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Plateaus and sinuous ridges as the fingerprints of lava flow inflation in the Eastern Tharsis Plains of Mars

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ABSTRACT

The Tharsis Montes rift aprons are composed of outpourings of lava from chaotic terrains to the northeast and southwest flank of each volcano. Sinuous and branching channel networks that are present on the rift aprons suggest the possibility of fluvial processes in their development, or erosion by rapidly emplaced lavas, but the style of lava flow emplacement throughout rift apron development is not clearly understood. To better characterize the style of lava emplacement and role of fluvial processes in rift apron development, we conducted morphological mapping of the Pavonis Mons southwest rift apron and the eastern Tharsis plains using images from the High Resolution Imaging Science Experiment (HiRISE), Mars Orbiter Camera (MOC), Context Camera (CTX), Thermal Emission Imaging System (THEMIS), and High Resolution Stereo Camera (HRSC) along with the Mars Orbiter Laser Altimeter (MOLA) Precision Experiment Data Records (PEDRs) and gridded data. Our approach was to: (1) search for depositional fans at the slope break between the rift apron and adjacent low slope plains; (2) determine if there is evidence that previously formed deposits might have been buried by plains units; (3) characterize the Tharsis plains morphologies east of Pavonis Mons; and (4) assess their relationship to the rift apron units. We have not identified topographically significant depositional fans, nor did we observe evidence to suggest that plains units have buried older rift apron units. Flow features associated with the rift apron are observed to continue across the slope break onto the plains. In this area, the plains are composed of a variety of small fissures and low shield vents around which broad channel-fed and tube-fed flows have been identified. We also find broad, flat-topped plateaus and sinuous ridges mixed among the channels, tubes and vents. Flat-topped plateaus and sinuous ridges are morphologies that are analogous to those observed on the coastal plain of Hawai'i, where lava flows have advanced from the volcano's several degree flank onto the nearly zero degree coastal plain. When local volumetric flow rates are low, flow fronts tend to spread laterally and often thicken via endogenous growth, or inflation, of the sheet-like flow units. If flow advance is restricted by existing topography into narrow pathways, inflation can be focused into sinuous, elongate ridges. The presence of plateaus and ridges—emplaced from the rift zones, across the plains to the east of Pavonis Mons—and a lack of fan-like features, or evidence for their burial, are consistent with rift apron lavas crossing a slope break with low local volumetric flow rates that led to inflation of sheet-like and tube-fed lava flows.

1. Introduction

The Tharsis Volcanic Province of Mars is a broad volcanic rise that includes several large shield volcanoes, including the NE-trending chain of the Tharsis Montes, Arsia, Pavonis, and Ascraeus Mons (Fig. 1) (Carr et al., 1977; Greeley and Spudis, 1981; Mouginis-Mark et al., 1992; Hodges and Moore, 1994). These volcanoes have each experienced an episode of main flank development involving eruptions from the summit, followed by rifting to the northeast and southwest, to form extensive rift zones and deposits that are collectively known as the Tharsis Montes rift aprons (Fig. 2) (Carr et al., 1977; Crumpler et al., 2007). The rift aprons are thought to have largely involved lava emplacement from within the chasmata (chaotic terrains formed by collapse of the

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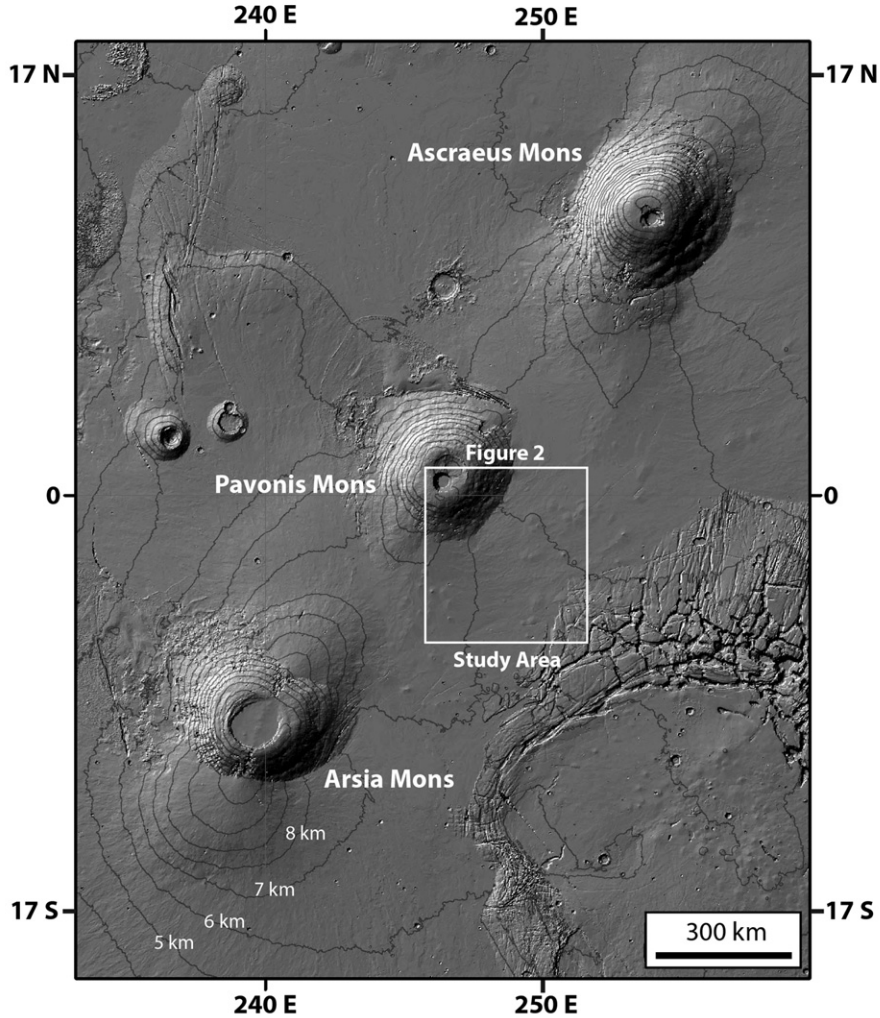

Fig. 1. MOLA shaded relief image of the Tharsis Montes. Each shield volcano displays a main flank and rift aprons to the NE and SW. The change from main flank to rift apron and vent field involves a decrease in slope from 4–6° to 1–3°. The rift apron and vent field flows extend out onto the regional Tharsis plains, where slopes decrease to <1°. The study area in Fig. 2 is shown in the white box. Contours shown in black are at a 1 km interval, and labeled to the South of Arsia Mons.

main flank) (Carr et al., 1977; Crumpler et al., 2007). Post-Viking era data have shown that rift apron development involved significant lava emplacement through rift zone-aligned groups of low shields and fissure vents (Plescia, 2004; Bleacher et al., 2007a; Bleacher et al., 2009). Some lava flows erupted during rift apron development are at least several hundred kilometers long (Garry et al., 2007) and extend across a topographic and slope boundary that transitions from the 1° to 3° slope of the rift aprons (Plescia, 2004; Bleacher et al., 2007a) to the nearly 0° slope of the Tharsis plains.

It is also proposed that development of the rift aprons might have involved the release of large volumes of water, subsequent fluvial erosion, and/or possible emplacement of mud deposits (Mouginis-Mark and Christensen, 2005; Murray et al., 2010). Murray et al. (2010) suggest that the rift aprons themselves might be composed primarily of mud flows instead of lava flows. The features that lead to this interpretation are complex channel networks, which are typically composed of single-stem non-leveed rilles that can also display sections of branching channels with terraced walls and islands. These features can be over 100 km in length and rarely display obvious lateral or distal margins. Bleacher et al. (2007a) conducted morphologic mapping of portions of the Tharsis Montes southwest rift aprons, and suggested these complex channels result from modification of existing surface units, which they called the channel network terrain (CNT). However, Bleacher et al. (2007a) did not present an interpretation of the mode of modification. Mouginis-Mark and Christensen (2005) and Murray et al. (2010) suggested that the source of this surface modification was erosion by overland flow of water (Fig. 3). However, no fluvial depositional features have been identified as would be expected if fluvial erosion cut channels 10 s to 100 s of kilometers long. Although a fluvial erosion interpretation is difficult to explain if no depositional fans are associated with the channels, it is possible that these features might have been buried by subsequent lava emplacement, if the plains flows are younger than the rift aprons (including any fluvial activity). This is possible as the abundant volcanic vents identified on the Tharsis plains (Plescia, 2004; Bleacher et al., 2007a, 2009; Keszthelyi et al., 2008; Baptista et al., 2008; Baratoux et al., 2009; Hauber et al., 2009, 2011; Wilson et al., 2009; Brož and Hauber, 2012; Richardson et al., 2013; Brož et al., 2014) could be comparatively young (Hauber et al., 2011) and could represent volcanic plains that are genetically unique from the rift apron flows. Regardless, active lava flows can also produce depositional fans at slope breaks as lava is debouched from channels onto the lower slope terrain (Carr and Greeley, 1980). Thus, the lack of depositional fans at this slope break would neither definitively support nor refute either hypothesis.

Numerous investigations have described morphologies and structures within the rift aprons (Plescia, 2004; Mouginis-Mark and Christensen, 2005; Garry et al., 2007; Bleacher et al., 2007a, b; Mouginis-Mark and Rowland, 2008; Bleacher et al., 2009; Murray et al., 2010), but only a few studies (e.g., Garry et al., 2007), focused on lava flows extending from the rift aprons onto the adjacent Tharsis