DETECTION OF LAVA FLOW UNIT THICKNESSES AND CHARACTERISTICS ON MARS: FIRST RESULTS FROM MARS ORBITER LASER ALTIMETER (MOLA) DATA. James W. Head¹, Nicole Seibert¹, Stephen Pratt¹, D. Smith², M. Zuber², and the MOLA Science Team. ¹Dept. of Geological Sciences, Brown University, Providence, RI 02912; ²NASA GSFC, 20771; ³MIT, Cambridge, MA 02139. James_Head_III@Brown.edu.

Introduction: Volcanism is an important process in planetary resurfacing, heat transfer, and crustal formation and evolution, and the volcanic stratigraphy of a planet provides significant clues to its thermal and compositional evolution. Mars is characterized by a wide range of volcanic landforms and deposits [1] and the volcanic stratigraphy shows clear evidence for changes in flux and style with time [2-5]. Crucial to the deconvolution of the volcanic stratigraphic record is information on the morphology and morphometry of volcanic flows and flow units. The Mars Orbiter Laser Altimeter (MOLA) was designed to obtain a network of data points of high vertical resolution [6] to address such questions, and here we report on the initial results from altimetry profiles that cross several flow units.

Lava flows and flow units make up much of the surface of the volcanic edifices on Mars, and their morphology and morphometry provide important information for understanding styles of emplacement and estimating rheological properties of the lava [7,8]. The morphological features of lava flow deposits depend on several factors: the composition and temperature-dependent rheological properties of the erupted materials; environmental variables such as the flow cooling rate under the ambient atmospheric conditions and surface temperature; and the physical parameters of the eruption, such as vent size and shape, total lava effusion rate, slope of the ground over which the flow advances, and planetary gravity [7]. Effusion rate commonly varies during an eruption, flows advance down slopes which often vary systematically with distance from the vent, and lava rheology changes with progressive cooling. Thus, there are many interdependencies between the above parameters [7]. Although shadow measurements and photoclinometry have provided initial estimates of flow parameters [5,8,9], MOLA data can provide very important information on a wide variety of characteristics including: 1) flow height and width, 2) flow cross-sectional shape and area, 3) evidence for levees and channels, and their morphometric characteristics (e.g., channel width and depth), 4) flow rms slope, 5) along-strike variations in flow properties, 6) regional slope, 7) relation to vents, and 8) relation to adjacent and subjacent stratigraphic units. Here we report on initial results for eight flow units detected in the MOLA data.

Examples of flow unit definition and characterization: (Table 1, Profiles 1-8; north is to the right in all profiles):

**Arsia Mons 1:** A prominent flow unit (Table 1, Profile 7) is observed in Viking data on the distal flanks of Arsia Mons (about 1100 km from the summit), which is part of series of flow units comprising Tharsis Montes [5,9,10]. Here, the distal portions of an Amazonian flow unit (At4) are superposed on an older unit (AHT3), both apparently derived from Arsia Mons [10]. The MOLA profile crosses the flow unit almost normal to its flow direction and clearly reveals the topography as the unit transitions from an elongated flow to a terminal lobe about 10-50 km from its terminus. MOLA data show that the flow is emplaced on a slope of older (AHT3) material (upward slope at the southern edge of the profile) and that it has a width of about 75 km and a thickness of about 270 m. A distinctive superposed lobe (northern part of the surface) has a width of about 50 km, a thickness of about 100 m, and is broadly convex upward. The unusually great thickness of this flow unit is most plausibly related to ponding, inflation, and multiple breakouts in the vicinity of the distal end of the flow.

**Arsia Mons 2:** This flow unit (Table 1, Profile 1) is in unit At6 (the apron of flows emerging from the flanks of Arsia [5,9]), is visible in Viking images, occurs on the northern flanks of Arsia Mons about 200 km from the summit, and is about 11.2 km wide and 80 m high. The along-profile background slope is less than ~1°; the margins of the flow are very well defined and the flow is slightly convex upward, with a hint of 20-30 m deep central channel offset slightly to the south.

**Arsia Mons 3:** This flow unit (Table 1, Profile 2) is also in unit At6, occurs on the flanks of Arsia Mons about 220 km from the summit, and is about 10 km wide and 100 m high. The MOLA along-profile data show a background slope of ~1.25°; the margins of the flow are very well defined and the flow is slightly convex downward with a suggestion of a 3 km wide, ~50 m deep complex central channel.

**Alba Patera 1:** A prominent flow unit (Table 1, Profile 3) is observed in Viking data along the western flanks of Alba Patera [11,12] where Hesperian-Amazonian-aged flows extend radially beyond the graben-encircled summit region, flowing part way down the western flanks of the edifice and underly-
ing an apron of younger flows that emanate from the central part of the caldera [12]. This flow unit is about 450 km from the summit, is about 30 km wide and is typically ~125 m in thickness but ranges up to about 220 m thickness along its northern edge. The MOLA data show a regional along-profile slope of less than 0.5\(^\circ\).

**Alba Patera 2**: A flow unit observed in Viking data (Table 1, Profile 4) occurs along the northern slopes of Alba Patera about 400 km from the summit and is in unit Aam (middle member of the Alba Patera Formation [10]). The along-profile slope (~1.5\(^\circ\)) is steeper than in Alba Patera 1 and may be related to edifice asymmetry and tilting [13], and the flow is narrower (9 km) and thinner (~80 m). MOLA data suggest the presence of levees 2-3 km wide and the presence of a central channel with a convex-upward surface.

**Elysium Mons 1**: A flow unit, prominent in Viking images and detected in MOLA data (Table 1, Profile 5), is observed along the northwestern slopes of Elysium Mons (along-profile slopes of ~1\(^\circ\)) and is part of the apron of flows (Ael2) surrounding this edifice [14]; the profile crosses the flow unit about 425 km NW of the summit. The flow unit is about 10 km wide and 40-70 m thick, and a central depression is observed, apparently representing the central lava channel seen in Viking images.

**Elysium Mons 2**: A second flow unit observed along the western slopes of Elysium Mons, is detected in MOLA data (Table 1, Profile 6), is part of the same flow apron that surrounds Elysium Mons (Ael2). The profile intersects the flow about 330 km WNW of the summit of Elysium Mons. The flow unit is about the same width as the Elysium Mons 1 flow unit, but is thinner (about 40 m) and appears slightly convex downward.

**Syrtis Major 1**: Hesperian-aged flow units form the major low-lying shield structure in Syrtis Major [14,15,13] and this feature is capped by two caldera-like features (Nil and Meroe Paterae); many radial flows emanate from the summit region. On the basis of imaging spectrometer data, this area is interpreted to be formed of shergottite-like basalts [16]. One flow observed in Viking images and detected in MOLA data (Table 1, Profile 8) is located on the northern flanks of the Syrtis Major structure [15,13] is typically 25-30 m thick (locally up to 38 m thick on the southern margin) and has a convex downward profile. This is the thinnest flow unit of the group examined so far.

**Discussion and conclusions**: Initial analysis of these Mars Orbiter Laser Altimeter profiles clearly show that MOLA data represent an important tool in documenting the stratigraphic relationships between and among different local and regional geological units (Profile 7). Also promising is data on the surface roughness of the flow units at the MOLA along-track altimetry scale. Distinctive variations in RMS slopes can not only be seen in regional photogeologic units, but preliminary data on these individual flows (Table 1) shows that there are variations in the mean RMS slopes between flow units and between shield types and ages. For example the Hesperian-aged flow unit on the low Syrtis Major shield [15,13] has an RMS slope of about 0.78, while all other flows analyzed have RMS slopes of between 1.3 and 2.1. Many more examples, and detailed imaging [17] and regional MOLA coverage will be required to distinguish between primary flow roughness and subsequent alteration processes such as eolian mantling, but these initial results are promising.

Finally, initial analysis of MOLA profiles across individual lava flow units clearly shows that flow units and their morphology and morphometry can be documented using data from the MOLA instrument. Among the many features clearly detected and documented in this preliminary analysis are flow heights and widths, cross-sectional shape, steep flow margins, evidence for flow levees and channels, local and regional slopes on which the flows are emplaced, variations in flow characteristics as a function of distance from the source [e.g., compare proximal (Arsia Mons 2 and 3) and distal (Arsia Mons 1) flows from Arsia Mons], evidence for different flow types [9], and flow unit thickness variations between edifices of different morphology, morphometry [13], and possibly composition [16]. Additional and higher density MOLA data will permit along-flow analyses, and the comparison of additional flow units of different ages and settings and is essential in the quantitative study of the volcanology and thermal evolution of Mars.


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<th>Flow</th>
<th>Orbit Number</th>
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<th>Location</th>
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<th>Width</th>
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