UPDATES TO THE CATALOG OF THARSIS PROVINCE SMALL VOLCANIC VENTS, MARS.

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Introduction: The Tharsis province of Mars displays a variety of small volcanic vent morphologies (10s km in diameter). These features were identified in *Mariner* and *Viking* images [1-4]. Based on these data Hodges and Moore [4] published the *Atlas of Volcanic Landforms on Mars* in which they conducted a detailed survey to identify, describe, and classify all volcanic features on Mars as a basis for interpretation and discussion of the volcanic evolution of the planet. They provided detailed descriptions of 12 large, named volcanic constructs in the Tharsis region. Smaller vents were discussed within eight sub-groups, showing a total of ~100 identified features in the region and they suggested that additional small vents likely existed, which were undetectable at available data resolutions.

Mars Orbiter Laser Altimeter data did show small vents to be more abundant than originally observed [5,6], and recent studies are classifying their diverse morphologies [7-9] using several post-*Viking* image data sets. Building on this work, we are mapping the location of small volcanic vents in the Tharsis province using the MOLA gridded data product, and all publicly released *Viking*, THEMIS, HRSC, CTX, MOC, and HiRISE images. This project is called the Catalog of Tharsis Province Small Volcanic Vents and follows in the footsteps of Hodges and Moore [4]. Here we report on the results of the first year of work on this three year funded MDAP project.

Objectives & Approach: The project is driven by two main scientific objectives: 1) characterizing the spatial distribution and alignment relationships of small vents across the province, and 2) investigating the temporal relationships between individual small vents, as well as between sub-groups of randomly distributed vents. In order to accomplish our objectives the project includes two tasks. The first task involves the mapping of small vents (Figure 1), determination of their morphologic and morphometric characteristics, and the assignment of a geographic data point, in essence the development of the catalog. The second task comprises the application of nearest neighbor and two point azimuth statistical analyses to the catalog results to quantify the spacing and alignment relationships between vents and to help differentiate fields from one another. The integrated results from both of the proposed tasks enable us to test the hypothesis that the distribution of small vents in the Tharsis region represents major magma production events and that they display the effects of causal processes related to the timing, location, and style of magma generation, ascension through the crust, and eruption at the surface. By testing this hypothesis we are providing new insight into the sequential development of the province, which in turn helps link the magmatic and volcanic history with the tectonic and magnetic history of the region:

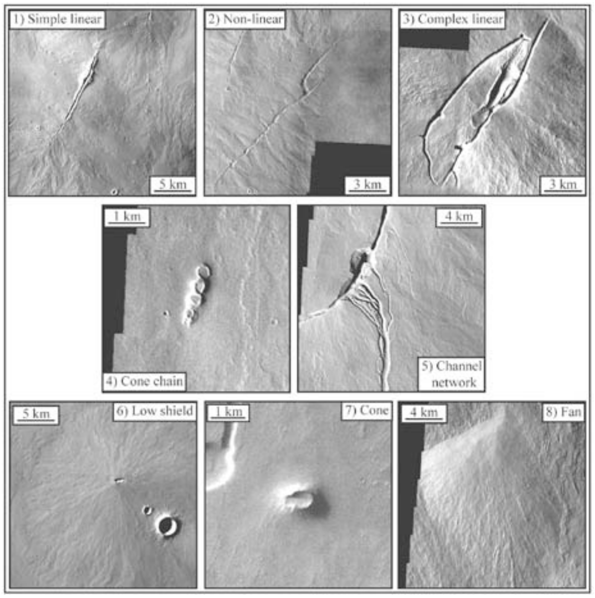

Figure 1. A combination of THEMIS VIS and HRSC images showing the eight vent types identified thus far in our mapping, including: 1) simple linear, 2) non-linear, 3) complex linear, 4) cone chain, 5) channel network, 6) low shield, 7) cone, and 8) fan vents.

Results: Thus far this project has driven or supported three peer-reviewed publications [10-12] and two student-led LPSC abstracts [13,14]. Here we briefly review these results.

Pavonis Mons South Volcanic Field: Our preliminary study included the small vent field south of the Pavonis Mons SW rift apron. Here a coalesced vent field displays 88 identifiable constructs. This field covers ~480 by 270 km and extends from 244°–249° E longitude to 1°–9° S latitude. Nearest neighbor analyses indicate that the vents are randomly spaced (not to be confused with geologically random), which we interpret to indicate that resource depletion did not force a systematic spacing (in other words, the individual vents did not share a shallow magma source but each represent a unique packet of magma that independently rose through the crust). Alignment analyses show a strong north trend between vents in the field, which is offset by several 10s of degrees from the trend of the Tharsis Montes. Tectonic mapping [15] suggests that tectonism during the Noachian likely produced north-trending crustal fractures that might extend into this area related to the formation of Claritas Fossae. We suggest that buried Noachian crustal fractures likely controlled the distribution of small vents in this field by providing the easiest pathways to the surface for each ascending magma body.

South Tharsis Magnetic Boundary: A sharp crustal magnetic field contrast of almost two orders of magnitude at 185 km altitude, as determined by electron reflection (ER) magnetometry, exists between the non-magnetic bulk of the Tharsis province and its relatively strongly magnetized southwestern region. Much of this boundary is located away from the nearby Arsia Mons volcano and was not likely affected by the formation of that feature. However, small vents in this region indicate that some magma did rise through the crust in the post-dynamo era, thereby providing a source of crustal demagnetization. By matching modeled estimates of the minimum volume of magma required to demagnetize the crust with mapped estimates of erupted volume on the surface we estimated an upper bound for intrusion to extrusion ratios in this area at 250-750, or an order of magnitude higher than the published global estimate for Mars [16]. Although this upper bound likely exceeds the true ratio, it does suggest that intrusion to extrusion ratios might differ across the planet and supports our interpretation that the Pavonis Mons South Volcanic Field represents magma ascension through the crust as opposed to radially emplaced magma from a Pavonis Mons rift system.

Olympus Mons Lava Fans: Lava fans on Olympus Mons are suggested to represent eruptions fed from depth or along rift zones [17,18], or lava tube breakouts [1]. We identified 135 lava fans or fan complexes on the flank of Olympus Mons. Of these, 86 displayed a lava tube trending into its apex and 25 additional fans were located in close proximity to a tube suggesting a genetic relationship [13]. The 24 remaining fans were not associated with tubes. As such, we suggest that the majority of Olympus Mons fans represented lava tube breakouts, and identified 24 potential candidates for rift zone activity. Nearest neighbor analyses indicated a non-random distribution for the entire population of fans, which we interpret as a possible indicator of more than one fan population or formation process.

Syria Planum: Baptista et al. [19] presented a geologic history for the Syria Planum region including the formation of a large volcano (with flows extending over 100 km to the south) in the west followed by development of a shield field to the east. These events occurred as several populations of graben and surface fractures were forming. We identified a unique late stage volcanic event [14] that involved the formation of 17 small vents that coalesced to form a northeast trending ridge in the northern Syria. This coalesced field is clearly superposed over the vent field described by Baptista et al. and suggests either a transition of eruptive activity from southern to northern Syria or a completely unique magmatic event later in the region's evolution.

Ongoing & Future Work: Our proposed work effort includes mapping small volcanic vents across the Tharsis province. At this time we have restricted ourselves to known volcanic vent fields. We are currently mapping vents in the Arsia Mons caldera, south of Ascraeus Mons, and two fields previously described to the east of Pavonis Mons that are tentatively called the Pavonis East Field and Fortuna Field [20]. As we continue mapping the known fields we will begin to examine the Tharsis plains for previously unidentified small vents and vent fields. We continue to conduct nearest neighbor and 2 point azimuth analyses as we complete the mapping of each field. Thus far our results suggest that vent fields within Tharsis represent significant magma production events that appear to be unique from major shield building events. If this hypothesis holds true for any of the vent fields then their development must be considered in models for Tharsis province development and evolution.

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