DOWNFLOW MORPHOLOGIC VARIATIONS IN HAWAIIAN AND MARTIAN LAVA FLOWS; ***David A. Crown and Matthew N. Peitersen,*** *Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260;*

Determination of the physical properties and emplacement conditions of planetary lava flows is dependent upon observations of flow morphology, measurement of flow dimensions, and the development and use of appropriate dynamical models. Rheologic and thermal models have been used to calculate values for the viscosity, yield strength, and effusion rate of martian lava flows [1-10]. Understanding the relationship between lava flow morphology and eruption conditions, cooling history, and the physical properties of lavas is complicated by the diversity of flow types and lava compositions, variable source conditions during eruptions, variations along flow in underlying topography and surface roughness, and the complexities introduced by temperature-dependent rheologic properties, crust formation, vesiculation, and crystallization. Results from modeling studies are used to assess the evolution of volcanic processes on planetary surfaces with only limited amounts and types of data. Most models of flow behavior use average values of flow width and/or thickness based on a few measurements and do not consider width and thickness as independent variables, but rather assume a constant cross-sectional area [11]. In planetary studies, width and thickness may be two of few known or measurable parameters. Changes in downflow dimensions reflect variations due to the temperature (or time) dependencies of volcanic processes and lava properties; the nature and magnitude of the response of a flow to changes in underlying slope also provides important but often neglected information regarding its eruption and emplacement history. Utilization of all relevant data is essential for accurate interpretations of lava flow dynamics and styles of planetary volcanism.

In order to interpret downflow morphologic variations in martian lava flows, data from terrestrial flows are being analyzed. The recent eruptions of Puu Oo (Episodes 1-20, 1983-1984) were well observed, and maps were produced indicating pre-flow topography, planimetric areas, thicknesses, and flow front positions at various times [12]. Flows greater than 1 km in length emplaced during Episodes 1-9 have thus far been examined; these flows are single lobed or branch into several main lobes. The flows are predominantly a'a, but some events initially emplaced pahoehoe adjacent to the vent which underwent a transition to a'a within approximately a km. Flow width, thickness, velocity, and the underlying slope were determined for each flow as a function of distance from the vent; mean values and ranges are shown in Table 1.

Average Flow Dimensions. Flow lengths range from 1750 to 8250 m over average slopes between ~1° and 7°. In general, greater flow lengths occur where average slopes are larger. A weak correlation also exists between flow length and average flow thickness; however, only small variations in average flow thickness (3.0 - 7.5 m) exist for the population studied. No correlation is evident between average flow width and flow length, average flow thickness, or average slope traversed. Average thickness increases with average flow length as well as with average slope, suggesting that, if flows behave as Bingham materials, yield strengths are greater in longer flows and perhaps increase downflow. This thickness-slope correlation is strongest for flows whose width or thickness increase linearly as a function of downflow distance. Downflow changes in flow morphology due to increases in yield strength may occur after some critical distance at which the effects of cooling and crystallization significantly influence flow properties. If yield strength were a constant material property, flow thickness should be negatively correlated with slope; this relationship is not observed between mean values or within individual flows. Using the equation $\tau_y = \rho g h \sin\theta$ [13], where τ_y = yield strength, ρ = flow density = 2500 kg/m^3, g = gravitational acceleration = 9.8 m/s^2, h = flow thickness, and θ = slope, and mean values from Table 1, yield strengths range from 2.1×10^3 to 2.2×10^4 Pa for these flows, comparable to the range calculated by Fink and Zimbelman [14] for Episode 2-5 Royal Gardens flows based on field measurements made at their distal ends. Yield strength variations within individual flows would be greater since measured flow thicknesses range from 0.6 to 11 m and local slopes range from 0° to 31.4°.

Downflow Variations in Flow Dimensions. Analysis of data for individual flows illustrates that while no systematic changes in flow width are evident, three different types of behavior can be recognized (listed in order of frequency of occurrence): 1) a flow narrows with downflow distance, 2) a flow steadily increases in width and then steadily decreases in width, or 3) a flow exhibits a cyclic increase in width with downflow distance. Decreases in flow width with distance can be attributed to either decreases in the local flow rate or to the inability of a flow to spread due to an increase in viscosity. A cyclic increase in flow width may result from variations in vent conditions resulting in surging behavior. Relationships between width and slope and width and thickness are not consistent, although some flows show a slight positive correlation between width and thickness. Variations in thickness within individual flows are small and no consistent trend is apparent, although in some cases flows tend to increase slightly in thickness with downflow distance. The correlation between average flow thickness and average slope is not mimicked at the individual points along flows where thickness measurements were obtained.

The lack of a strong correlation between flow width and thickness and the variable nature of downflow changes in width and thickness have important implications for modeling studies. Data from Puu Oo Episode 1-9 flows do not support previous assumptions that the width or cross-sectional area of a flow remains constant throughout its emplacement. The different types of downflow changes in width may be indicative of different source conditions, and upon further analysis, may be used to define different classes of flow behavior which require different modeling approaches or constraints.

Sensitivity to Topography. The width and thickness of an individual flow do not change systematically with slope. Thus it appears that these flows are not sensitive to changes in topography at the scale at which measurements were made (20 foot contour interval) or that the response of flows is not a simple function of slope; the flow geometry may have a time-delayed response to variations in topography at this scale due to flow rheology or to slope-dependent changes in flow rate. It is also possible that flows are much more strongly controlled by topography and surface roughness at much smaller scales. An assessment of the topographic scale sensitivity of lava flows is necessary to provide proper constraints for theoretical models and for optimal design of instruments used to make topographic measurements of planetary surfaces.

Comparison to Martian Lava Flows. Analyses of downflow morphologic variations in planetary lava flows have been initiated by measuring changes in width exhibited by a series of lobate flows associated with Tyrrhena Patera in the southern highlands of Mars [10, 15-16]. These flows are contained in a unit extending from the summit of Tyrrhena Patera to the southwest for over 1000 km; the average regional slope in the region is ~0.002° [15]. Width measurements were made every ~3 km along 22 flows. Flow widths range from 1.6 to 42.2 km with mean flow widths between 2.5 and 25.6 km. Flow lengths range from 12.5 to 114.8 km, but should be considered minimum values since flows cannot be traced to their source vents. A weak positive correlation exists between width and flow length. The downflow behavior of the flow width is not consistent; some flows steadily increase or decrease in width over their lengths and others remain constant in width or exhibit irregular variations. Further analysis of these flows, including detailed descriptions of their surface and margin morphologies, and flows in other areas on Mars will allow martian flows to be classified on the basis of these changes and their characteristics to be compared to relevant terrestrial flows.

Table 1. Characteristics of Hawaiian Lava Flows: Puu Oo Episodes 1-9

Episode and Flow	Flow Length (m)	Flow Width Range (m)	Mean Flow Width (m)	Thickness Range (m)	Mean Thickness (m)	Slope Range (degrees)	Mean Slope (degrees)	Mean Flow Front Velocity (m/hr)
1/1	2550	100-250	150	n/a	n/a	1-7	2.4	n/a
1/2	5675	100-700	345	n/a	n/a	1-14	4.0	1384
2/1	7625	100-475	258	3.0-10.5	6.2	1-14	5.0	51
3/1	5150	100-400	198	2.8-7.5	4.5	1-7	3.0	85
3/2	3800	100-650	315	3.5-7.2	5.4	1-14	3.0	26
3/3	4525	25-650	286	2.5-7.4	4.9	1-7	2.8	8
3/4	8175	50-600	237	3.0-9.0	5.2	1-14	5.3	118
4/1	7925	25-650	213	3.1-10.7	7.5	0-31	6.8	125
5/1	5900	50-325	149	0.6-5.0	3.0	1-7	3.1	73
5/2	8250	25-450	230	0.8-11.0	4.7	1-17	6.1	175
6/1	6250	125-800	448	3.0-7.5	4.8	1-5	1.9	100
7/1	2600	100-350	246	2.0-6.0	4.2	0-14	2.6	94
7/2S	6500	50-600	252	2.7-4.5	3.6	0-4	1.4	147
7/2NE	6750	100-600	246	2.7-4.5	3.7	0-7	1.5	150
7/2M	5600	125-600	291	3.0-4.5	3.8	0-7	1.7	154
7/2N	4900	125-600	311	3.0-4.5	3.7	0-4	1.3	113
8/1	3575	125-675	223	3.5-4.5	4.0	0-3	1.5	136
8/2	1750	325-500	312	3.0-3.5	3.1	1-7	2.9	n/a
9/1	5125	75-550	347	3.0-7.5	5.1	0-4	1.6	112

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