

**GEOLOGIC MAPPING OF THE OLYMPUS MONS VOLCANO, MARS.** J.E. Bleacher<sup>1</sup>, D.A. Williams<sup>2</sup>, D. Shean<sup>3</sup>, R. Greeley<sup>2\*</sup>, <sup>1</sup>Planetary Geodynamics Laboratory, Code 698, NASA GSFC, Greenbelt, MD, 20771, [Jacob.E.Bleacher@nasa.gov](mailto:Jacob.E.Bleacher@nasa.gov), <sup>2</sup>School of Earth & Space Exploration, Arizona State University, Tempe, AZ, 85282, <sup>3</sup>Malin Polar Science Center, Applied Physics Lab, University of Washington, Seattle, WA, 98105 \*Deceased.

**Introduction/Background:** We are in the third year of a three-year Mars Data Analysis Program project to map the morphology of the Olympus Mons volcano, Mars, using ArcGIS by ESRI. The final product of this project is to be a 1:1,000,000-scale geologic map. The scientific questions upon which this mapping project is based include understanding the volcanic development and modification by structural, aeolian, and possibly glacial processes.

The project's scientific objectives are based upon preliminary mapping by Bleacher et al. [1] along a ~ 80-km-wide north-south swath of the volcano corresponding to High Resolution Stereo Camera (HRSC) image h0037. The preliminary project, which covered ~20% of the volcano's surface, resulted in several significant findings, including: 1) channel-fed lava flow surfaces are areally more abundant than tube-fed surfaces by a ratio of 5:1, 2) channel-fed flows consistently embay tube-fed flows, 3) lava fans appear to be linked to tube-fed flows, 4) no volcanic vents were identified within the map region, and 5) a Hummocky unit surrounds the summit and is likely a combination of non-channelized flows, dust, ash, and/or frozen volatiles. These results led to the suggestion that the volcano had experienced a transition from long-lived tube-forming eruptions to more sporadic and shorter-lived, channel-forming eruptions, as seen at Hawaiian volcanoes between the tholeiitic shield building phase (Kilauea to Mauna Loa) and alkalic capping phase (Hualalai and Mauna Kea).

**Methods:** To address our science questions we are conducting flow morphology mapping on the Olympus Mons main flank at ~ 1:200,000 scale using the Context Camera (CTX) image mosaic as our base data. This scale enables a distinction between sinuous rilles and leveed channels, which is fundamental for interpreting abundances among, and changes between, tube- and channel-forming eruptions. We identify Channeled, Mottled, Hummocky, Smooth, Tabular, and Scarp Materials morphology units. We do not uniquely interpret a mapped unit as tube-fed flows as was done by [1]. Instead, we map sinuous rilles and chains of depressions as linear features. We

identify fans as location features forming topographic highs surrounded by radiating flow patterns. We distinguish elongate topographic ridges as surface features. To assist in the identification of ridges and fans we derive local contour maps at 25, 50 and 75 meter intervals from the HRSC DTMs and MOLA DEMs.

Primary science issues driving this research project are identifying where the volcanic materials were erupted from, and determining if rift zones are present. In order to address these issues we separate the Channeled and Mottled units into 1) caldera-sourced, 2) fan-sourced, and 3) flank units. We also map as linear features boundaries between significant flow fields. Often we observe two distinctly different channelized flow fields that would be mapped singularly as the Channeled unit. However, distinguishing between these flow fields might provide insight into eruption recurrence rates.

**Results:** After conducting 1:1,000,000 structural mapping of Olympus Mons [2], we are now focused on the morphology mapping on the flank of the volcano.

Our mapping of CTX data at ~ 6 m/pixel shows that surfaces that would have been mapped as lava tubes by [1] from HRSC data (12-20 m/pixel) can be divided into several other units (typically Mottled, Smooth, and Channeled). This is shown in Figure 1 where a topographic ridge with sinuous rille and fan is seen to be dominated by the mottled unit and some small channels. As such, we now infer the presence of tube-fed flows by a combination of at least two of the following criteria: rilles or pit chains, topographic ridges with smooth or mottled surfaces, fans, and/or non-impact raised rim depressions. As such, a tube-fed flow can comprise several Olympus Mons morphologic units. These criteria are also based upon field work funded by the Moon & Mars Analog Missions Activities Program and a Hawaiian analog is demonstrated in Figure 1 [3]. We will conclude our morphologic mapping by interpreting which flow surfaces are tube-fed and adding this information as a surface feature.

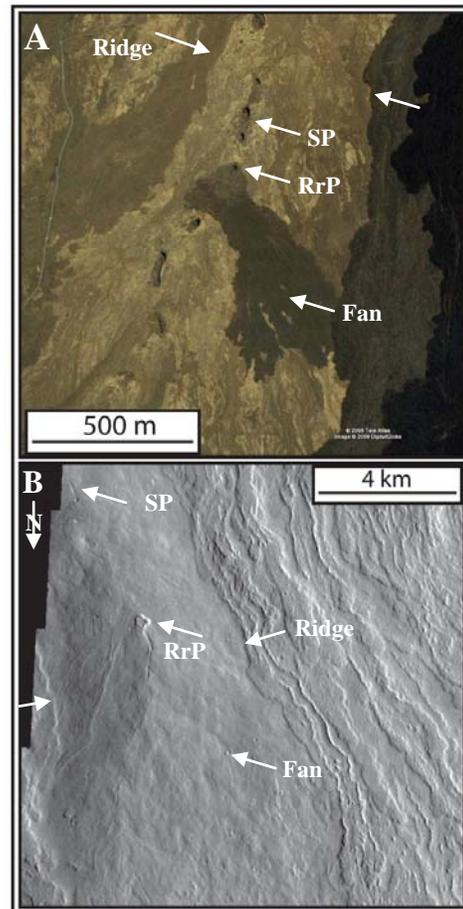
Our observations also suggest that an inference by [1] that tube-fed flows are embayed by younger channel-fed flows is not always consistent. If in fact a number of major tube systems are observed to be the locally youngest flow features, then based on comparison with the Hawaiian volcanoes, Olympus Mons might be in an evolutionary stage similar to Kilauea and Mauna Loa (tholeiitic shield building) as opposed to Hualalai and Mauna Kea (alkalic capping).

The Mottled and Hummocky units of [1] were noted as difficult to distinguish, in other words, a possible over-interpretation. The distinction between the units was based on surface roughness, Mottled being rough at the 10s-100s m scale and Hummocky at the 100s-1000s m scale. The CTX mosaic confirms that these two units are unique. The Mottled unit is now seen to represent the development, or near development, of small channeled flows (not detectable at the mapping scale of 1:200,000 but at full resolution), whereas the Hummocky unit appears to be a mantled lava flow surface, or a location where channels did not form near the caldera.

Along the base of the volcano, particularly to the N and SE, are several flat topped plateaus that are unique from the apparently normal faulted cliffs of the basal scarp. We infer these features to be analogous to the Ninole Hills of Mauna Loa, HI [5,6]. These features are thought to represent an older volcano surface that remains after flank collapse. As such, these locations provide a window into older Mauna Loa flank construction [4] or possibly even Hualalai [5]. The Olympus Mons plateaus are similar in that they preserve lava flow textures on the upper surfaces, stand above the younger, embaying lava flows, and might be associated with large flank collapses expressed as the aureole deposits [6]. If these martian features are similar to the Hawaiian Ninole Hills, then they would be an ideal location to assess possible changes in magma composition for the Olympus Mons volcanic system.

**Ongoing Mapping:** We have identified map units and features that appear to remain consistent across Olympus Mons and provide insight into the development of the volcano. We are currently continuing our mapping from the south flank, clockwise around the volcano. The northwest flank does show a surface mantle similar to that of the Hummocky unit near the summit [7]. This

region might prove to require the addition of new map units. Otherwise, our unit identification and mapping efforts suggest that the current approach will be sufficient to complete the project and to provide new insight into the current science questions outlined in our proposal.



**Figure 1.** A) Landsat image (Google) showing the Pöhue Bay lava flow with several rimless pits that are sinuously aligned (SP) along the axis of a raised ridge (Ridge). Some pits also display raised rims (RrP), with one as the source for a ~750 m 'a'ā flow (Fan). B) Themis image showing an Olympus Mons lava tube with rimless pits that are sinuously aligned (SP) along the axis of a ridge (between arrows marked "Ridge"). A raised rim pit (RrP) also is located at the apex of a lava fan (Fan). Although the ridge typically shows a mottled surface it also displays minor channels.

**References:** [1] Bleacher et al., (2007), JGRE 112, doi:10.1029/2006JE002826. [2] Williams et al., (2010), LPSC 41, #1053. [3] Bleacher et al., (2011), LPSC 42, #1805. [4] Lipman et al., (1990), Bull. Vol. 53, 1-19. [5] Holcomb et al., (2000), Geology, 28, doi:10.1130/091-7613(2000)28. [6] McGovern et al., (2004), JGRE 109, doi:10.1029/2004JE002258. [7] Basilevsky et al., (2005), Solar System Research, 39, 2, 85-101.