DOWNFLOW MORPHOLOGIC VARIATIONS IN HAWAIIAN LAVA FLOWS: IMPLICATIONS FOR MODELING PLANETARY LAVA FLOW EMPLACEMENT; ***David A. Crown and Matthew N. Peitersen,*** *Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260.*

Models for the emplacement of lava flows on planetary surfaces utilize morphologic properties of flows to constrain eruption conditions, cooling history, and/or the physical properties of lavas. A variety of thermal and rheologic models have been used to assess the types of volcanic processes that have occurred on other planets [1-11]. Most models of flow behavior use average values of flow width and/or flow thickness based on a limited number of measurements. The precision of these measurements, in particular of flow thickness, is highly variable. Changes in flow dimensions along the length of a lava flow represent the combined influences of a series of complex phenomena, including variations due temperature-dependent rheologic properties, variations due to time-variable supply conditions, and changes in the nature and geometry of the underlying surface, as well as the development of a brittle crustal layer. Variations in downflow dimensions thus provide important information regarding eruption and flow emplacement history, but are rarely used in quantitative analyses of flow dynamics. In order to interpret and utilize downflow morphologic variations of planetary lava flows, data from well documented terrestrial flows are being analyzed [12, 13].

Puu Oo Lava Flows. The ongoing activity at Puu Oo on the east rift zone of Kilauea volcano in Hawaii is among the most extensively studied and well documented eruptions [14, 15]. For Episodes 1-20 (1983-1984), maps exist that indicate planimetric areas of lava flows, flow thicknesses, pre-flow topography (20 ft contour interval), and positions of flow fronts at various times [14]. Flow width, thickness, velocity, and the underlying slope have been determined as a function of downflow distance using these maps for 54 flow lobes greater than 1 km in length (Figure 1). From these data, cross-sectional areas, flow rates, and aspect ratios can be computed at semi-regular intervals along an individual flow. All flows examined are single-lobed or branch into several main lobes. The flows are predominantly a'a, but some episodes initially emplaced pahoehoe at the vent which underwent a transition to a'a within approximately a km.

Downflow Variations in Width and Thickness. Significant variations in flow width along individual Hawaiian lava flows are observed; these changes are not systematic but several types of behavior are repeated, including 1) flow narrowing with downflow distance, 2) a steady increase in width followed by steady decrease, and 3) a cyclic increase in width. Interpretations of specific flow width geometries are complicated by interactions between concurrently active flows and overlapping by subsequent flows [13]; however, in general, these trends can be attributed to variations in source conditions, rheologic properties, or emplacement history. Variations in thickness within individual flows (0.4-11 m, mean = 3.7 m for entire population) are small in comparison to width variations and no consistent trends are observed, although in some cases flows tend to increase slightly in thickness downflow. No consistent relationships between flow width and thickness are evident, although several flows show a slight positive correlation between width and thickness.

Influence of Topography. Local pre-flow slopes (*i.e.*, averaged over the distance containing three 20-foot contours) range from 0-31.4° for individual positions along Puu Oo flows. Average slopes for entire flows range from 1.3-6.8°. No obvious correlations between flow width or thickness and underlying slope are evident. The apparent lack of sensitivity of width and thickness to changes in slope suggests a direct dependence on topography at scales significantly smaller than that at which slopes were measured. It is likely that the scale of topography that significantly influences flow morphology is proportional to flow thickness, although an improved correlation between thickness and slope for Puu Oo flows with average thicknesses of > 6 m (≈ contour interval) was not found. Due to rheologic changes and local variations in flow rate, the morphologic expression of the effects of variations in slope may be delayed in time and occur downstream. Continued study of the response of lava flows to changes in slope is critical for accurate interpetations of flow morphology. Further analysis of the Puu Oo flows will include detailed examination for delayed or indirect correlations between flow dimensions and underlying slope and for correlations over small portions of a flow where slopes may be unusually constant or anomalously high or low.

Implications for Modeling Planetary Lava Flows. Individual lava flows emplaced in Episodes 1-20 of the eruption at Puu Oo exhibit significant downflow variations in width, behavior which should be accounted for in models of flow dynamics. The variable nature of flow width in a given flow and the different types of width behavior recognized suggest that the change in lava rheology due to cooling is not the primary factor controlling flow width. The apparent lack of a strong correlation between flow dimensions suggests that flow width and thickness should be treated as independent variables and that the cross-sectional area of a flow is not a constant value.

In many studies, lava flows are assumed to behave as Bingham materials characterized by a bulk yield strength [1, 3-5, 7-10, 15-18]. An isothermal Bingham model has been used to interpret flow morphology [16]. Although different expressions have been used to relate yield strength to flow dimensions [see 15], the most commonly used equation is $\tau_y = \rho \; g \; h \; \sin\theta$, where τ_y = yield strength, ρ = flow density, g = gravitational acceleration, h = flow thickness, and θ = slope [17]. If yield strength were a constant material property, flow thickness should be negatively correlated with slope; this relationship is not observed in data from Puu Oo. If yield strength is nonisothermal, then the documented variations in flow geometry suggest that the yield strength fluctuates significantly over the lengths of many flows and in some cases decreases downflow. This type of rheologic behavior is improbable, as a flow moves downslope, increased cooling should increase both its viscosity and yield strength. While the Bingham model has proven useful for comparing large, diverse populations of planetary lava flows, use of a bulk yield strength term is inconsistent with detailed observations of flow dimensions, which are thought to be directly related to this rheologic parameter. Fom analysis of well documented Hawaiian lava flows, it appears that a bulk yield strength for a lava flow constrained by morphologic characteristics has an uncertain physical meaning. Thus, use of the yield strength parameter is of limited value for interpretations of thermal and rheologic processes involved in lava flow emplacement.

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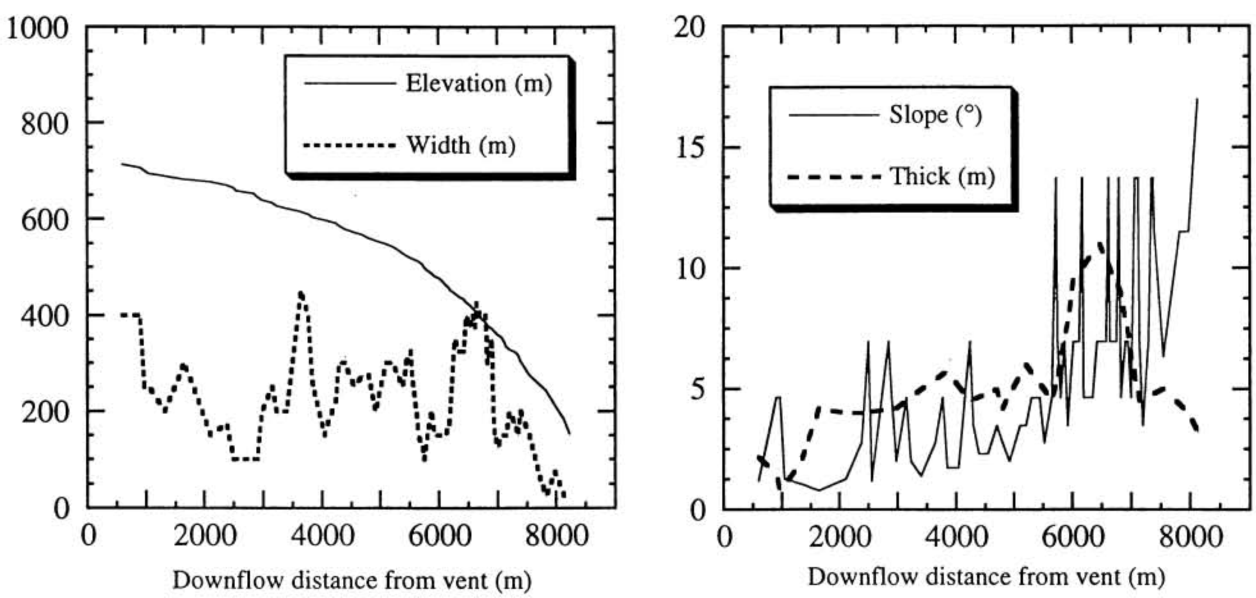

Figure 1. Puu Oo Episode 5, Flow 2. Left) Pre-flow topography (elevation) and flow width as a function of downflow distance from the vent. Right) Downflow changes in underlying slope and flow thickness. Note lack of systematic variations in or correlations between flow width, flow thickness, and underlying slope.