NEW OBSERVATIONS OF THE DIVERSITY OF ERUPTION STYLES ALONG THE SW RIFT ZONE OF ARSIA MONS, MARS. P. J. Mouginis-Mark, Hawaii Institute of Geophysics and Planetology, SOEST, University of Hawaii, Honolulu, Hawaii 96822, USA. <pmm@higp.hawaii.edu>

Abstract

A great diversity in the eruptive style of Arsia Mons volcano can be identified from THEMIS, MOC and MOLA data. Collectively, these data sets provide the first opportunity to study lava shields within the summit caldera, kilometer-scale pit craters on the upper flanks, and the entire length of lava flows from vent to distal flow lobes. As such, a more complete picture of the history of this volcano is emerging which has both similarities to the other Tharsis Ridge volcanoes (Pavonis and Ascraeus Montes) and differences with Olympus Mons.

Introduction

Recent observations [1] of extensive ash deposits near the summit of Arsia Mons volcano (9.5°S, 238.8°E) have indicated that this volcano has had a more complex history, including large explosive eruptions, than had previously believed from analysis of Viking Orbiter images [2, 3]. Data from the Mars Orbiter Camera (MOC), the Thermal Emission Imaging System (THEMIS), and the Mars Orbiter Laser Altimeter (MOLA) have now provided extensive coverage of the volcano, and have enabled a greater diversity of volcanic features to be studied along the NE – SW structural trend through the volcano that is interpreted to be a rift zone [3]. The transition from the summit caldera (elevation ~16.3 km above datum), to the upper flanks (~12 – 16 km) and lower flanks (~7 – 12 km) is striking. Along this potential rift zone, it is possible to identify numerous collapse pits that are believed to be the vents for the ash deposits [1], over a dozen small shields on the caldera floor [2, 3], and a complete sinuous rille/lava flow complex. The new insights into these features are now described.

Lower Flank Lava Flows

Daytime THEMIS IR images show almost the entire length of a lava flow, which originates from a vent at an elevation of ~11.3 km on the southern lava fan (Fig. 1, 2). Historically, it has been difficult to identify the vent areas for lava flows on Mars [4]. We have speculated that sinuous rilles, such as the ones near the summit of Elyisum Mons [5], could be the source areas for lava flows which had high effusion rates. However, until now it has not been possible to trace the downslope flow(s) associated with a rille because the rille either disappears into compound flow units or the image does not cover a sufficiently large area. But on the SW flank of Arsia Mons, both the vent and the associated distal flow fronts can be identified in the same image. The sinuous rille formed ~34 km from the base of the main shield and is ~65 km long. No enlarged source crater or topography can be identified around the vent. The flow extends a further 135 km downslope. Close to the distal end, the flow splits into four segments, which have widths of ~2.3 – 3.2 km and pronounced central lava channels.

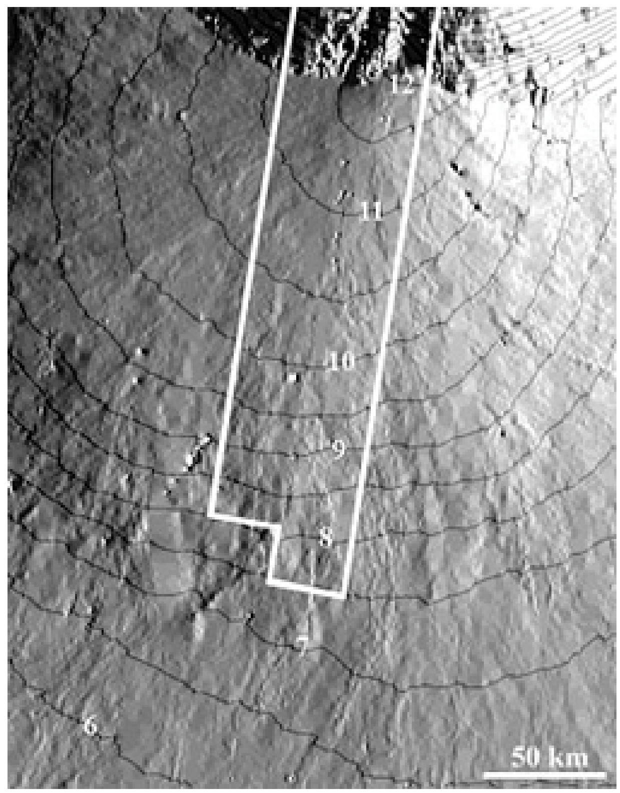

Figure 1: Shaded relief image derived from MOLA data for the southern flank of Arsia Mons volcano. The summit is just off the top of the image. Contours are at 500 meter intervals, and the marked elevations are in kilometers above Mars datum. Notice that the upper flanks have a shallower slope than the lower flanks. The area of coverage of Figure 2 is also shown. North is towards the top.

Unfortunately, MOLA data are insufficient to measure the thickness of the flow otherwise this flow would be an excellent candidate for modeling the rheology of the lava as well as study the effects of slope on flow and channel width and depth.

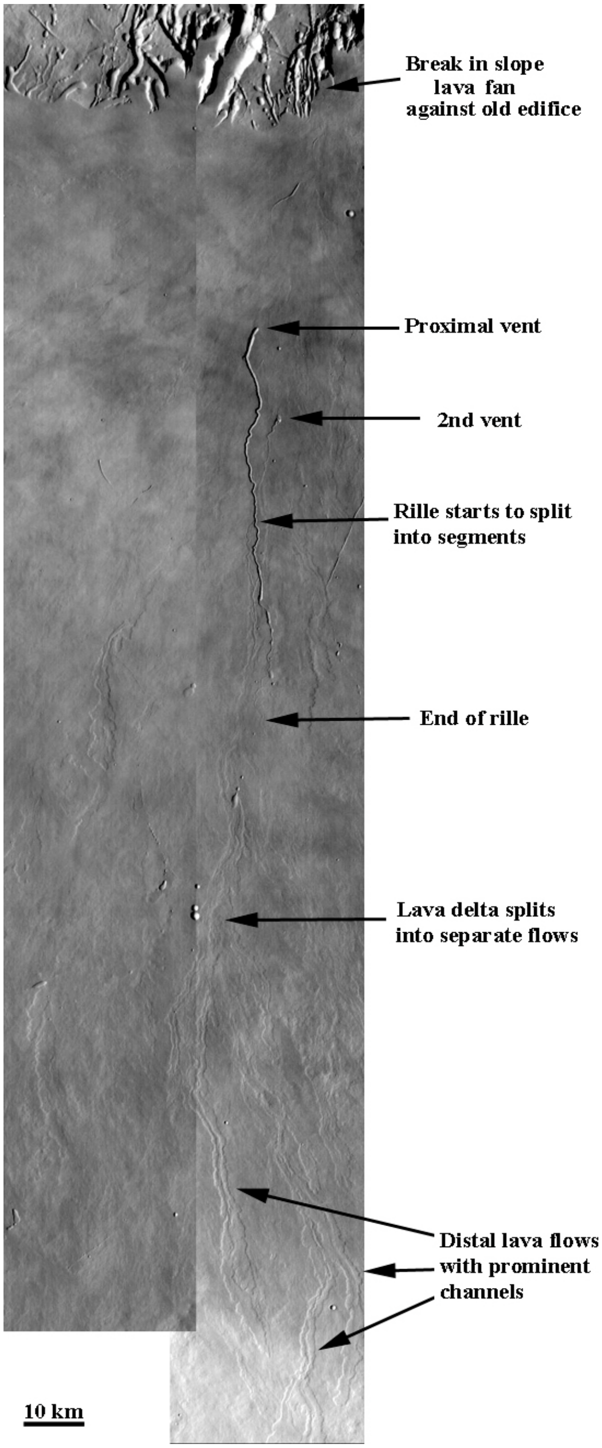

Figure 2: Mosaic of two daytime IR THEMIS images (frames I01116001 and I01453001), showing the entire length of the sinuous rille/lava flow sequence described in the text. See Figure 1 for location.

What is apparent is that the transition from sinuous rille to lava flow occurs at a subtle break in slope on the flank of the volcano, with the rille restricted to the shallower slopes. At the increase in slope, lava appears to have spilled out of the rille and formed a series of surface flows. This is not an abrupt transition as numerous over-spill points can be seen, but the loss of lava from the rille resulted in a reduction in rille width. The rille eventually ends as several isolated pit craters, which may indicate that a lava tube was formed.

Middle Flank Pit Craters

The upper flanks of Arsia Mons, from ~12 km elevation to the caldera rim crest, display a dramatically different morphology. Figure 3 shows that many circular to elongate craters ~1 - 6 km in diameter cluster along the rift zone. Close inspection of these craters reveals that no lava flows were erupted from these pits, and that several pits have concentric patterns around their rims indicative of slumping. Similar craters have been observed on Alba Patera, and have been interpreted [6, 7] to have formed shortly after the emplacement of a dike into the edifice. At Alba Patera, an explosive phase of plinian activity was proposed as the most likely cause of the collapse [7]. Were this model to be applied to Arsia Mons it would be consistent with the identification of extensive ash deposits at comparable elevations on the NW flank of the volcano [1].

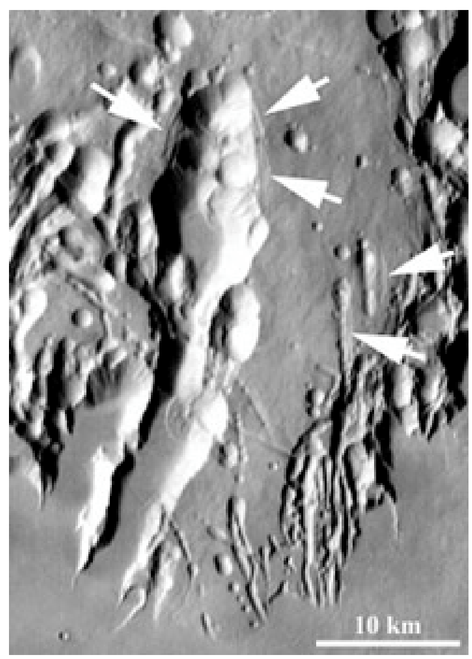

Figure 3: Just south of the caldera rim, there are numerous pits up to ~6 km in diameter. Notice the lack of lava flows and the concentric sag-like features around the elongate pits (arrowed). THEMIS IR frame no. I0453001.

Intra-Caldera Lava Shields

First recognized on low-Sun Viking Orbiter images [2], a series of over a dozen small lava shields can now be recognized in both topographic (Fig. 4) and image (Fig. 5, 6) data. These shields form almost a north-south line extending across the caldera floor, with two additional shields on the SW portion of the caldera floor. Heights measured from the 1/128th degree MOLA DEM range from ~80 – 140 m, and widths from ~8 – 54 km. THEMIS VIS data (Fig. 5) show that these features are indeed analogs to terrestrial shield volcanoes, with many different flows radiating away from a summit crater. The few MOC images that cover these intra-caldera shields (Fig. 6) also show that some of the craters have multiple levels, perhaps indicative of former lava lakes successively filling and draining the summit area.

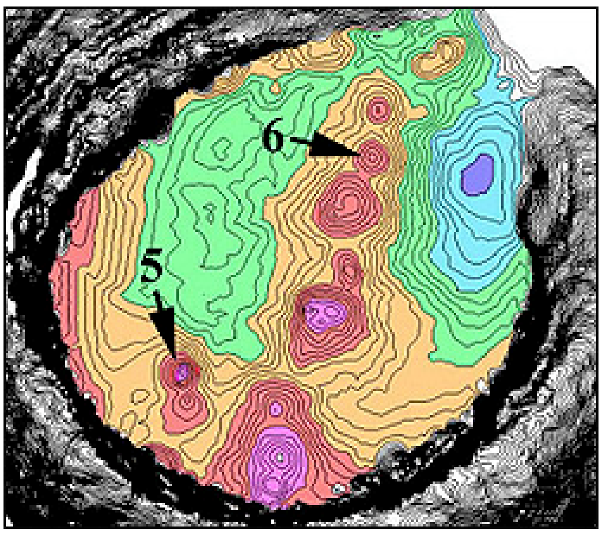

Figure 4: Topographic map of the floor of Arsia Mons caldera, derived from the 128th degree MOLA DEM. Contour interval is 25 meters, and clearly shows the locations of at least a dozen separate small shield volcanoes on the floor. Colored contours are for the elevation range 16,175 – 16,475 m, while black contours mark higher elevations on the caldera rim. Unlike other Martian calderas, Arsia Mons has a relatively flat caldera floor, which enables the shields built along the fissure to be easily identified. The locations of Figures 5 and 6 area shown. Width of caldera is ~110 km. North is towards the top of the image.

An important issue regarding these shields is their apparent absence from much of the caldera floor. Clearly their origin is related to the structural trend that extends NE – SW through the summit area. But their origin is also enigmatic because possible rift zones also exist on the volcanoes Pavonis and Ascraeus Montes [2, 6] and yet no intra-caldera activity can be identified on these other volcanoes in either the MOLA or MOC data sets.

Implications

The first identification of an entire long (>100 km) lava flow on Mars has importance for several of the current models of lava flow rheology [8, 9] because it enables us to define the total length of the lava flow, and to correlate the flow area with the geometry of the rille [5]. The observations presented here also clearly demonstrate that sinuous rilles on Mars can be the source of long lava flows. As more THEMIS data become available for other volcanic regions, particularly Elysium Planitia (where rilles and flows have been individually identified but not correlated with each other [4, 5]), the possibility for the identification of other vent areas and matching them with specific lava flows should provide new constraints for modeling flow fields on Mars.

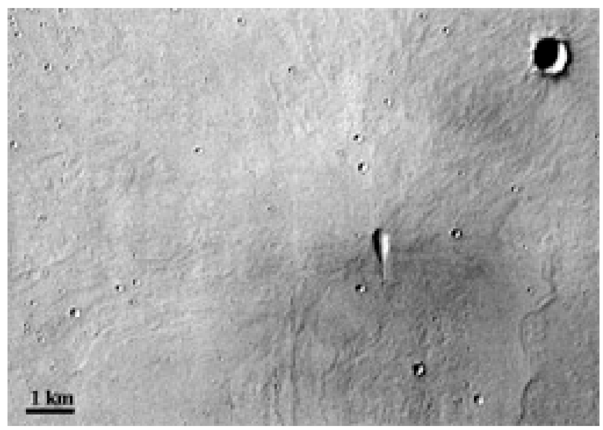

Figure 5: THEMIS visible image of a lava shield in the center of Arsia Mons caldera. See Figure 4 for location. Lava flows can be seen radiating in all directions from the elongate summit crater. MOLA data indicate that this shield is ~90 m high. North is towards the top. THEMIS frame number V04399002.

The diversity of activity identified here within a relatively small portion of Arsia Mons also warrants additional attention, because it has specific implications for models for the internal structure of Martian shield volcanoes [6, 7]. The simplest interpretation of the intra-caldera lava shields is that they were formed during a single eruption, when a dike approached the surface and allowed relatively small volumes of lava to be erupted. The reason why such features have not been identified on other volcanoes on Mars remains problematic, but may be associated with the observation that Arsia Mons is the only Tharsis volcano where pit craters on the outer flanks extend all the way to the rim of the caldera. These collapse pits high on the rim may indicate that dikes were able to penetrate to much higher elevations on Arsia Mons than the other volcanoes.

If this interpretation of shallow dikes is correct, then an explanation may exist to explain why the three Tharsis Ridge volcanoes have the extensive set of collapse pits near their summits, but that such features are absent on Olympus Mons. The NE - SW structural trend, and the resultant concentration of dikes and volatiles in a specific part of the volcano, may be the cause. Numerous shallow dikes along the Tharsis Ridge volcanoes may have favored the concentration of juvenile volatiles from the magma at a few preferred places. When subsequent intrusions interacted with these volatiles, explosive eruptions would have occurred [6, 7]. The implication is therefore that Olympus Mons lacked rift zones, and so was able to disperse juvenile volatiles over a sufficiently large area to prevent subsequent explosive activity.

Figure 6: MOC view of the elongate summit crater of one of the lava shileds on the floor of Arsia Mons caldera. See Figure 4 for location. Notice the prominent layering on the western (left hand) side. This shield is higher (total height ~160 m) and broader than the one shown in Figure 5. Image resolution is ~6.6 m/pixel. North is towards the top. MOC frame no. E1003391.

References

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