that *Tanaka and Scott* [7] mapped as Hdu and Hdl (the upper and lower members of the Dorsa Argentea Formation), and HNu, in the geologic map of the south pole they produced from Viking data. Recent detailed mapping of the south polar region using MOLA data [8] supports the interpretation that the DAF and the related unit HNu are volatile-rich, and these deposits have been interpreted as representing the remnants of a formerly larger south polar ice sheet. This interpretation is supported by the presence of esker-like ridge systems [9, 10], flat marginal areas interpreted to be ponded debris, and sinuous channels leading from the margins of the deposit and interpreted to be drainage from meltback products [11]. The proposed basal melting origin for the pitted terrain [6], specifically for Angusti and Sisyphi Cavi is also supported.

Ghatan and Head [12] have interpreted several mountains mapped by *Tanaka and Scott* [7] located within an area between 20° and 340°W as subglacial volcanoes, which may have played a role in local meltback of the larger, Hesperian-aged south polar ice sheet. Two of these volcanoes are located adjacent to Cavi Sisyphi, and may have contributed to basal melting during its formation. This study focuses on a basin of the Cavi Angusti area of the pitted terrain, and using new MOLA and MOC data, presents evidence for volcanic activity within the basin. We assess the influence of this activity on pit formation and whether this process, as well as deflation, could account for the observations.

Description: The basin is centered at approximately 79°S and 70°W. It is elongated in a direction away from the pole, and measures about 100 km x 50 km. The walls of the basin are curved and cuspate, and have measured slopes of about 11° which shallow out at the base in a concave manner. There is a breach in the wall towards the north, which connects to a more elongated, sinuous pit that is also part of the Cavi Angusti complex. Other than this break, the rim of the basin is intact to an elevation of 1500 m, with higher levels existing in places, especially along the eastern margins. The walls also appear to display a staircase geometry, visible in both MOC images and the shaded relief map (Figure 1). The size of the basin, its surface area to volume ratio, and the staircase geometry of the walls are not consistent with those of terrestrial deflation basins, which tend to be broad shallow depressions with smooth, shallow sloped walls [13].

MOC wide angle images of the basin indicate a rather smooth floor, with several small craters visible. A shaded relief map of the basin shows a slightly more hummocky texture to the floor, and reveals several additional small craters, some which appear to be exhumed and partly filled with material (Figure 1). Located within the basin are two topographic highs, one more rounded, and the other elongate (designated mountain and ridge, respectively). The MOLA data show that the lowest points within the basin are on the floor where it meets the wall (Figure 2).

The mountain, located in the geographic center of the basin, is approximately 20 km in diameter, 770 m tall, has a basal elevation of 1050 m, and a summit elevation of 1820 m. In both MOC and shaded relief views, the mountain appears to have relatively steep, hummocky slopes (mean value of 6°, steeper towards top and shallower at base), a flat-top, and to be perched on a low platform. This platform extends away from the mountain in all directions about one diameter length from the edge, and has lobate edges as well as a clear terminal scarp. The ridge, located slightly northwest of the mountain, is elongated in the same direction as the basin. It has the same basal elevation as the mountain, and a summit elevation of about 1600 m. It also sits on a platform. Between the mountain and the ridge is a saddle that stands at an elevation of 1100 - 1150 m. Volumes were calculated for the basin, the mountain and the ridge. The basin has a total volume of 2500 km^3 up to the 1500 m contour, the mountain has a volume of 51.6 km^3, and the ridge has a volume of 30.6 km^3.

Also seen on the shaded relief map is a lobate feature with clear terminal scarps that extends away from the mountain in a northerly direction, parallel to the elongate trend of the basin. It measures 30 km x 14 km. In the shaded relief map this lobate feature is seen to clearly display a unique texture from the rest of the floor material, and to spread out away from the mountain. The lobate feature is seen in MOC wide angle images displaying a low albedo feature, and is also visible in detrended topography data [14]. A second area of low albedo is visible in MOC wide angle images, and is located on the slope of the ridge. These albedo features are seen in MOC images from all seasons. Trending parallel to the northern scarp of the lobate feature are two other lobate scarps, which the topography data show to down step in a staircase manner.

Interpretation: The lobate feature emanating away from the mountain is here interpreted to be a lava flow. Its dimensions are consistent with a lava flow origin, as are the lobate and cuspate nature of its margins, and its clear terminal scrap [15, 16]. It spreads outwards as it emanates away from the mountain, suggesting that the mountain is the source, and that the mountain is actually a volcano.

A single MOC narrow angle image (M1003510) is located on the flow. This image reveals a unique texture from all other MOC narrow angle images of the basin floor. It displays various albedo markings, some dark blocks, and some small scale (~100 m) polygonal cracking. While not distinctly characteristic of a lava flow, such features are known to be associated with terrestrial lava flows, such as those of Kilauea Iki [15]. The two other lobate scarps that are parallel to the flow could likely be previous flows, as could the platform upon which the mountain sits. The topographic data show that these scarps form a staircase geometry, and suggest that the scarps are the fronts of flows that underlie the most recent flow. The area of low albedo located on the ridge, appears similar to the lobate feature, and could also likely be a lava flow.

The mountain itself, while similar in height, width, and volume to other martian features interpreted as volcanoes [17], is different in some morphological respects. It is somewhat flat-topped and has relatively steep slopes for a martian volcano [18, 19]. Because of its geographic location, in the center of a basin incised into the volatile-rich deposits of a formerly larger Hesperian-aged south polar ice sheet, there exists the possibility that at times during the eruptive history of the mountain, it erupted into ice-rich surroundings. The anomalous characteristics of the mountain from other similar sized martian volcanoes (its flat-top and steep slopes) are well explained by a subglacial constructive history [20]. The mountain is also physically similar to other mountains near the south pole interpreted to be subglacial volcanoes erupted into the larger Hesperian ice sheet [12]. The close vicinity of the ridge to the mountain, as well as their common basal elevation, similar heights and volume, and the low albedo feature seen in MOC images, suggests that the ridge is related to the mountain, and that it may also have formed subglacially, and thus could be a moberg ridge [20].

While the mountain and ridge may have a subglacial origin, the flow emanating away from the mountain is unlikely to have formed subglacially, as lava erupted beneath ice tends to form pillows and hyaloclastites, and is confined by the surrounding ice walls [21]. Thus a general geologic history of the basin is: 1) Emplacement of the Hesperian-aged ice sheet and associated units occurred; 2) Eruption of the mountain and ridge into the volatile rich deposits of the Hesperian-aged ice sheet melted and removed a volume of water equivalent to the basin up to the 1500 m contour (2500 km^3); 3) Later subaerial eruptive stages produced several lava flows.

Meltwater production: A simple test of this hypothesis is an ice-to-magma ratio. Based on heat flow calculations modeled from Icelandic work [22], it is estimated that a volume of approximately 450 km^3 of magma would be necessary to melt the 2500 km^3 of ice that once filled the basin. The combined volume of the mountain and ridge is 82.2 km^3. Thus, approximately 20% of the required magma is seen in extrusive deposits, leaving the additional 80% to have cooled intrusively, and to have released its heat conductively. This is the same ratio of intrusive-to-extrusive material calculated to be responsible for the production of meltwater in the Grimsvotn geothermal area in Iceland [23, 24]. Thus, the mountain and ridge together could plausibly be responsible for removing the ice from the basin, allowing for later subaerial eruptions.

Conclusions: The irregular pits and depressions of the south polar region of Mars have previously been attributed to eolian deflation [3-5] or basal melting [6]. We outline an interpretation in which subglacial volcanic eruptions within the basin led to development of a tuya and moberg ridge, which, along with heat from intrusive materials, were sufficient to melt the volume of ice comprising the basin. Subsequent to basin formation, continued volcanic activity was subaerial, and formed lava flows.

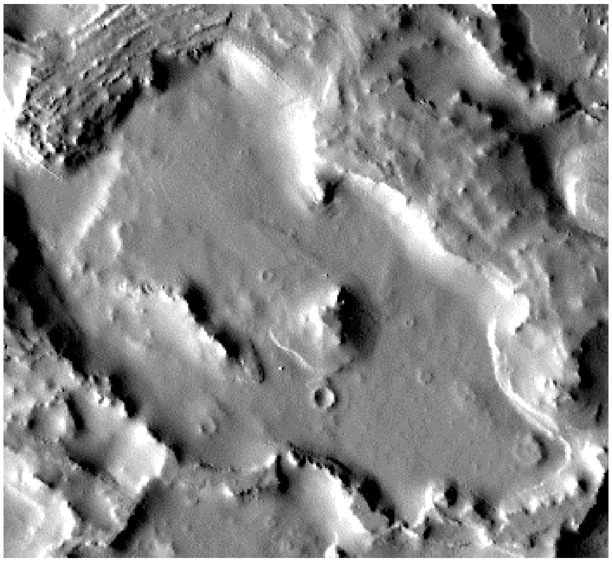

Figure 1. MOLA shaded relief map of basin.

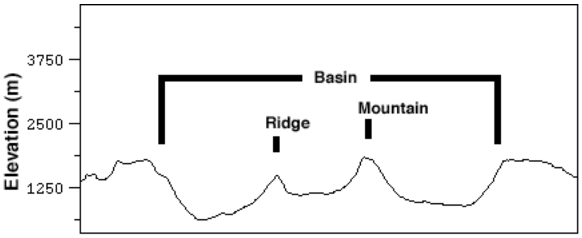

Figure 2. MOLA topographic profile across basin.

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