VARIATIONS IN LAVA FLOW WIDTH RELATED TO EFFUSION RATES THROUGH LABORATORY SIMULATIONS.

Tracy K.P. Gregg[1] and Jonathan H. Fink[2], [1]Dept. of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, tgregg@whoi.edu, [2]Dept. of Geology, PO Box 871404, Arizona State University, Tempe, AZ 85287-1404.

Lava flows observed on Venus, Mars and Earth commonly display a large-scale lobate planform; that is, the flow margin is not straight but is comprised of a series of outwardly convex cusps that are pseudo-symmetric around the downstream flow direction [1-5]]. It has been suggested that these variations in flow width may be related to effusion rate [3] or underlying topography [4]. Based on results of a series of laboratory simulations in which polyethylene glycol (PEG) wax was extruded at a constant rate and temperature into a tank filled with cold sucrose solution, we propose that the size of individual cusps within a single lava flow is related to the interplay of effusion rate, underlying slope, and cooling rate. Thus, we can constrain lava effusion rate if the other factors are known or assumed.

Models that attempt to constrain or estimate lava flow rheology from the solidified flow commonly include flow width as a parameter [6, 7]. This is largely because width is relatively easily measured. Commonly, an "average width" will be used for the entire lava flow, but recent investigations [3-5, 8] indicate that this is a significant simplification of the flow process. Bruno and others [9, 10] have demonstrated that qualitative properties of lava flow emplacement can be determined from the fractal nature (or lack thereof) of a lava flow margin. Clearly, understanding the planform of a lava flow and what controls its final shape is vital to constraining emplacement dynamics for those lava flows which were not observed while active--a category which includes all extraterrestrial and deep-submarine flows, as well as the majority of terrestrial flows. Unfortunately, complications that cannot always be quantified in nature (such as precise variations in pre-flow topography, or slight changes in effusion rate or eruption temperature) may strongly influence flow planform. In laboratory simulations, these parameters can be carefully controlled, and the resulting variations in flow width can be more easily quantified than in natural flows.

We performed 253 laboratory experiments in which PEG was extruded at a constant rate and temperature into a tank filled with cold sucrose solution; the tank floor was inclined 10°-60° from the horizontal in 10° increments [11]. Each simulation was quantified by a single dimensionless parameter (Ψ) which incorporates all key physical parameters of both an extrusion and its environment [12]. We obtained four morphologic regimes in the laboratory: pillowed, rifted, folded and leveed [12], with each regime corresponding to a specific range of Ψ values. "Rifted" flows commonly generated cuspate flow margins.

Within the laboratory, the "cusps", or regions of slight narrowing in the flow width, were produced at periodic standstills of the flow front; i.e., where flow advance temporarily ceased because at the flow front, solidification of the flow was occurring at a slightly higher rate than heat transport. In the experiments, these standstills lasted for only a few seconds while the hydraulic pressure of the liquid PEG within the solid carapace increased sufficiently to rupture the crust--somewhat similar to the descriptions of inflated basalt flows on Hawaii [Hon et al., 1994]. The momentarily increased driving pressure of the liquid PEG caused the flow width to increase where the liquid PEG escaped from its solid confines, creating the episodic narrowing observed in the final planform; we term these episodic advances "rifting events". In the final planform of the flow, these points of narrowing always represent locations where the flow front advance temporarily stalled; however, each standstill does not necessarily leave a tell-tale necking in the flow width (Fig. 1).

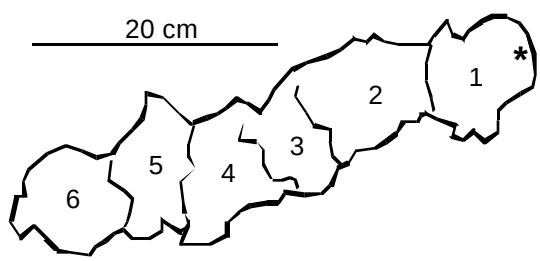


Figure 1. Sketch of laboratory simulation with origins of rifting events marked by solid lines. The vent is marked with an asterisk; flow is to the left. This simulation corresponds to the data in Table 1.

The large lobes demarked by necking of the flow width are approximately the same size within a given simulation, once slope effects are considered; lava flows observed on Elysium Mons, Mars, display planform characterisitcs similar to those observed in the simulations [3, 5]. To analyze the experiments, we digitize video imagery taken from a down-looking camera during the simulations. The elapsed time since eruption onset and the location of each rifting event are noted. We then calculate the area of the lobes generated by each rifting event, and the volume of each lobe is estimated from the time and the known volumetric effusion rate. Therefore, we only examine simulations in which the entire PEG supply was being delivered to the flow front, without proximal breakouts or branching. Here we focus on lobe area, however, because that is most easily measured on planetary imagery.

Within a given simulation, the area of individual lobes is relatively constant (Table 1), and because the effusion rate is stable throughout the experiment, the volumes of each of these lobes are also similar. This

suggests that in the absence of pre-existing topography, the lobe size is determined by eruption and emplacement conditions (Y).

Table 1. Bud size in laboratory simulation.

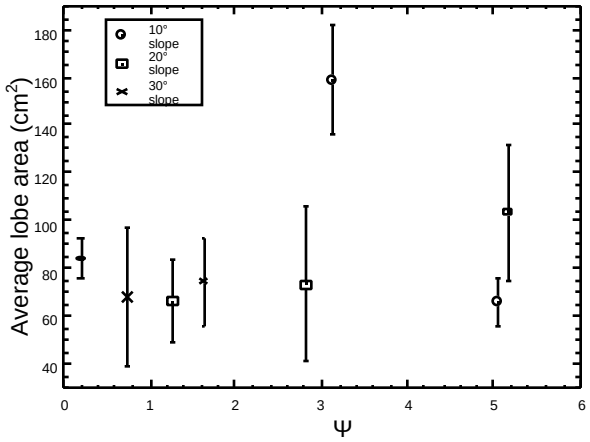
Exp. #	slope	Ψ	lobe	area cm^2	average cm^2	st. dev. cm^2
206	10°	0.51	1	80	77.5	13.3
			2	92.5		
			3	57.5		
			4	88.5		
			5	72.5		
			6	90		

Increasing the underlying slope has a slight effect on lobe dimensions: individual lobes become longer and narrower, and the necking caused by rifting events becomes less pronounced. Because most lavas are emplaced on underlying slopes <<10°, and because the rifting events are easily identified on simulations performed on 10° slope, the slope effect should not pose a serious problem in interpretation of extraterrestrial lava flows.

Lobe area and volume increase slightly with increasing effusion rate and increasing Ψ values (Fig. 2). However, all simulations that generated cuspate flow margins were within the "rifting regime" and therefore we have examined a limited range of Ψ values.

Gregg and Fink [11] demonstrated how effusion rate can be constrained to within a few orders of magnitude for extraterrestrial lava flows if thermophysical properties are assumed for the lavas and known ambient parameters are incorporated into the calculations for Y. Based on the gross similarity of lava flow planform of flows from Elysium Mons [3] and those generated in the "rifting regime" in the laboratory, we propose that the Elysium flows were also emplaced within the "rifted regime". Using a basaltic composition [11] gives a range of effusion rates of ~10^{-1} to 10 m^2/s/m length of fissure. Of the flows mapped by Mouginis-Mark, flow "C" has the largest average lobe size and flow "B" has the smallest average lobe size, although much of flow B is hidden by a younger impact crater. By comparison with laboratory simulations, flow A had the highest effusion rate (~10 m^2/s/m, and possibly greater, considering that some of the lobes may contain channels) and flow B had the lowest rate (~10^{-1} m^2/s/m). These rates are comparable to those observed at subaerial Hawaiian eruptions [1]. Assuming eruptive fissure lengths of 1- 10 km, the Elysium flows were emplaced between 2 months (flow A) and 1 week (flow B).

Figure 2. Individual lobe dimensions increase slightly with increasing Ψ value for a given underlying slope.



References. [1] Wolfe, E.W., ed., 1988, USGS Prof. Paper 1463. [2] Crown, D.A., T.K. Porter and R. Greeley, 1991, LPSC XXII:261. [3] Mouginis-Mark, P.J., 1992, LPSC XXIII:939. [4] Crown, D.A. and M.N. Peitersen, 1996, LPSC XXVII:271. [5] Peitersen, M.N. and D.A. Crown, 1996, LPSC XXVII:1011. [6] Schaber, G.G., K.C. Horstman and A.L. Dial, 1978, PLPSC 9th:3433. [7] Zimbelman, J.R., 1985, PLPSC 16th:D157-D162. [8] Kilburn, C.R.J. and R.M. Lopes, 1991, JGR 96:19,721. [9] Bruno, B.C., G.J. Taylor and S.K. Rowland, 1992, GRL 19:305. [10] Bruno, B.C., G.J. Taylor and S.M. Baloga, 1994, Bull. Volc. 56:193. [11] Gregg, T.K.P. and J.H. Fink, 1996, JGR 101:16,891. [12] Fink, J.H. and R.W. Griffiths, 1990, J. Fluid Mech. 221:485.