PRELIMINARY LAVA TUBE-FED FLOW ABUNDANCE MAPPING ON OLYMPUS MONS.

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Introduction: Our objective is to characterize effusive martian volcanism based on the percentage of lava flows emplaced via lava tubes, based on an approach to characterize and contrast the eruptive processes of Kilauea, Mauna Loa, and Mount Etna [1,2]. We are mapping the flows of Olympus Mons to estimate the percentage of surface flows that were emplaced via lava tubes, channels, or sheets, using the Themis daytime IR images, supplemented with Themis VIS and MOC images. Preliminary results indicate that the latest stage of effusive activity was typified by channel forming eruptions, which are often diverted around and embay tube-fed flows.

Background: Lava tubes are flow structures found within basaltic flow fields [3,4]. They are thermally insulated conduits that transport lava from vents to flow fronts. Terrestrial lava tubes form through two dominant processes: 1) roofing of lava channels, and 2) progressive advancement of lobate toes or inflation of coalesced toes or sheets at the flow front [5-24]. Tube formation is facilitated by long-lived eruptions, with low to moderate, fairly steady effusion rates [23-25], while channels are generally related to shorter-lived eruptive durations, and higher, fluctuating effusion rates [23-25]. Because channels and tubes tend to form as a result of different eruptive conditions their abundance can be used to characterize the latest effusive stage of a volcano. Volcanoes with higher abundances of tubes likely erupted their lavas during steady, long-lived eruptions compared with volcanoes dominated by channel-fed flows.

When lava tubes transport lava below full capacity, skylights can form by roof collapses. Further collapse after the eruption, if the lava tube drains, results in chains of pits axial to the lava tube [5-25]. When transporting lava at full capacity tubes are often under confining pressures. In these cases inflation axial to the flow can produce elongate tumuli, large ridges, and rootless vents, which can act as sources for secondary flows [11, 14, 16-18, 21, 23-25]. Therefore, the presence of lava tubes can be inferred on the basis of surface features such as chains of collapse pits, elongate tumuli, and rootless vents [1,2,26]. These features were used to infer the presence of tube-fed flows (TFFs) on the martian volcanoes Alba Patera, Olympus Mons, Syrtis Major, and Elysium Mons [28-35].

Approach: In order to characterize martian volcanoes we are mapping flow types, beginning with Olympus Mons. The purpose of mapping the lava flows is to estimate the percentage of flows emplaced via lava tubes. We define a lava tube as a thermally insulated conduit often under confining pressure, whether drained or plugged, in order to determine how common are the conditions that form TFFs. We map lava tubes based on the presence of collapse pits or, when collapse pits are lacking, infer tube presence based on features interpreted to have formed by inflation. These are the same features that have been used in the past to suggest the presence of martian TFFs [28-35].

Our mapping is based on a Themis daytime IR mosaic (currently covering ~90%) of Olympus Mons at 100 m/pixel. The base mosaic is supplemented by Themis VIS and MOC images allowing mapping at higher resolutions (36, 18, and 1-3 m/pixel respectively), but over much smaller areas. Preliminary mapping was conducted for three regions (15˚N, 229˚E, 18˚N 231˚E, 21˚N 225˚E), over which coverage exists at all resolutions, in order to define the mapping units and to examine the effect of image resolution. Mapping was first conducted at the lowest resolution in order to eliminate biases that could be included by mapping at higher resolutions first. Understanding the effects of resolution will indicate whether 100 m/pixel is a sufficient resolution for TFF abundance estimates.

Results: We have defined six units: 1) channelized unit, 2) pitted unit, 3) unpitted, raised ridges, 4) smooth, tabular unit 5) smooth unit, and 6) smooth, mottled unit. Channelized surfaces are areas where repeated, sub-parallel linear patterns are present. At 100 m/pix these features appear to be channel-fed flow margins or levees, while at higher resolutions they are clearly leveed flows. Included within this unit are the stubby, tabular flow fronts that are associated with channels upflow. The pitted unit is identified by the presence of sinuous chains of collapse pits with apparently smooth surfaces adjacent to them. The pit chains are sometimes on flat featureless surfaces but typically are located axial to topographic ridges and are most likely indicative of TFFs. Unpitted, raised ridges are similar to pitted, raised ridges but lack collapse pits. They often consist of linear groups of mounds, forming a ridge with mottled to linear patterns radiating from the crests. This unit represents likely TFFs formed under confining pressures. The smooth, tabular unit consists of stacked tabular surfaces with lobate margins. Smooth surfaces are areas with no apparent margins. The smooth, mottled unit consists of areas that appear similar to pitted and unpitted surfaces but lack a clear ridge-like appearance. This unit can be a local topographic high and is often found in unconnected clusters.

Preliminary mapping results show that TFFs might not be distributed evenly across the volcano supporting previous observations [29,30]. On the western flank of Olympus Mons channels cover up to 80% of the surface and TFFs cover 6-8% while the southern scarp is covered by 77% channels and 10% TFFs. However, lava flows on the eastern flank that cover the basal scarp are only 31% channels and up to 16% TFFs. Generally, TFFs are embayed by the channelized unit.

Discussion: Our results likely underestimate true TFF abundances because even at the highest resolutions features indicative of TFF presence might go unnoticed. Also, in areas where roof collapse and/or inflation have not occurred, identification of TFFs is nearly impossible. Another potential source of error for TFF abundance estimates occurs when lava flow direction is parallel to the orientation of the incident sunlight in the image. In this case differentiating the surface into map units is difficult. Themis VIS and MOC images provide some insight to the flow types present, but generally these images do not cover the entire area in question. As Themis continues to acquire images, and more data is released, overlap of the daytime IR images should allow an opportunity to map these areas under different lighting conditions, producing more accurate TFF abundance estimates.

Areas for which multiple image resolutions are available show that Themis daytime IR and higher resolution images produce comparable TFF abundance estimates. Areas mapped as the channelized unit on IR images are clearly leveed flows in VIS and MOC images. Areas mapped as unpitted, raised ridges sometimes contain collapse pits at higher resolutions suggesting the lack of pits on some topographic ridges at 100 m/pixel is a resolution effect and that these ridges are pressurized TFFs. There is a tendency to map areas as smooth surfaces at higher resolution that correlate to pitted or unpitted raised ridges at 100 m/pixel. This is a context issue as the full scale of the ridge is often lost at higher resolutions resulting in mapping the area as a smooth surface and not a ridge. In some cases the smooth units appear to be subtle topographic highs as channel-fed flows pool up against or flow around them. It is possible that these surfaces are remnants of previous TFFs that were subsequently buried by younger channel-fed flows. Further analysis of the relationships between units might result in higher TFF abundance estimates.

Summary and Conclusions: Estimating lava tube abundances based on lava tube mapping is a technique that has been used to characterize terrestrial volcanoes [1,2]. Mapping of this type is used here to estimate the abundance of lava tube-fed flows on Olympus Mons. Preliminary mapping indicates that lava tube abundances can be estimated from Themis daytime IR at the same level of accuracy when compared with Themis VIS and MOC images at higher resolutions. Based on the preliminary maps we have defined six map units. By mapping several possible TFF units, a range of TFF abundances can be reported. Preliminary TFF estimates suggest that lava tubes are not evenly distributed across Olympus Mons, supporting previous interpretations [29,30]. Although some TFFs are younger than the adjacent channelized flows, areas that likely represent TFFs are often embayed by channels, which likely typify the latest effusive stage of Olympus Mons. The distribution of TFFs could be compared with slope distributions in the future to characterize more fully the volcano's history.

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