DOWNFLOW WIDTH BEHAVIOR OF MARTIAN AND TERRESTRIAL LAVA FLOWS;

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Lava flow morphology is typically the primary type of data available for constraining planetary volcanic processes. Flow emplacement (and hence morphology) is controlled by topography, rheology, and thermal history, but the exact relationship between these factors and the resulting flow shape is not well understood [1]. Accurate interpretation of flow dynamics is dependent upon well-constrained flow geometry. Previous modeling studies have commonly assumed relatively constant flow widths [2] and/or cross-sectional areas [3], use a single value for width based upon a limited number of measurements [4-6], or do not consider width at all. Recent analysis of individual flow lobes in the Puu Oo flow field on the east rift zone of Kilauea Volcano show that flow widths vary by up to an order of magnitude [7]. Significant width variations in Martian flows on Tyrhenna Patera, Alba Patera, and Elysium Mons are also observed. Complex flow-forms may be the result of spatially-interacting, temporally-discrete episodes in addition to contemporaneously emplaced flows. Variations in width with downflow distance from the vent may provide critical clues to flow emplacement processes and volcanic stratigraphy; furthermore, flow width is one of the few characteristics that can easily be measured from planetary mission data. The relative widths and lengths of lava flows are presumably a function of the relationship between the lateral spreading rate and flow front advance. Width/length "aspect ratios" are used to quantify this; however, they are highly dependent upon flow history interpretations. Although topography is thought to be a primary control, recent studies [7-8] have demonstrated a marked insensitivity of flow morphology to topographic variations at 20 to 40 foot scales.

Lava Flow Study Sites: As part of an ongoing analysis of lava flow emplacement mechanisms, flow morphology at three Martian and two terrestrial volcanic centers was investigated. For Puu Oo, a contemporary, well-studied basaltic cone with associated flows, 52 lobes were examined. Flow widths were measured as a function of downflow distance from the vent, using the maps of Wolfe et al. [9]. Widths of five flows on Glass Mountain, a series of prehistoric rhyolite/dacite flows in California, were also measured, assuming the summit as the presumed vent. Flow widths were measured on the USGS West of Kephart Quadrangle. Vents for Martian flow lobes could not be clearly identified; a reference position was substituted as an inferred source. Thirty-nine previously mapped flows on Alba Patera [10] and 22 flows on Tyrrhena Patera [6] were analyzed. Five flows north of Elysium Mons were mapped using Viking orbiter images and MTM Quadrangles 30212 and 35212; these conform roughly to flows mapped earlier by Mouginis-Mark [11]. Results of these studies are summarized in Table 1. In general, Martian flows are roughly equivalent in size, and approximately an order of magnitude larger than the terrestrial analogs.

Table 1: Lava Flow Characteristics [7, 8]

Characteristic	Glass Mt	Puu Oo	Tyrrhena Patera	Alba Patera	Elysium
Flow length					
range	2940 - 6000 m	1200 - 1350 m	12.5 -114.8 km	9.3 - 173.3 km	25.6 - 82.3 km
mean	4250 m	4796 m	43.6 km	41.5 km	40.3 km
Flow width					
minimum	60 m	25 m	1.6 km	1.2 km	1.8 km
maximum	876 m	825 m	42.2 km	15.1 km	10.5 km
Average flow width					
range	214 - 759 m	100 - 450 m	2.5 - 25.6 km	1.2 - 6.8 km	4.8 - 8.2 km
mean	422 m	246 m	7.9 km	2.9 km	6.3 km
Aspect ratios:					
mean width/length	0.044 - 0.26 (0.11)	0.016 - 0.36 (0.076)	0.09 - 0.43 (0.20)	0.020 - 0.261 (0.106)	0.087 - 0.28 (0.18)
maximum width/length	0.054 - 0.30 (0.15)	0.033- 0.44 (0.14)	0.13 - 0.71 (0.32)	0.0430-0.356 (0.148)	0.13 - 0.35 (0.26)
mean width/max width	0.77	0.50	0.66	0.71	0.70

Downflow Width Variations in Individual Flows: Results of this study do not support previous modeling assumptions that lava flows maintain relatively constant widths. A wide variety of width behavior was observed; some flow widths remained constant, while others varied by over an order of magnitude. The following trends were identified: linear widening with distance from the vent, linear narrowing, cyclic and/or irregular width increases and decreases, constant or dynamically-constant width behavior, sudden narrowing, swelling (widening followed by narrowing), and constriction (narrowing followed by widening). Specific explanations for width behavior are generally lacking, even in well-observed Puu Oo flows. Cyclic behavior may be caused by flow surging, as documented in the field [9] and is most likely supply dependent. Constriction may be caused by topographic flow channeling, stagnation followed by reinvigoration and continued advance, stagnation followed by break-out of a new lobe, or flow superposition, sometimes caused by reuse of a channel (Figure 1). Proper identification and characterization of flow margins are necessary to distinguish between alternative hypotheses.

Complications due to Branching and Flow Stratigraphy: In addition to variations within individual flows, compound flow fields, including simple, convoluted, and interweaving patterns, are observed on Earth and Mars. Branching flows at Puu Oo were observed to either diverge or interact during emplacement. Partial to complete superposition of subsequent flows obscures the emplacement history. For unobserved flow emplacement, delineation of flow lobes is complicated by these phenomena.

Width/length Comparisons: The gross morphology of lava flows can be compared via non-dimensional ratios (Table 1). Aspect ratios representing overall planimetric signatures were complied by normalizing mean and maximum widths to flow length. Terrestrial values are commonly low; Martian values range from near-terrestrial at Alba Patera to significantly greater at Tyrrhena Patera. Mean width was also normalized to maximum width; this "width ratio" quantifies the relative importance of width changes in a single flow. In general Martian flows have higher width ratios than Puu Oo basaltic flows, but lower than silicic Glass Mountain flows. Because, in most cases, Martian flows cannot be traced to a source, definitions of length are subject to uncertainty and use of width/length aspect ratios is problematic. Alternative explanations of width behavior may also complicate analysis. Multiple interpretations of the same flow are possible, resulting in greatly different W/L ratios (Figure 1).

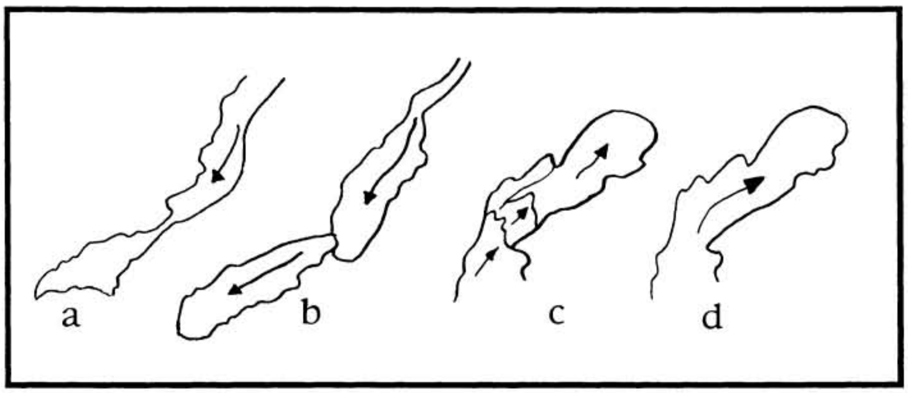

Figure 1. Flow geometry illustrations. a. Single-lobe constriction of Puu Oo Episode 9 flow (adapted from [9]). b. Tyrrhena Patera: Compound shape interpreted as breakout from previous flow lobe (from [6]). c. Elysium: Flow interpreted as series of breakouts (modified from [11]). d. Elysium: Alternative single-lobe interpretation of flow in c.

An example of this is the Elysium flow located at 33.5° N, 213.25° W. Mouginis-Mark (11) interpreted this flow shape as the result of continued breakout from the stagnated fronts of 3 discrete lobes, yielding high Wmax/l (maximum width to length) ratios for the breakout lobes (0.57-0.59). Interpreting these features as a single lobe leads to a lower Wmax/l (0.16). The proximal end of this flow field is unclear due to low image resolution; if it is assumed that the flow emerged from the Elysium Mons caldera, then the Wmax/l ratio is 0.033. Mean width/maximum width ratios are less influenced by length interpretation, although variations might result if the width behavior for a flow varies strongly in regions not included in the interpreted flow lobe.

Conclusions: Interpretation of flow dynamics from flow morphology requires well-constrained flow geometry. Interactions between flows and subsequent emplacement of additional flows atop or adjacent to existing structures may produce complex planimetric forms which may complicate analysis. A thorough understanding of both downflow width behavior within individual flows and flow interactions may simplify this task.

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