CROSSFLOW TOPOGRAPHIC EFFECTS ON THE EMPLACEMENT OF LEVEED LAVA FLOWS: IMPLICATIONS FOR VENUSIAN LAVA FLOWS;
Patricia G. Rogers, *Johns Hopkins University / NASA Headquarters*; Maria T. Zuber, *Massachusetts Institute of Technology*; Bruce A. Campbell, *Smithsonian Institution.*

Through integration of theoretical modeling and field studies of lava flows, we can attempt to understand the flow dynamics and emplacement mechanisms that give rise to their final morphologic features. By understanding the development of such features on terrestrial flows, we hope to extrapolate analytical models to studies of lava flows on other planets. However, the final dimensions and detailed morphology of a lava flow depend upon the complex interaction between effusion rate, rheologic parameters, and underlying topography. This work examines the dependence of the commonly used Bingham flow model [1, 2] on topographic slopes parallel and perpendicular to the flow direction, and assesses the impact of slope uncertainties on interpretation of remote sensing data for Venus.

Based on analysis of flow characteristics such as channel width, flow depth, and levee width, estimates of yield strength and flow rate for an isothermal Bingham-plastic flow can be made [1, 2, 3, 4]. However, for less than ideal situations, such an analysis can lead to incorrect estimates of yield strength and flow rates. While it is often straightforward in the field to determine if a lava flow has undergone a complex emplacement history, analysis of remote sensing data for lava flows may not lend itself to simple analytical approaches. If one wishes to extrapolate such approaches to remote sensing and planetary data, it is important to quantify the sensitivity of a given model to uncertainties in various parameters. We focus here on a study which combines fluid dynamic modeling with field observations to determine how underlying surface topography may affect lava flow emplacement. The effects of a confining topographic slope on the growth of lava flow levees is examined, and constraints on the inference of flow rheology based on these features are determined. This model is then applied to lava flows on Venus, which travel great distances over very shallow slopes and for which crossflow topographic effects may be particularly relevant.

We carried out a detailed topographic survey of lava flow channels in Kilauea, Hawaii. Downflow and crossflow profiles were measured using an infrared laser ranging system, and downslope changes in the rheological properties of these lava flows were examined using an analytical model for a Bingham fluid [1]. Two endmember flows are examined: a 1972 Mauna Ulu flow in which reasonable rheologies can be inferred from the channel widths and levee margins, and a 1982 flow near the Kilauea rim which experienced a more complex emplacement history. The 1972 flow exhibits a good correlation between levee width and distance from the vent, interpreted to result from a significant increase (2 orders of magnitude) in the apparent yield stress downflow (Figure 1). However, the 1982 flow is topographically constrained, having traveled through a pre-existing gully which appears to have inhibited the formation of primary levees. As such, the inferred yield strengths exhibit no dependence upon distance from the vent for this flow. These cases illustrate the wide range of flow behaviors observed for even rather simple short-term effusive events.

To examine the effect of crossflow or confining topography on the emplacement of leveed flows and subsequent estimates of yield stress, we first looked at the driving force at the base of a flow:

$$F = \rho g h[\sin\gamma + \frac{\delta h}{\delta y}]$$

where ρ is the density of the flow, **h** is the height, γ represents the crossflow gradient, and $\delta \mathbf{h}/\delta \mathbf{y}$ represents the driving force due to the parabolic shape of the upper flow surface. Since the flow stops moving when the yield stress (σ_y) equals the basal shear stress, we can use the above equation to solve for the cross-sectional flow profile. In the case with γ equal to zero, the crossflow profile is:

CROSSFLOW EFFECTS ON LAVA FLOWS: Rogers, P. G., et al.

$$h^2 = \frac{2\sigma_y}{\rho g}\left(\frac{w}{2} - y\right)$$

where **w** is the flow width [1]. This equation was used to determine yield strength from levee width in the above field studies.

To examine how crossflow slope might effect levee development, we can look at the ratio of levee widths with (wb') and without (wb) the crossflow gradient:

$$\frac{w_b'}{w_b} = \frac{2\sin^2\theta}{\sin^2\gamma}\left[\frac{\sin\gamma}{\sin\theta} - \ln\left(1 + \frac{\sin\gamma}{\sin\theta}\right)\right]$$

Our results indicate that the levee width is greatly decreased with respect to the simple inclined-plane case if the crossflow and downflow slopes are comparable. If the two values are equal, a ratio of about 0.6 is obtained. These results are particularly relevant to lava flows on Venus, which appear to travel great distances over relatively shallow slopes, often less than 0.5^{o} [6]. We have identified several long flows on Venus which are outlined by radar bright margins that may indicate the presence of levees, and the above model will be used to examine the sensitivity of yield strength estimates to uncertainties in the Magellan topographic data.

References: [1] Hulme, G. (1974) *Geophys. J. R. Soc.*, 39, 361-383; [2] Hulme, G. (1977) *Phil. Trans. R. Soc. Lond. A.*, 285, 227-234; [3] Fink, J. and J. Zimbelman (1986), *Bull. Volc.* 48:87-96; [4] Wadge, G. and R. M. C. Lopes (1991) *Bull. Volcanol.*, 54, 10-24; [5] Dragoni, M. (1986) *J. Volcanology and Geothermal Res.*, 30, 305-325; [6] Ford, P. G. and G. H. Pettengill (1992), *J. Geophys. Res.* 97, 8, 13,103-13,114.

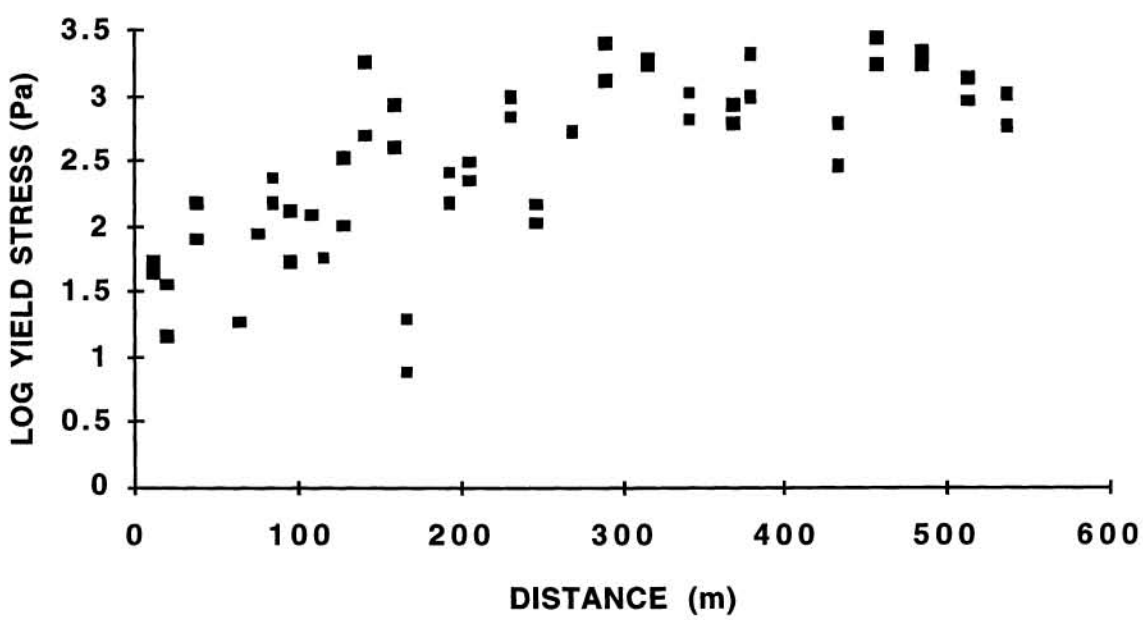

Figure 1. Yield stress vs. distance from vent for a 1972 Mauna Ulu flow.